High Intensity Electron Positron Accelerator (HIEPA)

Super Tau Charm Facility（STCF）in China

Hai-ping Peng

penghp@ustc.edu.cn

State Key Laboratory of Particle Detection and Electronics (SKLPE)

University of Science and Technology of China (USTC)

(On behalf HIEPA/STCF Steering Committee)

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Outline

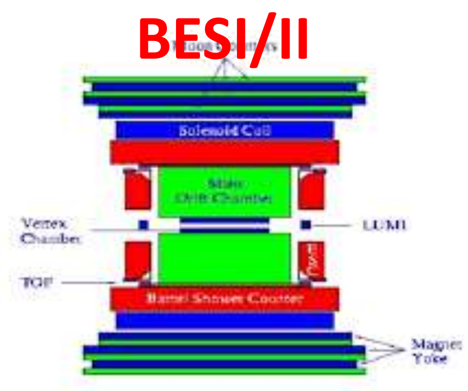
- History of τ-c facility in China
- Proposed Super τ-c facility in China
- Pre-Design consideration of Detector
- Highlight physics
- Activities
- Summary

30 Years of τ-c facility in China

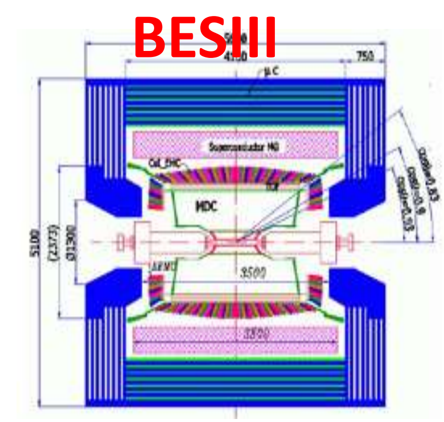
BEPCI (1988–2005)

$10^{31}cm^{-2}s^{-1} \Rightarrow 10^{33}cm^{-2}s^{-1}$

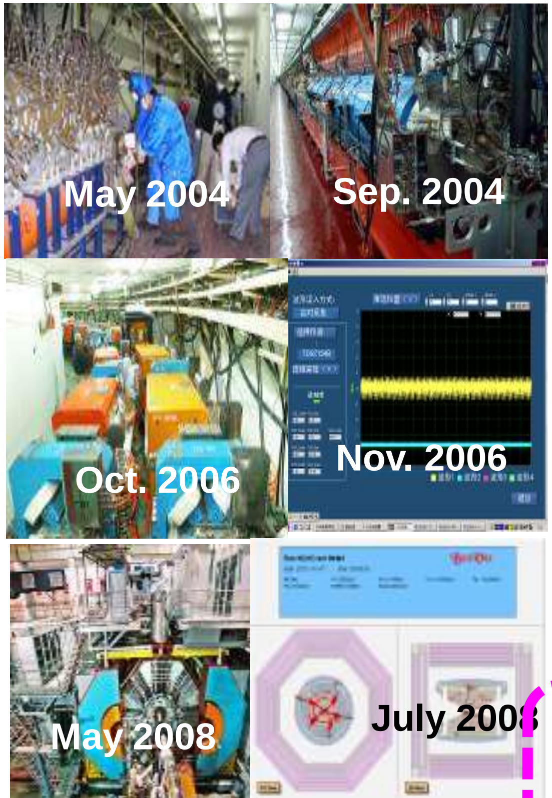
BEPCII (2006–now)



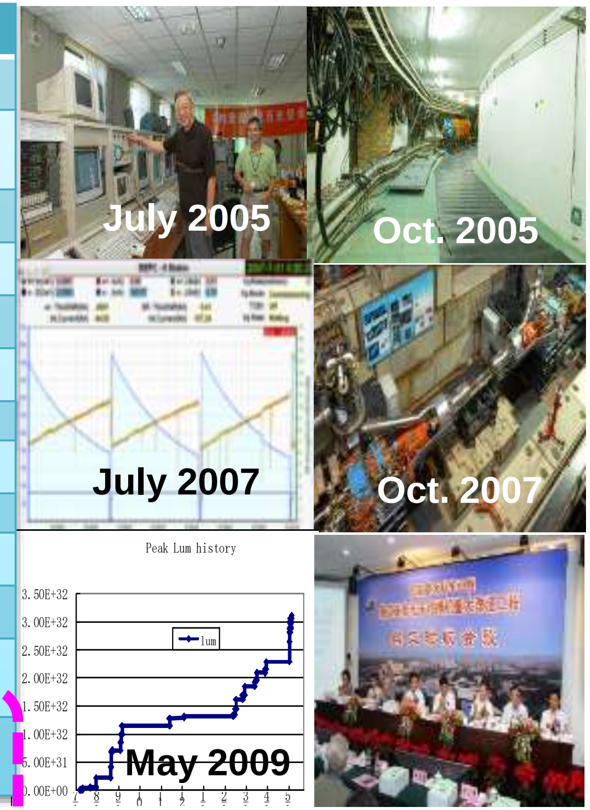
Side view of the BES detector

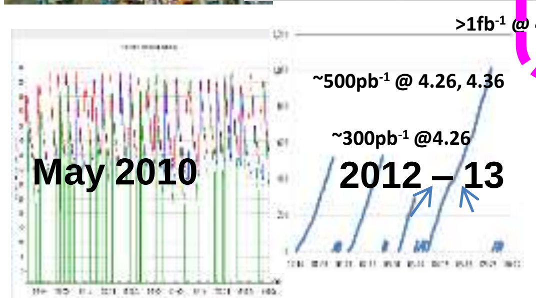


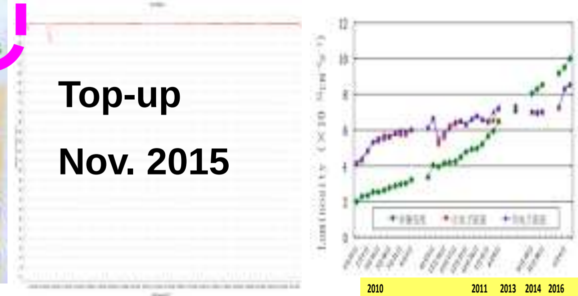
Milestones of BEPCII



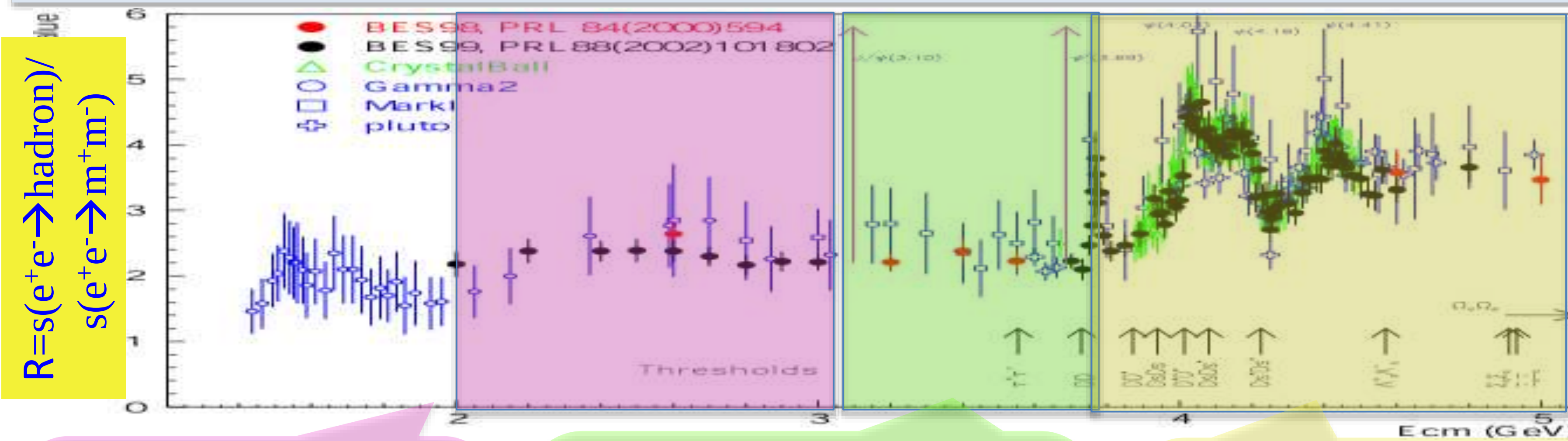
Jan. 2004	Construction started
May. 4, 2004	Dismount of 8 linac sections
Dec. 1, 2004	Linac delivered e^- beams to BEPC
July 4, 2005	BEPC ring dismount started
Mar. 2, 2006	BEPCII ring installation started
Aug. 3, 2007	Shutdown for IR-SCQ installation
Mar. 28, 2008	Shutdown for BESIII installation
July 19, 2008	First hadron event observed
May 19, 2009	Luminosity reached $3.3\times10^{32}cm^{-2}s^{-1}$
July 17, 2009	Pass the National test & check
April 8, 2011	Luminosity reached $6.5\times10^{32}cm^{-2}s^{-1}$
April 2013	Zc(3900) found & confirmed
Nov. 20, 2014	Luminosity reached $8.53\times10^{32}cm^{-2}s^{-1}$
April 5, 2016	Luminosity reached $10.0\times10^{32}cm^{-2}s^{-1}$







Broad Physics at τ-c Energy Region



- Hadron form factors
- Y(2175) resonance
- Mutltiquark states with s quark, Zs
- MLLA/LPHD and QCD sum rule predictions

- Light hadron spectroscopy
- Gluonic and exotic states
- Process of LFV and CPV
- Rare and forbidden decays
- Physics with τ lepton

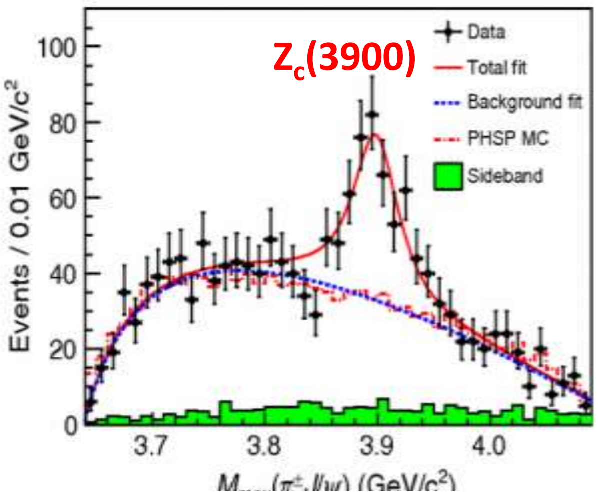
- XYZ particles
- Physics with D mesons
- f_D and f_{Ds}
- D_0-D_0 mixing
- Charm baryons

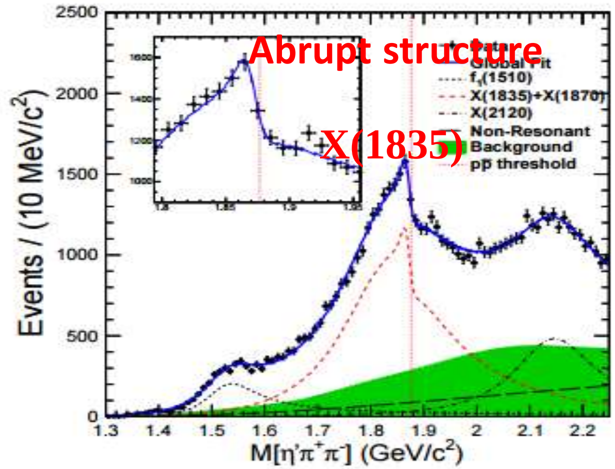
R scan

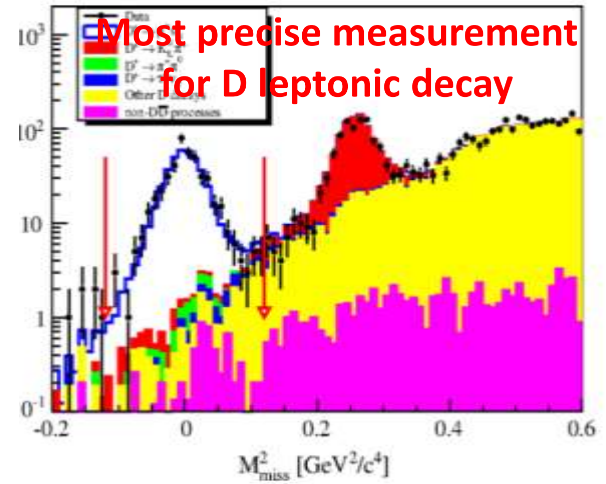
- **Precision $\Delta\alpha_{QED}$, a_μ, charm quark mass extraction.**
- **Hadron form factor(nucleon, Λ, p).**

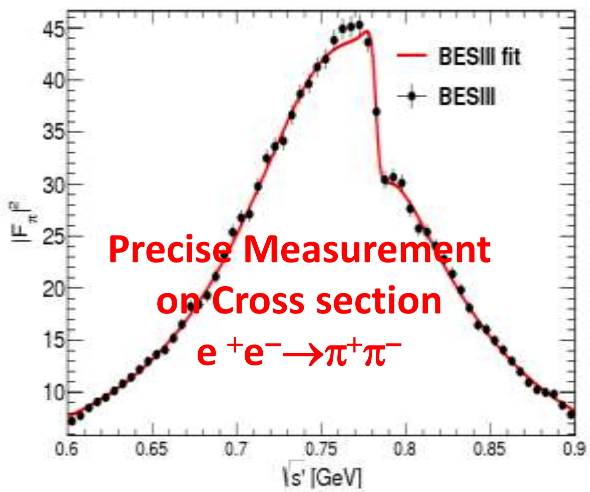
Blank at 5-7GeV to date

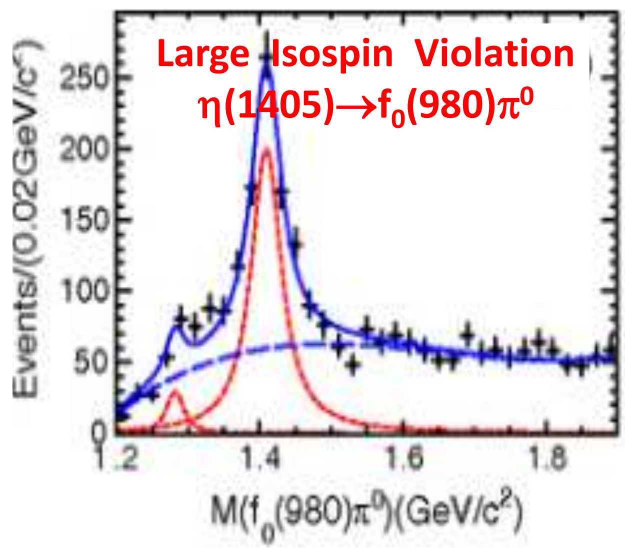
Fruitful BESIII Results

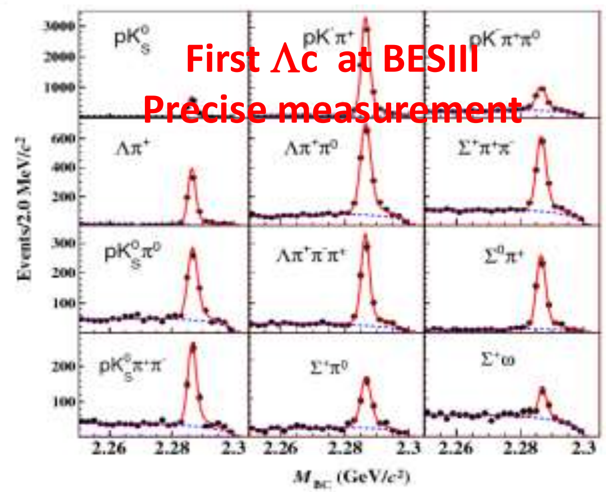












≥200 publications http://bes3.ihep.ac.cn/pub/physics.htm

τ-c facility in China

Features and limits of BEPCII/BESIII

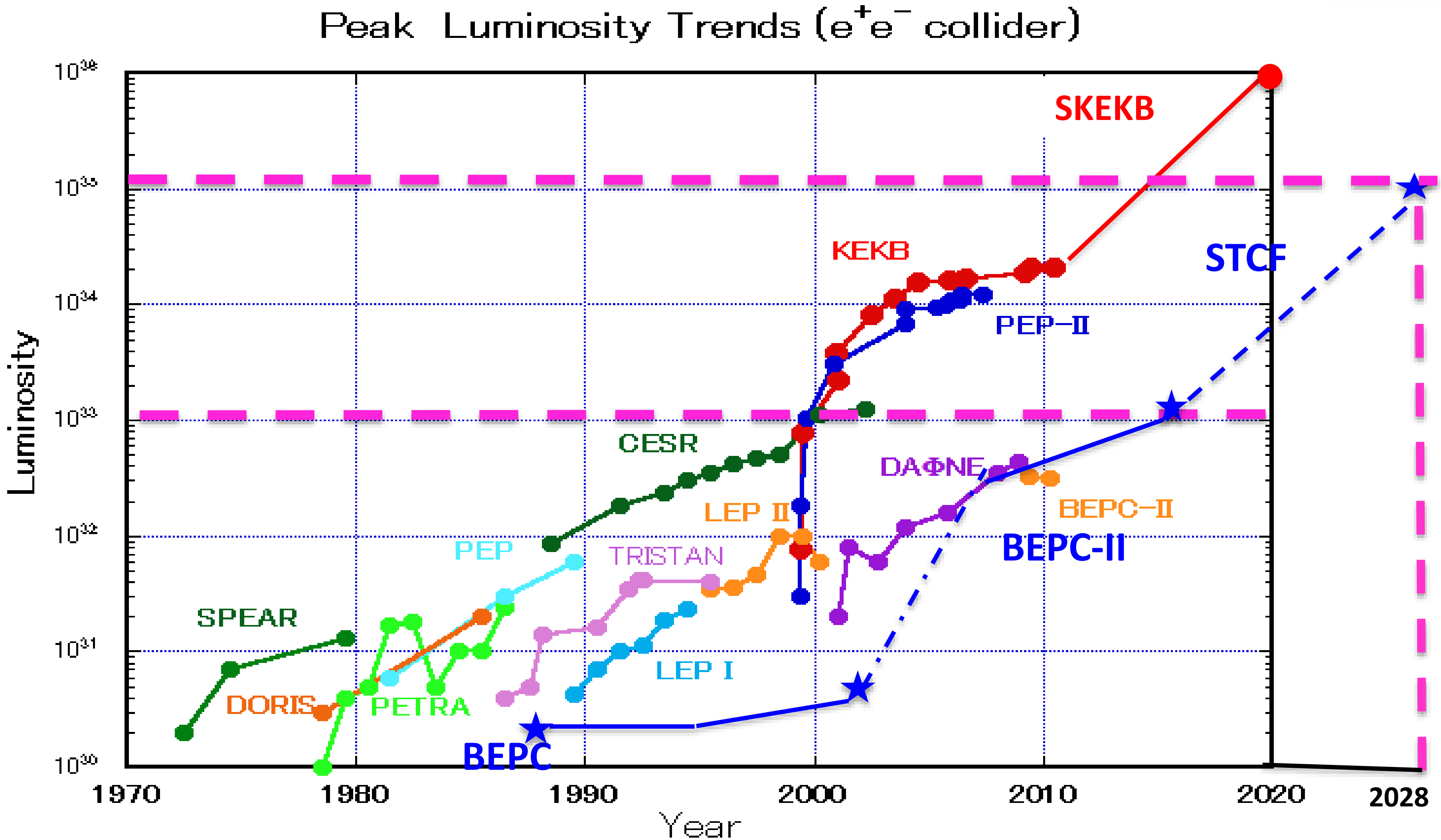
- Threshold production
- Clean Signal, low background
- High efficiency and resolution
- ……….

- limited Ecms range : 2-4.6 GeV
- Luminosity : 10^{33} cm^{-2} s^{-1}
- No major upgrade proposal to date

BEPCII/BESIII will end her mission in 8-10 years

A STCF far beyond BEPCII, is nature extension and a viable option for a post-BEPCII HEP project in China

STCF in Perspective



A luminosity 1×10^{35} $cm^{-2}s^{-1}$ at 4 GeV at 2028 is reasonable !!

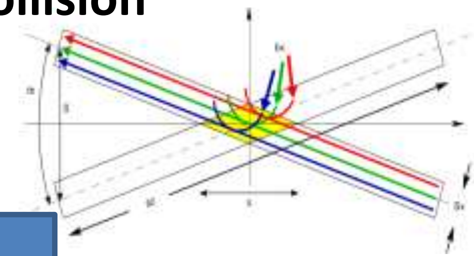
STCF in China

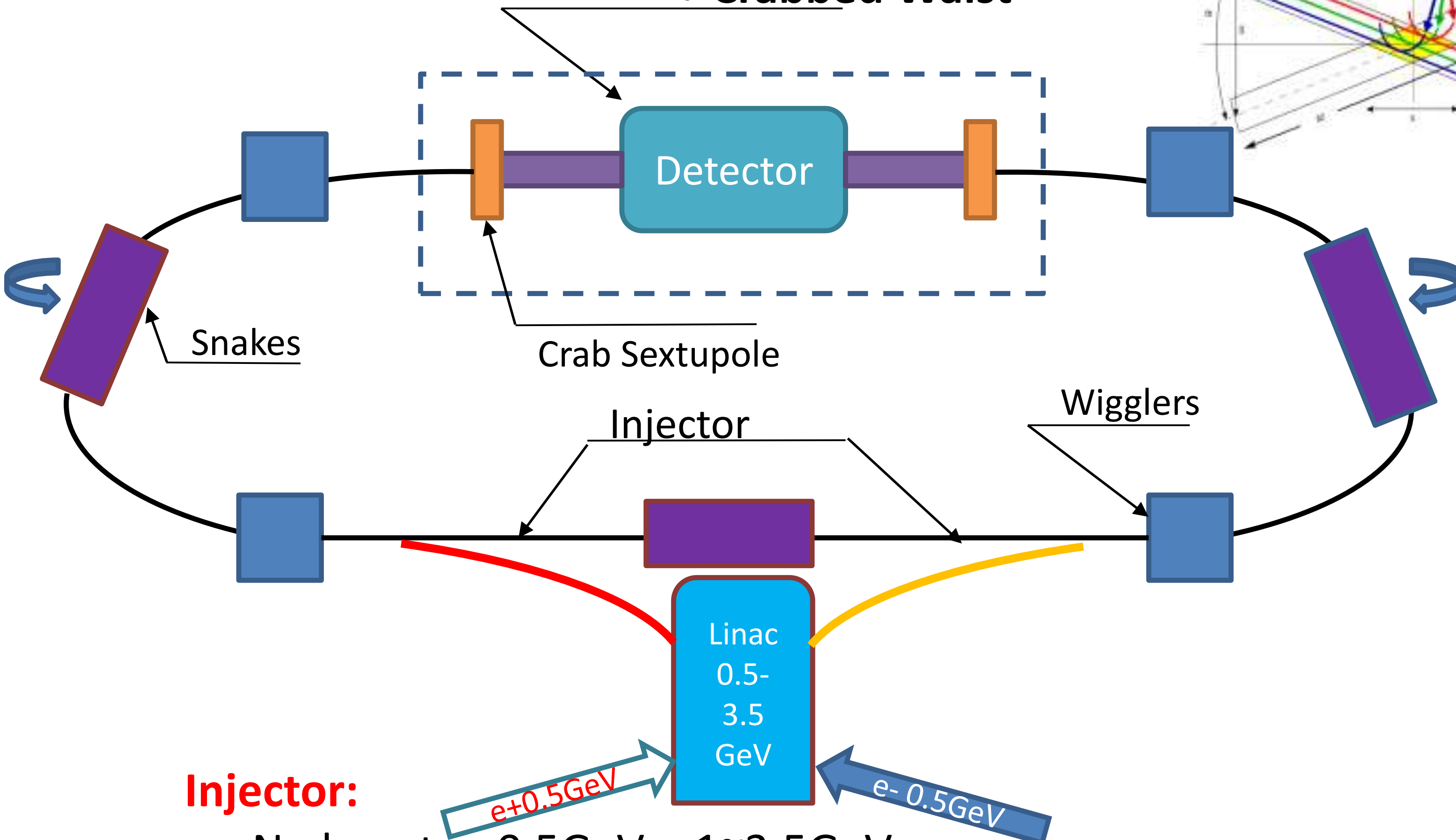
Super Tau-Charm Facility (STCF)

- Peak luminosity $0.5\text{-}1\times10^{35}$ $cm^{-2}s^{-1}$ at 4 GeV
- Energy range E_{cm} = 2–7GeV
- Polarization available on electron beam (Phase II)
- Basic Features of machine :
  - Symmetric machine with dual-ring
  - Large Piwinski angle collision + crabbed waist solution for the IR
  - Siberia snake for polarization
  - Total cost 4B RMB

Layout of Machine

Interaction Region : Large Piwinski Angle Collision + Crabbed Waist





Injector:

- No booster, 0.5GeV→1~3.5GeV
- e+, a convertor, a linac and a damping ring, 0.5GeV
- e-, a polarized e- source, accelerated to 0.5GeV

Parameters of Machine

Luminosity :

$$L = \frac{\gamma n_b I_b}{2 e r_e \beta_y^*} \xi_y H$$

- Increase beam current
- Minimize β Function β_y^*
- Optimize ξ_y and H

Strategy :

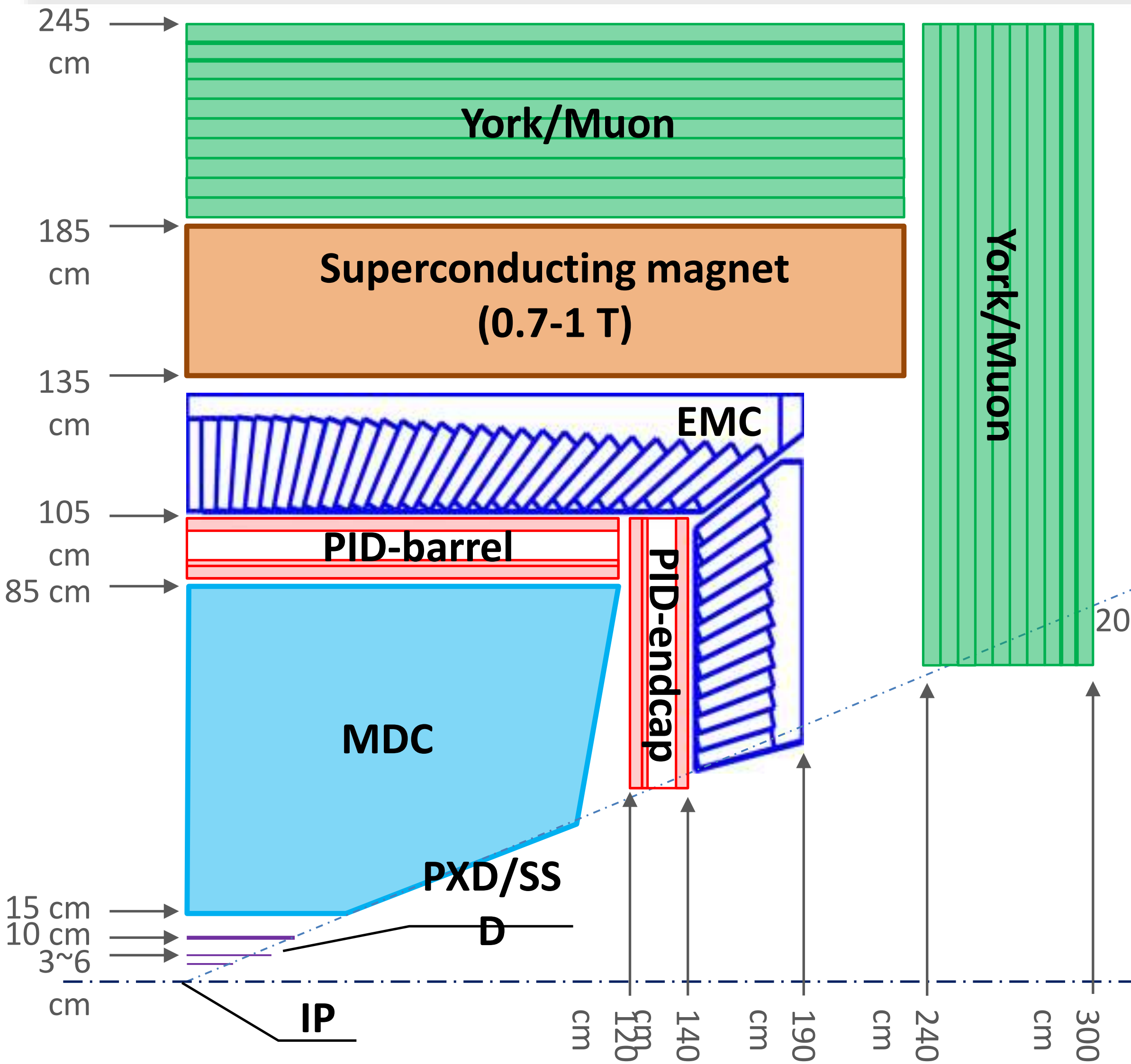
- (Phase 0) Pilot: 0.5×10^{35}
- (Phase I) Nominal: 1.0×10^{35}
- (Phase II) Polarized e-
- .....

Parameters	1	2
Circumference/m	~600	~600
Beam Energy/GeV	2	2
Current/A	1.5	2
Emittance$(\varepsilon_x/$	5/0.05	5/0.05
β Function @ IP (β_x^*/β_y^*)/mm	100/0.9	67/0.6
Collision Angle(full θ)/mrad	60	60
Tune Shift ξ_y	0.06	0.08
Hour-glass Factor	0.8	0.8
Luminosity/×10^{35}cm^{-2}s^{-1}	~0.5	~1.0

General Consideration of Detector

- **Much larger radiation tolerance, especially at IP and forward regions**
  - The detector and electronics should withstand the expected does
- **Efficient event triggering, exclusive state reconstruction and tagging**
  - high efficiency and resolutions for charged and neutral particles
  - Low noise and High rate capability
- **The Systematic uncertainty control**
  - Detector acceptance : geometrical acceptance or detector response
  - Mis-Measurement : mis-tracking, fake photon, particle mis-id, noise
  - Luminosity measurement
- **Reasonable cost**

Detector Layout



MUD
- μ/π suppression power >10/30

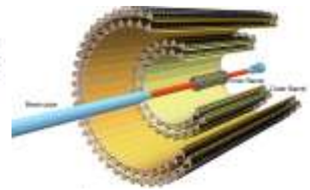
EMC
- Energy range: 0.02-2.5 GeV
- At 1 GeV σ_E (%)
  - Barrel(Cs(I): 2
  - Endcap (Cs): 4

PID
- π/K (and K/p) 3-4σ separation up to 2GeV/c

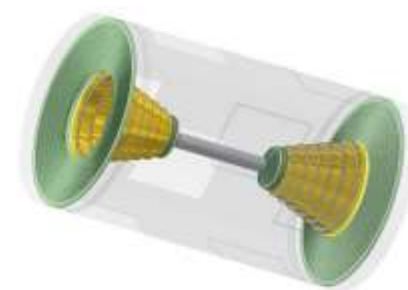
MDC (Low mass)
- σ_{xy}=130 mm
- dE/dx<7%, σ_p/p =0.5% at 1 GeV

PXD
- Material budget ~0.15%X_0/layer
- σ_{xy}=50 mm

Detector requirements & Baseline

- **Vertexing :**
  - Not very critical
  - But to combine with a central tracker to improve the tracking efficiency for low momentum track and resolution
  - Special design to cope with the large radiation close to IP
  - Technologies options :
    - ✓ A Low mass silicon detectors : DEPFET, MAPS …
    - ✓ MPGD : Cylindrical GEM/MicroMegas/Urwell

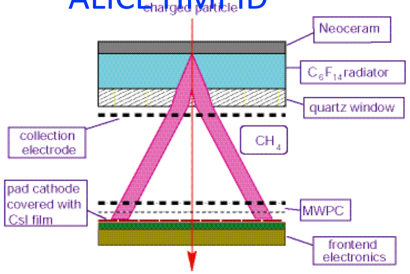


- **Central tracking :**
  - large acceptance, low mass, high efficiency and high resolution
  - A low mass drift chamber with smaller cell size and lighter working gas

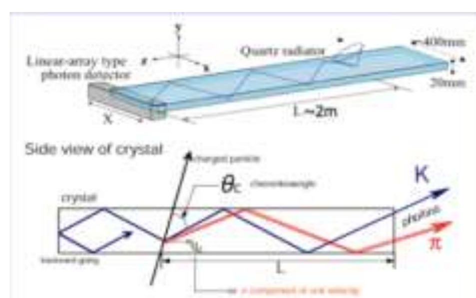
Detector requirements & Baseline

- **PID system :**
  - π/K separation up to 2GeV, compact (<20cm) and low mass (<0.5X_0)
  - Cherenkov-based technology is favorable for high momentum tracks, and dE/dx for the low momentum tracks
  - Technology options : RICH, DIRC-Like
    - ✓ Baseline Design : Proximity RICH, similar to ALICE HMPID, but with CsI-coated MPGD readout
    - ✓ Alternative Design : Aerogel + Position Sensitive Photon Detector, similar to BELLE-II ARICH

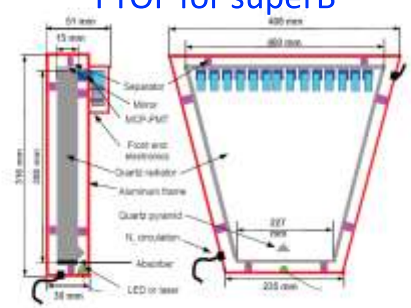
ALICE HMPID



iTOP for BELLE2

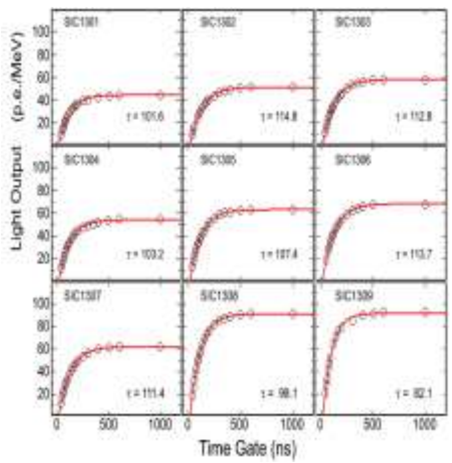


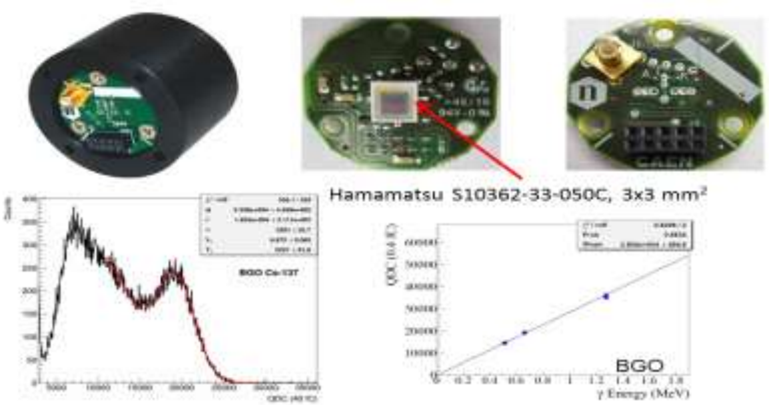
FTOF for superB



Detector requirements & Baseline

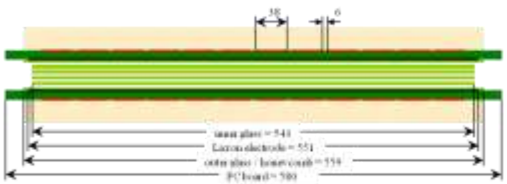
- **e/γ measurement :**
  - High efficiency for low energy γ
  - Good energy, position and time resolution
  - Fast response and Radiation hardened
  - Technology option : Crystal + novel photon detector (e.g. SiPM)
    - ✓ Crystal : pure CsI for barrel, LYSO for Endcap
    - ✓ Readout : Larger Area PD, APD and SiPM





Detector requirements & Baseline

- **μ detection**
  - Low momentum threshold (p~0.4GeV)
  - high μ efficiency and μ/π suppression power>10 (30)
  - Technology option ：
    - ✓ 2-3 inner layers with MRPC for precise timing
    - ✓ ~8 outer layers with RPC (Barrel : streamer, Endcap : avalanche)



MTD at STAR

Long-Strip MRPC Module at STAR
- Active area: 87 x 52 cm^2
- Read out strip: 87 cm x 3.8 cm
- Gas gaps: 0.25 mm x 5

Performance:
- Efficiency: > 98%
- Time resolution: < 80 ps
- Spatial resolution: 0.6 cm

- **Magnet**
  - Desirable to be adjustable from 0.5-1.0 T

Physics @ STCF

- ***Precise test of SM***
  - R Scan, Hadron form factor (nucleon, Λ, π), $\Delta\alpha_{QED}$, a_u
  - tau lepton decays, lepton universality test
  - CKM matrix, Decay constants (f_D/f_{Ds}), form factors
  - Neutral D mixing and strong phase
- ***New physics(tiny/forbidden in SM)***
  - Rare charmonium decays：LFV, LNV, BNV…
  - Rare charm decay : FCNC, LFV, LNV, invisible
  - Rare tau decay : FCNC, LFV, LNV
  - Rare light meson decay : $\eta/\eta'/\omega/\phi$
- ***CP Violation***
  - Unexpected large CPV in tau or charm: tiny in SM
  - CP violation in baryon/hyperon/charm baryon
- ***hadron physics***
  - meson, baryon, hyperon spectroscopy
  - threshold effects
  - Glueball: direct test of QCD at low energy
  - Multiquark, exotics, hybrids…..
  - Charmonium(-like) spectroscopy
  - Charmed baryon decays
- ***Exotic phyics***
  - Light dark matter : light Higgs boson(a_0), U boson
  - New interactions

rich of physics program, unique for physics with c quark and τ leptons, important playground for study of QCD, exotic hadrons and search for new physics.

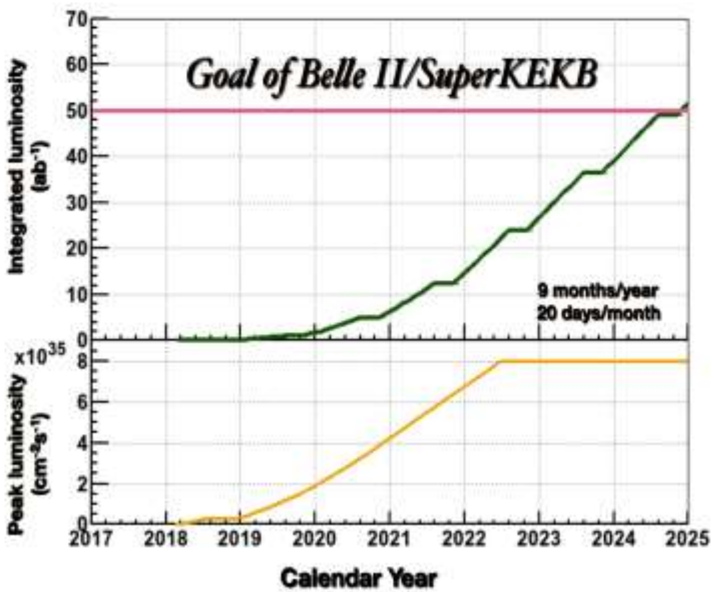
Integral Luminosity of STCF

- No Synchrotron radiation mode, assume running time 9 months/year
- Assume data taking efficiency 90%

$$10^{35}cm^{-2}s^{-1} \times 86400s \times 270days \times 90\% \sim \mathbf{2.0ab^{-1}/year}$$

10 years data taking, total 10~20 ab^{-1} conservatively

Excellent opportunities for the τ-charm physics



BELLEII

each 1 ab^{-1} dataset provides

- $\sim 1.1 \times 10^9$ $B\bar{B} \Rightarrow$ a B-factory;
- $\sim 1.3 \times 10^9$ $c\bar{c} \Rightarrow$ a charm factory;
- $\sim 0.9 \times 10^9$ $\tau^+\tau^- \Rightarrow$ a τ factory;
- wide $E_{CM}^{eff.}$=[0.5-10] GeV via ISR.

Native question : Compete between STCF and BELLE II ?

Data samples

Data samples with 1 ab^{-1} integral luminosity

	STCF					Belle II		
Data Set	process	σ/nb	N	ST eff./%	ST N	σ/nb	N	Tag N
J/ψ	–	–	1.0×10^{12}	–	–	–	–	–
$\psi(2S)$	–	–	3.0×10^{11}	–	–	–	–	–
D^0	$D^0\bar{D}^0(3.77)$	~ 3.6	3.6×10^{9}	10.8	0.78×10^{9}	–	1.4×10^{9}	–
D^+	$D^+D^-(3.77)$	~ 2.8	2.8×10^{9}	9.4	0.53×10^{9}	–	7.7×10^{8}	–
D_s	$D_sD_s^*(4.18)$	~ 0.9	0.9×10^{9}	6.0	0.11×10^{9}	–	2.5×10^{8}	–
τ^+	$\tau^+\tau^-(3.68)$	~ 2.4	2.4×10^{9}	–	–	0.9	0.9×10^{9}	–
	$\tau^+\tau^-(4.25)$	~ 3.6	3.5×10^{9}	–	–	–	–	–
Λ_c	$\Lambda_c\Lambda_c(4.64)$	~ 0.6	5.5×10^{8}	5.0	0.55×10^{8}	–	1.6×10^{8}	$3.6\times10^{4*}$

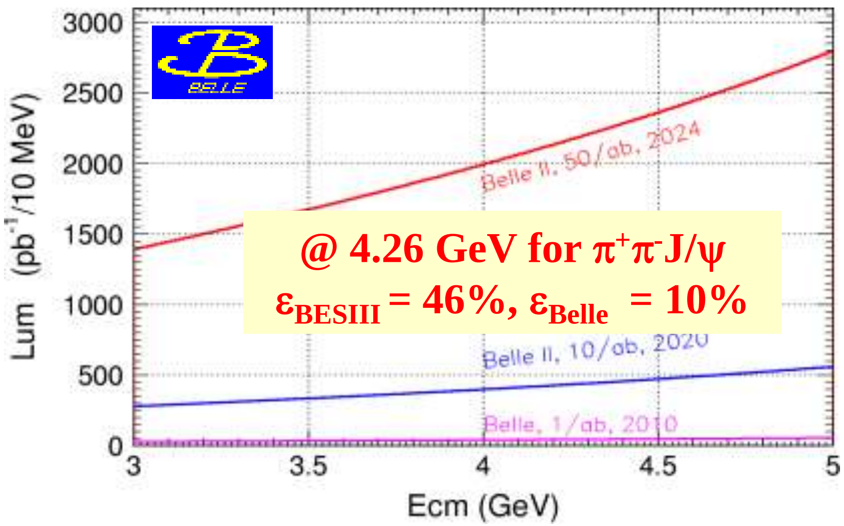
* process $e^+e^-\to D^{(*)-}\bar{p}\pi^+\Lambda_c^+$.

- STCF have more yields in τ and charm /per luminosity
- STCF is expected to have higher detection efficiency
- Belle II can have larger integral luminosity

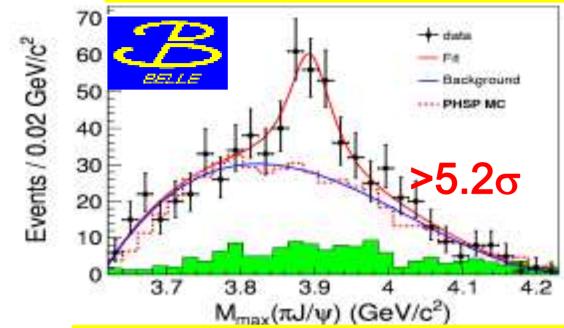
Charmonium-Like Physics

Fruitful results in past decade, a new territory to study exotic hadrons

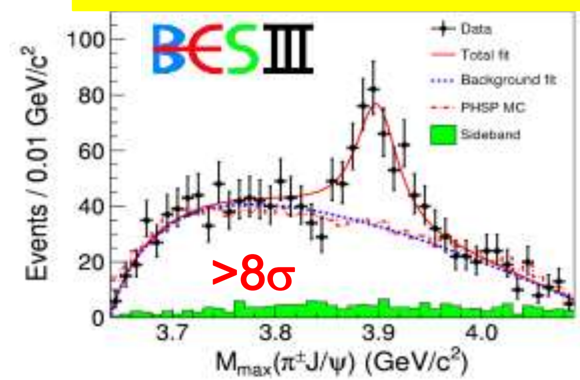
- **τ-C Factory :** $e^+e^-\rightarrow Y/\psi\rightarrow Z_c + X$
- **B Factor :** ISR, B decay



Belle with ISR: PRL110, 252002
967 fb^{-1} in 10 years running time



BESIII at 4.260 GeV: PRL110, 252001
0.525 fb^{-1} in one month running time



- **B factory :** Total integrate effective luminosity between 4-5 GeV is 0.23ab^{-1} for 50 ab^{-1} data
- **τ-C factory** : scan in region 4-5 GeV, 10 MeV/step, every point have 20 fb^{-1}/year, 10 time of Belle II for 50 ab^{-1} data
- τ-C factory have much higher efficiency than B Factory

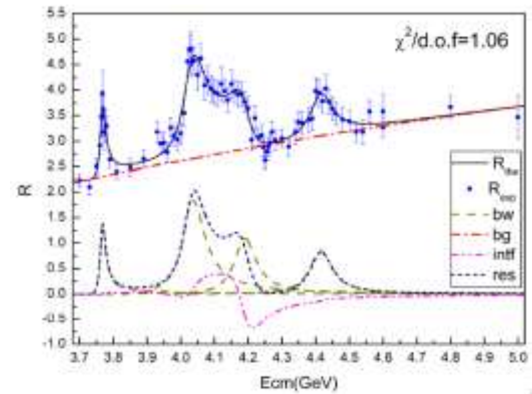
Charmonium-Like @ τ-c Factory

- ψ/Y/Hybrid(ccg) (1^{--}) produced in the e^+e^- collision
  - To determine the resonance parameters for the excited ψ or Y state
  - Precisely measure the x-sec of inclusive/exclusive final states at different Ecms
- Charge parity c=+1 states produced via radiative transition from vector ψ/Y
  - The decay rate $\psi(nS/nD)\to\gamma X(3872)$, X(3940)…
  - Search for $\chi_{cJ}(2P)$、$\chi_{cJ}(3P)$、$\eta_c(3S)$、 $\eta_c(4S)$、 …

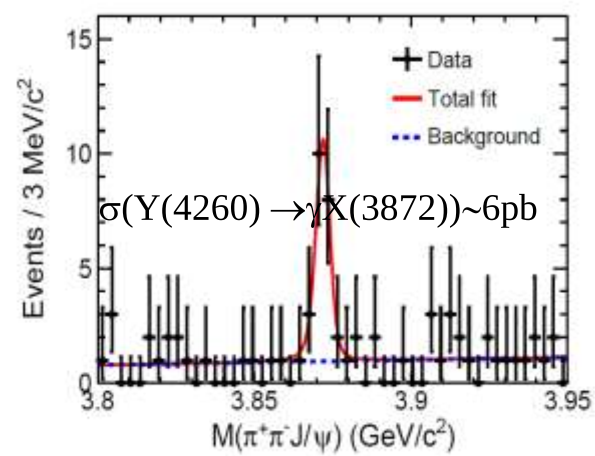
    $B(\psi(3S)\to\gamma\chi'_{cJ})$ = (7, 3, 1) x 10^{-4} for J=2,1,0

    [Rev. Mod. Phys. 80, 1161 (2008)]
- Search for new states from hadronic transition
  - To search for Zc, Zcs, hc(2P) ….

PLB 660, 315 (2008)



PRL 112, 092001 (2014)



Search for 1^{--} Hybrid $H_{ccg} \to \gamma\eta_c$ & $\gamma\chi_{c0}$

- 1^{--} Hybrid may produce directly in e^+e^- collision, and radiative decay to spin-zero charmonium states [in Hybrid, cc in spin-singlet, LQCD by Dudek'09]
  - Assume $\sigma(e^+e^- \to H_{ccg}) \sim O(10\text{–}100)$ pb [???]
  - $B(H_{ccg} \to \gamma\eta_c) \sim 2\times B(\eta_{c2} \to \gamma\chi_{c0}) \sim 4\times10^{-4}$
- Scan between 4-5 GeV for 1 year ($2ab^{-1}$), search for exotic structure in process $e^+e^- \to \gamma\eta_c$ and $\gamma\chi_{c0}$
  - Assume $\varepsilon B \sim 10\%$ for $\gamma\eta_c$ and $\gamma\chi_{c0}$ decay to γ+hadrons
- With 100 energy points between 4-5 GeV
  - $N^{obs}(\gamma\eta_c)$=O(8-80) events/point/year at peak
  - $N^{obs}(\gamma\chi_{c0})$=O(4-40) events/point/year at peak

CP Violation in τ Decay

- CP violation is observed in B, D and K sectors to date ， but not observed in lepton sector yet.
- The discovery of CPV in the tau sector would be a clean signature of NP
- One of the most promising CPV channels is $\tau^- \to K_S \pi^- \nu$
  - SM CP asymmetry from K_S-K_L mixing is expected to be :
    [Bigi & Sanda, PLB 625, 2005, Grossman &Nir JHEP 1204 (2012) 002]

$$\frac{\Gamma(K_L \to \pi^- l^+ \nu) - \Gamma(K_L \to \pi^+ l^- \overline{\nu})}{\Gamma(K_L \to \pi^- l^+ \nu) + \Gamma(K_L \to \pi^+ l^- \overline{\nu})} = |p|^2 - |q|^2 \simeq (3.27 \pm 0.12) \times 10^{-3}$$

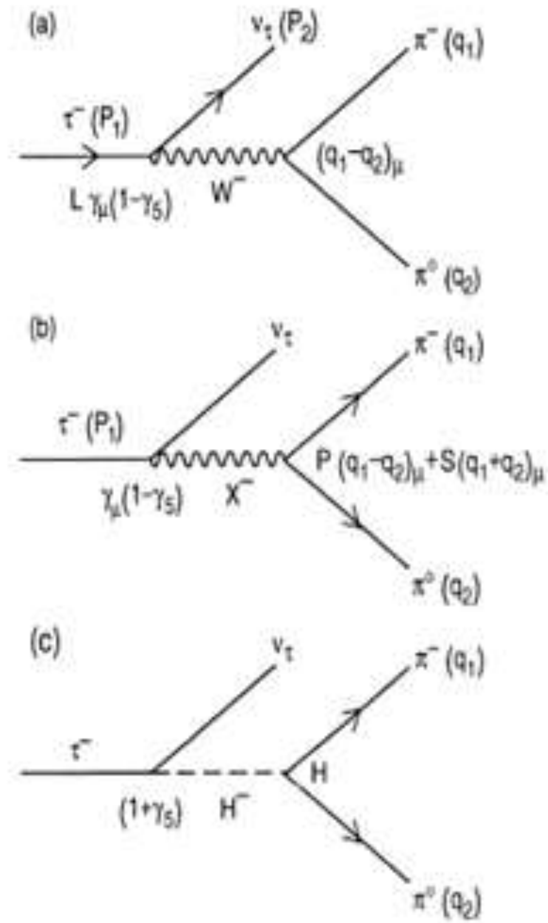
  - BaBar measurement [PRD 85, 031102]

$$A_\tau \equiv \frac{\Gamma(\tau^+ \to \pi^+ K_S \bar{\nu}_\tau) - \Gamma(\tau^- \to \pi^- K_S \nu_\tau)}{\Gamma(\tau^+ \to \pi^+ K_S \bar{\nu}_\tau) + \Gamma(\tau^- \to \pi^- K_S \nu_\tau)} = (-4.5 \pm 2.4 \pm 1.1) \times 10^{-3}.$$

  - Belle measurement [PRL 107, 131801]

$$|\mathrm{Im}(\eta_S)| < 0.026 \text{ or better}$$

$A_{cp} = (1.8 \pm 2.1 \pm 1.4) \times 10^{-3}$ @ W ~ [0.89-1.11] GeV



Charge Higgs, new Scalar, W_L-W_R Mixings, LeptonQuarks?

τ CPV in Angle Distribution

- Measurement on the angular CPV asymmetry is desirable
- Use T-odd rotationally invariant products in >=2 hadrons, such as

$\tau^- \to \pi^-\pi^0\nu_\tau / k^-\pi^0\nu_\tau$, $\tau^- \to \pi^-\pi^+\pi^-\nu_\tau / K^-\pi^+\pi^-\nu_\tau$: $P_2^\mathcal{T} \cdot (\vec{P}_{\pi^+} \times \vec{P}_{\pi^0})$

- Polarized of τ and beam are necessary
- Figure of Merits

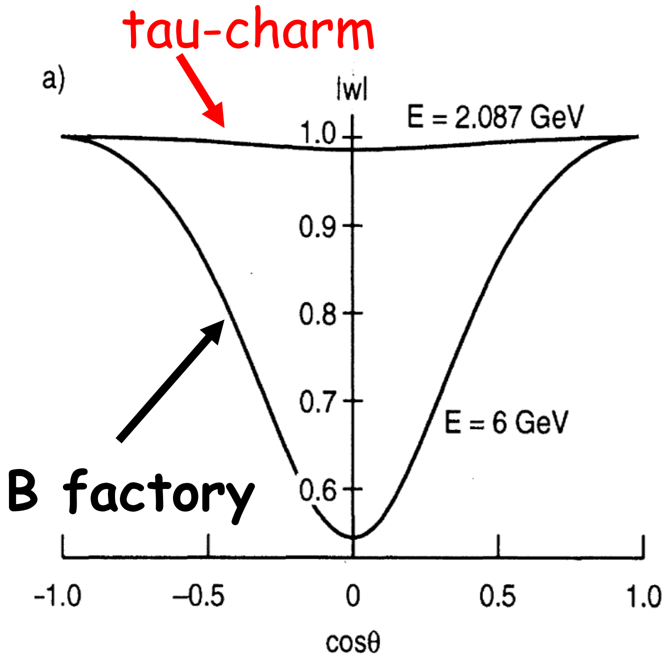
$$\begin{aligned} \text{merit} &= \text{luminosity} \times \bar{w}_Z \times \text{ total cross section} \\ &\propto \text{luminosity} \times (w_1 + w_2) \\ &\quad \times \sqrt{1 - a^2}a^2(1 + 2a) \ , \end{aligned}$$

Y. S. TSAI, PRD 51 (1995) 3172

BESIII @ 4.25 ($10^{33}cm^{-2}s^{-1}$) FOM=1

STCF @ 4.25 ($10^{35}cm^{-2}s^{-1}$) FOM=100

SuperKEKB @ ($8x10^{35}cm^{-2}s^{-1}$) FOM=52

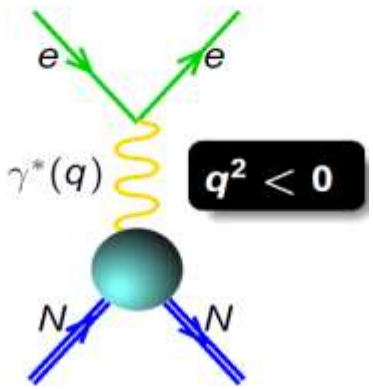


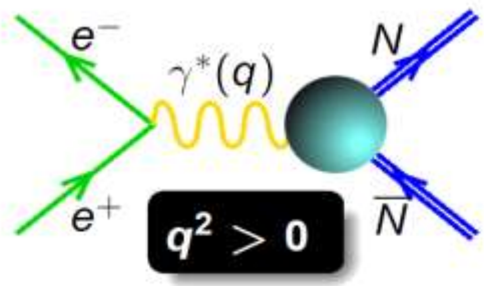
Nucleon Electromagnetic Form Factors (NEFFs)

Spatial distributions of electric charge and current inside the nucleon

$eN \rightarrow eN$ $\qquad$ $e^+e^- \leftrightarrow N\bar{N}, \Lambda\bar{\Lambda}$

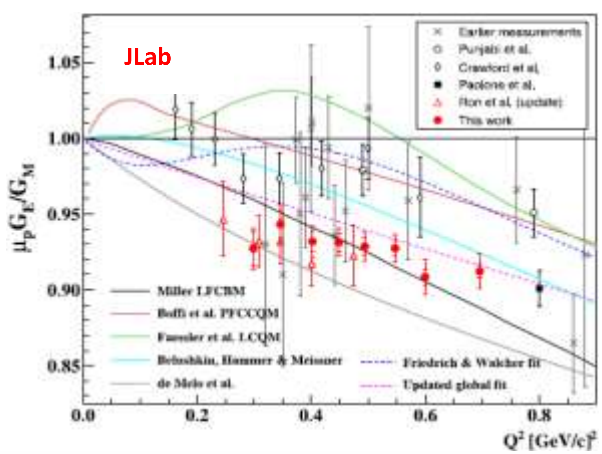
Space-like: FF real

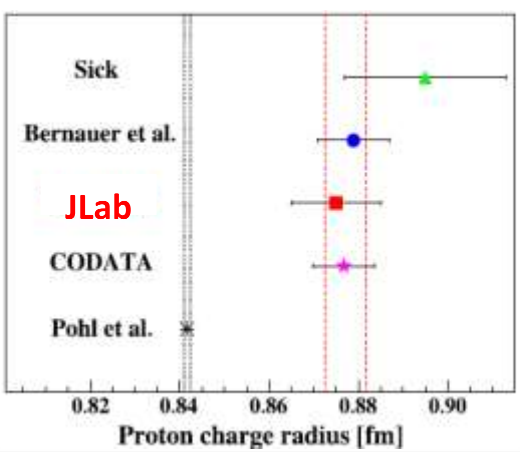




Time-like: FF complex

Complete picture of nucleon structure requires space-like and time-like FF



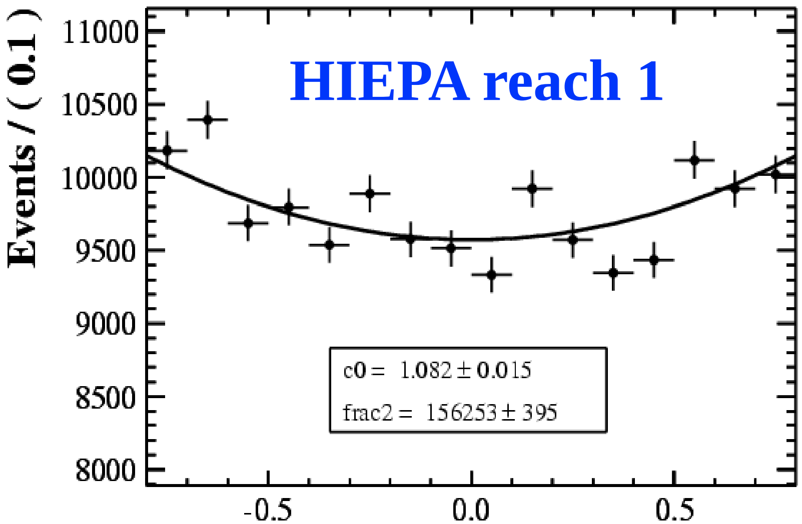


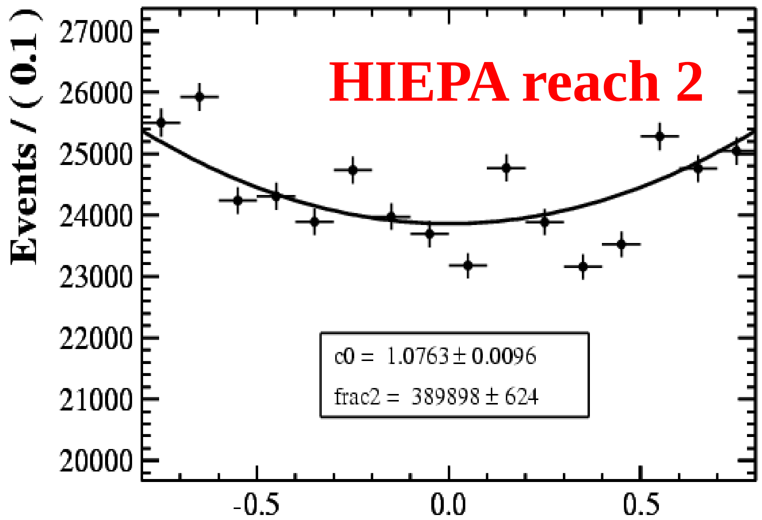
Space-Like FF

1% Precision

Proton FF ($\sqrt{s}$=2.23GeV) @ τ-c Factory

Nsig	$\delta R_{EM}/R_{EM}$	$\delta\sigma/\sigma$	Luminosity (pb^{-1})	comment	
614±24	24%	3.9%	2.631	BESIII test run	
3881±62	9.5%	1.6%	16.630	BESIII expected	
156253±395	1.5%	0.25%	669.533	HIEPAF reach 1	1 day
389898±624	0.96%	0.16%	1670.69	HIEPA reach 2	2 days





Activities

CDR → TDR → project application → construction → commissioning

- Weber page: http://wcm.ustc.edu.cn/pub/CICPI2011/futureplans/
- Domestic Workshops (2011, 12, 13, 14, 16)
- International Workshops (2015, 18)
- Report to USTC Scientific Committee and USTC presidents
- Report to Hefei High-tec Development Zone
- Report to Anhui Development Planning Commission
- Report to CAS Condition and Finance Bureau
- Report to USTC new president (2018/01)
- Organize for the project

Activities

Workshop on Physics at Future High Intensity Collider @ 2-7GeV in China

13-16 January 2015
USTC
Asia/Shanghai timezone

- Overview
- Scientific Programme
- Timetable
- Contribution List
- Author index
- Registration
  - Registration Form
- List of registrants

Tue 13/01 | Wed 14/01 | Thu 15/01 | Fri 16/01 | All days

Print | PDF | Full screen | Detailed view | Filter

08:00	Registration: Registration		USTC	08:00 - 08:30
	Welcome		USTC	08:30 - 08:40
	Introduction to Future High Intensity Collider @ 2-7 GeV in China	Prof. Zhengguo ZHAO	USTC	08:40 - 09:05
09:00	XYZ from B factories [Belle, Babar] and prospects at BelleII	Roman MIZUK	USTC	09:05 - 09:35
	XYZ results from hadron colliders	Dr. Liming Zhang ZHANG	USTC	09:35 - 10:05
10:00	Coffee break		USTC	10:05 - 10:25
	Charmonium-(like) physics at BESIII	Prof. Changzheng YUAN	USTC	10:25 - 10:55
11:00	Charmonium physics at PANDA	Frank NERLING	USTC	10:55 - 11:25
	Higher charmonium states	Ce MENG	USTC	11:25 - 11:55
12:00	LQCD results on hadron spectroscopy	Ying CHEN	USTC	11:55 - 12:25
	Lunch			

Fragrance Hill-Science Conference

Fragrance Hill science Conference, June, 2015, ~40 scientists and officials joint,

Very important conference for Large Scale/Key Project in China

香山科学会议简报

第 534 期

香山科学会议办公室　　二〇一五年八月二十六日

2-7GeV 高亮度正负电子加速器上的物理、应用及其关键技术

—— 香山科学会议第 533 次学术讨论会

粒子物理学(也称高能物理学)是研究比原子核更深层次物质的基本构成、相互作用以及自然界最基本规律的学科。经过几十年
验检验，粒子物理标准模型获得了巨大的成功，被认为是当今世
够最好描述微观世界的理论模型。特别是随着 2012 年 Higgs 粒
发现，人类对物质微观世界的认识达到了空前的高度。但是在标准模型框架中，仍有一系列最基本的问题，如暗物质是什么、CP 破坏的起源、为什么夸克和轻子只有三代等得不到合理的理论解释。物理学家们普遍认为自然界应该存在一个更基本的物理模型，而标准模型只是该模型在现有实验所能达到能标的有效近似。亟待更多的实验来揭开微观世界之谜。

加速器物理实验被认为是当今世界人类研究微观世界最有效的途径。当今的加速器物理实验可以分为两个前沿：一是高能量前沿(The Energy Frontier)，该类实验是在更高能量，更大范围检验标

Brief report of Fragrance Hill science conference

与建议

的基础上，形成如下的基本共识和建议：

1. 加速器粒子物理实验的研究水平反映了一个国家甚至人类的经济、
科学
展。
子物
动下一代加速器物理大装置立项，对于我国基础科学与技术的长远发展，具有重要的战略意义。

The project is strategic significance for the long term development of China's fundamental science and technology

2. 韬-粲能区有非常丰富的物理课题，有关键的科学问题和技术有待
电子加速器(HIEPA)应该是目前我国粒子物理、大科学中心多学科研究和交叉研究的综合平台的最重要选项之一。

Is one of the most important option for China's particle physics filed, Integrated National science center, the platform of multi-disciplinary research

3. HIEPA 的建成将是世界上在高精度前沿进行粒子物理研究的几大中心之一，将使得中国在继 BEPCII/BESIII 后，继续引领世界韬-
粲
量

is one of the unique particle physics center on precision frontier in the world

4. HIEPA 提供的新一代同步辐射 x 射线光源将与我国现有的或者将来的 x 射线光源互补，将为中国材料、物质结构、生物、化学、医

学、军事等领域的研究提供重要和独特研究平台。同时 HIEPA 还提供了我国未来进行其他高科技研究的潜力。但考虑到工程及技术的难点，应该在保证对撞机高亮度的前提下，合理协调同步辐射的运用，同 ... 及步骤。

Greatly promoted the development of high and new technology and culture talents in China

5. HIEPA 的建设将极大地推动中国相关高新技术的发展和高科技综合性人才的培养。将为中国高等院校和研究所输送大量的优秀人才，大幅度地提高中国高等院校从事大科学工程研究的能力，也为未来中国相关的大科学工程如环形正负电子对撞机（CEPC）等提供大量的技术和人才的储备。

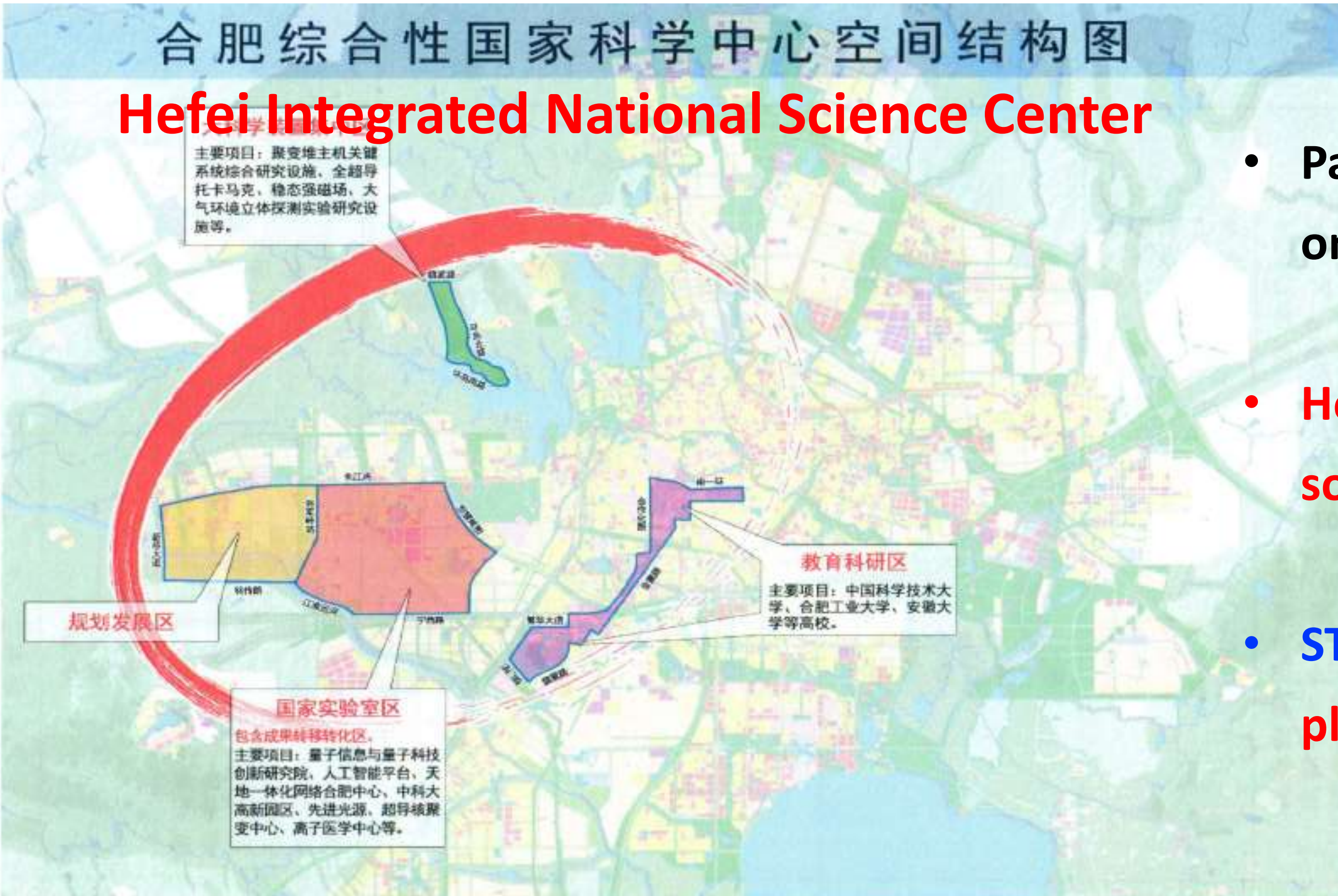
6. BEPCII/ ... 立即组织队伍，凝练物理 ... 探讨实现路径，尽快完成可行性研究报告以及及时开展预研究工作，争取 2025 年完成 HIEPA 项目的建设。

Complete feasibility study and carry out the pre- R&D work as soon as possible

report have been delivered to the Ministry of Science and Technology, National natural Science Foundation, Academy of Science of China

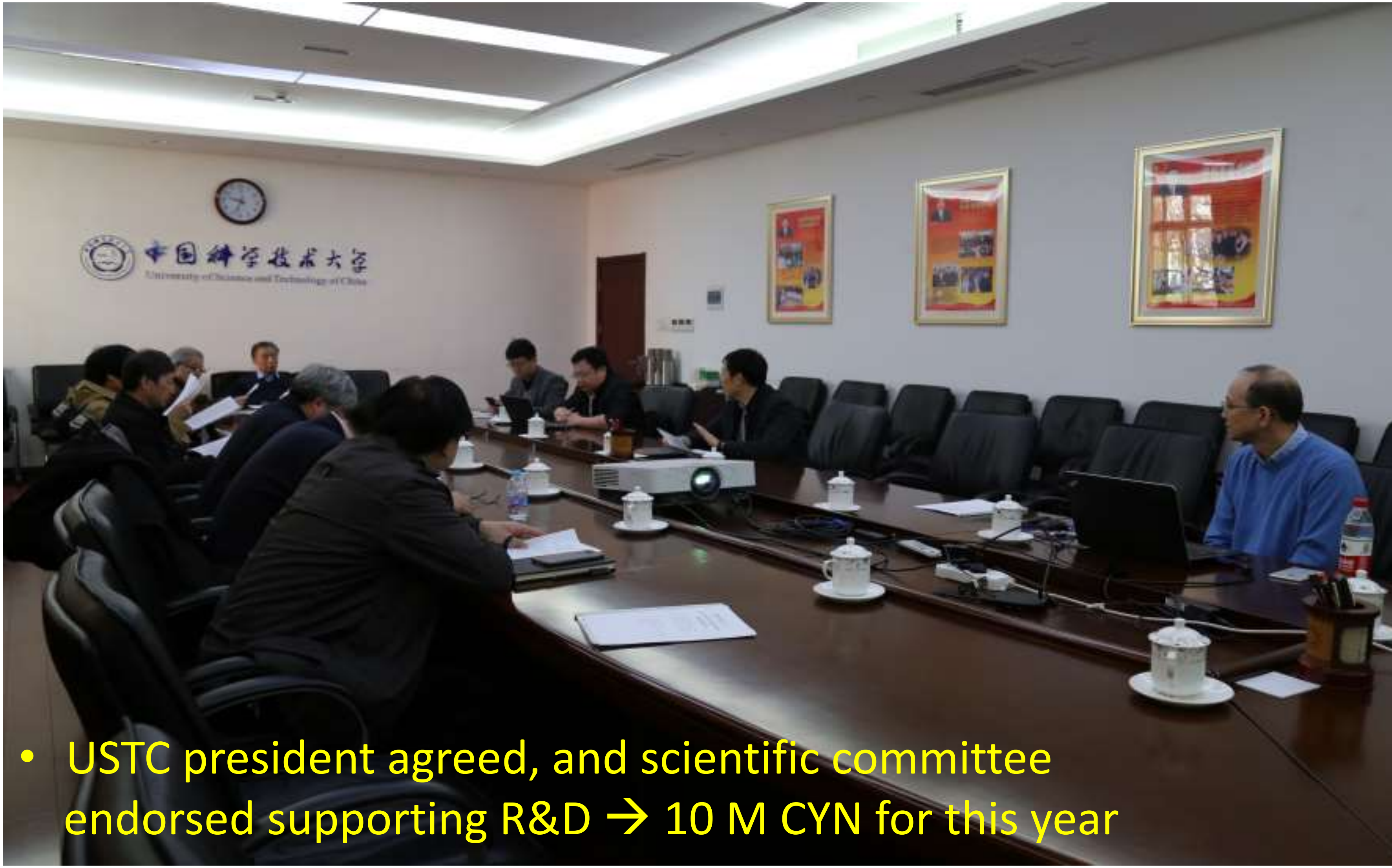
Candidate site : Hefei

One of three integrated national science center, which will play important role in 'Megascience' of China in near future



- **Pay a lot of attention on accelerator facilities**
- **Hefei Advanced light source is under design**
- **STCF is listed in future plan**

USTC Scientific Committee Review



- USTC president agreed, and scientific committee endorsed supporting R&D → 10 M CYN for this year

Tentative Plan

	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030-2040	2041-2042
Form International Collaboration														
Conception Design Report (CDR)														
Technical Design Report (TDR)														
Construction														
Commissioning														
Upgrade														

A unique precision frontier in the world for 30 years!

Summary

- **Super τ-c Factory (STCF):**
  - double ring with circumference around 600~1000 m
  - e^+e^- collision with $E_{cm} = 2 – 7$ GeV, $L = 1 \times 10^{35}$ $cm^{-2}s^{-1}$
- **STCF is one of the crucial precision frontier**
  - rich of physics program
  - unique for physics with c quark and τ leptons,
  - important playground for study of QCD, exotic hadrons and search for new physics.
- **We initialized 10 M CNY (1 USD = 6.5 CYN) to start R&D.**
- **An International collaboration is essential for promoting the project.**

Welcome to join the effort

谢谢 Thanks.

Backup Slides

High-Luminosity Asymmetric B Factory

- Target luminosity is $\mathscr{L} = 8\text{x}10^{35}\ \text{cm}^{-2}\text{s}^{-1}$ (x40 w.r.t. BELLE)
- Achievable in the *nano-beam scheme* (P. Raimondi for SuperB)
  - double beam currents
  - squeeze beams @ [illegible]

Lorentz factor

beam

beam-beam

$L = \frac{\gamma}{2e_e} \ldots$

beam aspect [illegible] at the IP

vertical beta-function at the IP

reduced CM boost

- reduced vertex separation, Δt resolution
- increased detector hermeticity

squeezed beams @ IP

- greatly improved constraint for decay chain vertex fitting

parameter		[illegible] LER	[illegible]	SuperKEKB LER	SuperKEKB HER	units
beam energy	E_b	3.5	8	4	7	GeV
CM boost	βγ	0.425		0.28		
h[illegible]				41.5		mrad
ho[illegible]			24	3.2	4.6	nm
			0.66	[illegible]37	0.40	%
b[illegible]			5.9	32/0.27	25/0.30	mm
			1.19	3.6	2.6	A
bea[illegible]			90	0.0881	0.0807	
			2	10/0.059		μm
			0	$8\text{x}10^{35}$		$\text{cm}^{-2}\text{s}^{-1}$

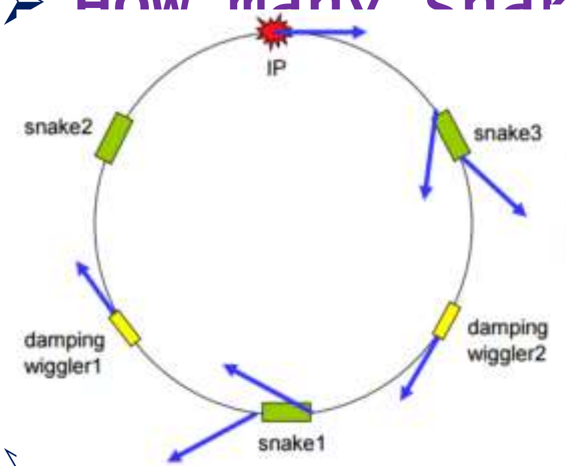
x40 luminosity

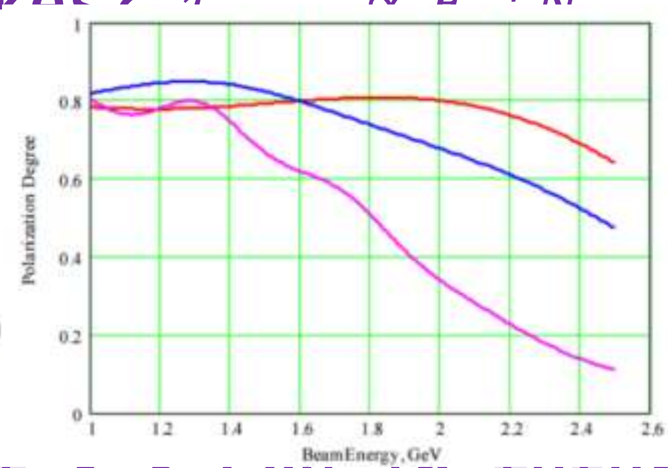
- higher background rates (~10-20x)
  - detectors occupancy, radiation damage, fake hits, pile-up noise in the calorimeter
- higher event rate
  - higher trigger rate, DAQ, computing
- x40 produced signal events

To achieve high polarization

- Siberia Snakes
  - Mini-rotator
    - Very large trace bending angle, increases emittance
    - Spin resonance
  - How many snakes? $\tau \propto E^{-7}N^2$

Courtesy of Prof. Dong Wang, SINAP





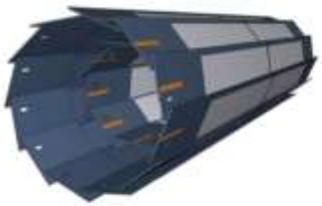
Courtesy of Dr. Anashin, Dr. Aulchenko, et al., BINP Tau Charm Report

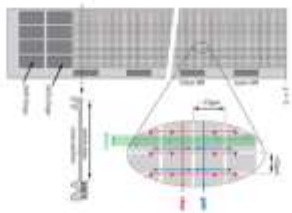
  - For Energy of 3.5 GeV in future, 7 snakes

Inner tracker Technologies

DEPFET

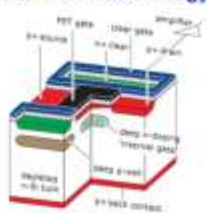
- Two layers of PXD: 1.8 cm and 2.2 cm in radius, consisting of 8 and 12 modules for innermost layer and the second, respectively.



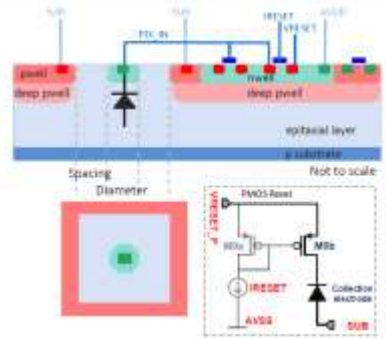


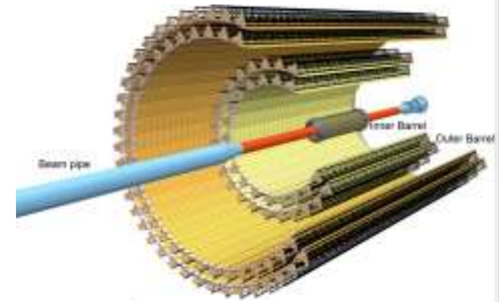
Number of pixels per module	250 x 1536
Pixel size (r-phi, z)	50μm x (60-75) μm
Frame time	20 μs
Material budget per layer	0.15% X_0
Resolution (r-phi, z)	<10μm, < 20μm
Occupancy at 1.8 cm radius	0.2 hits $\mu m^{-2}s^{-1}$
Radiation environment	~1 Mrad/year

DEPFET Technology



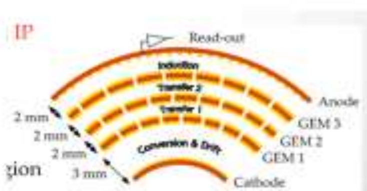
MAPS (ALPIDE)



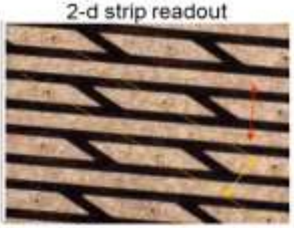


Pixel size: 29*27μm, high resistivity epitaxial, deep PWELL, reverse bias, global shutter (<10 μs), triggered or continuous readout, resolution < 5um, material budget <0.3%X_o

Cylindrical GEM



2-d strip readout

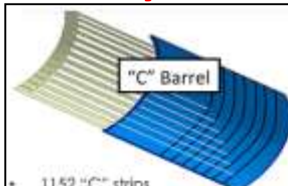


X pitch 650μm → X res 190 μm
V pitch 650μm → Y res 350 μm

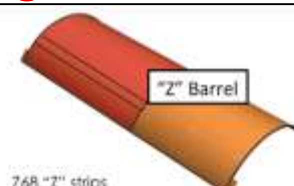
Material Budget	
Total 1 layer	0.49%
Total 4 layers	1.95%

Pixel readout would be required for the innermost layers at HIEPA

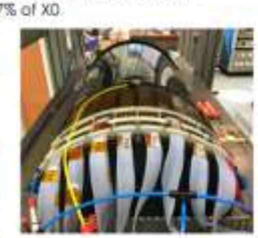
Cylindrical MicroMegas



- 1152 "C" strips
- Pitch from 0.67 to 0.33 mm
- 221 mm radius
- PCB thickness 100 μm
- Drift thickness 250 μm
- Drift Field 2.4kV on 3 mm gap

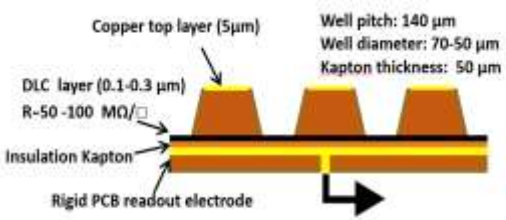


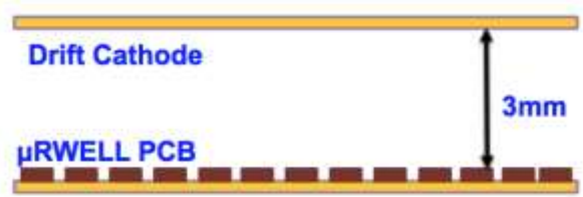
- 768 "Z" strips
- 225 mm radius, 0.529 mm pitch
- PCB thickness 200 μm
- Drift thickness 250 μm
- Drift Field 2.4kV on 3 mm gap
- 0.37% of X0



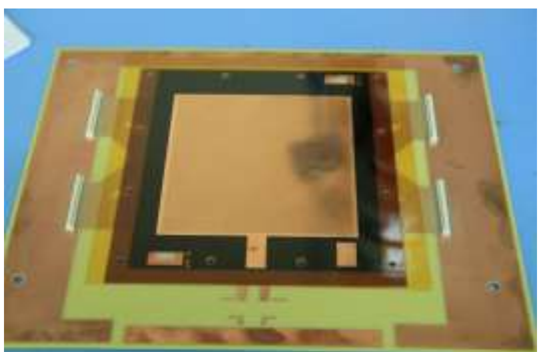
A new MPGD : uRWELL

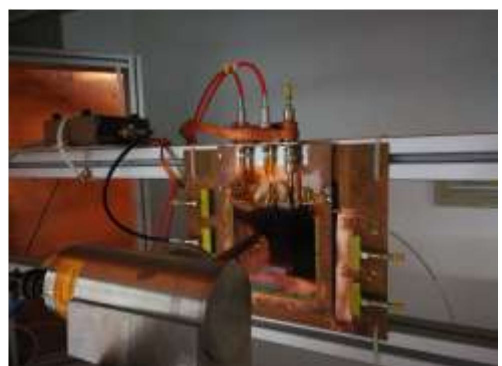
- Very compact, spark protected, simple to assemble, flexible in shapes (rather easy to make a cylindrical detector)

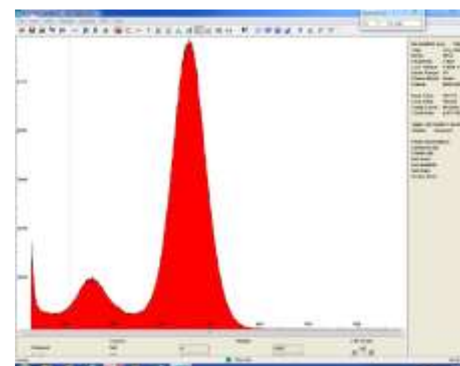




- A possible solution to HIEPA inner tracking. R&D underway at USTC.

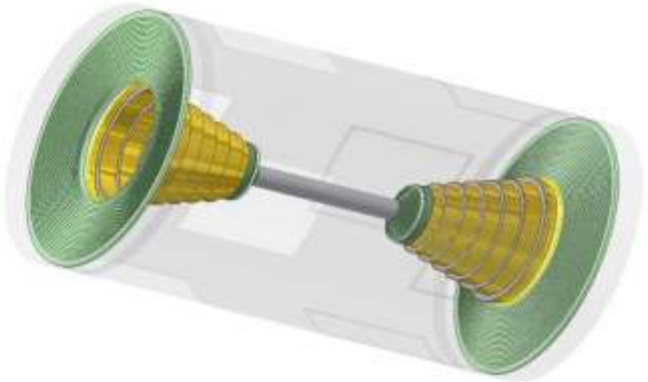






Outer tracker : A Drift Chamber

- BESIII drift chamber can serve as a good starting point
  - R_{in} has to be enlarged to avoid the very high rate region at HIEPA
  - Smaller cell size for inner layers to accommodate a higher count rate
  - No Au coating on Al wires and thinner W wires to reduce material
  - A lighter working gas to reduce material
  - Sharing field wire layers at the axial-stereo boundaries to reduce material

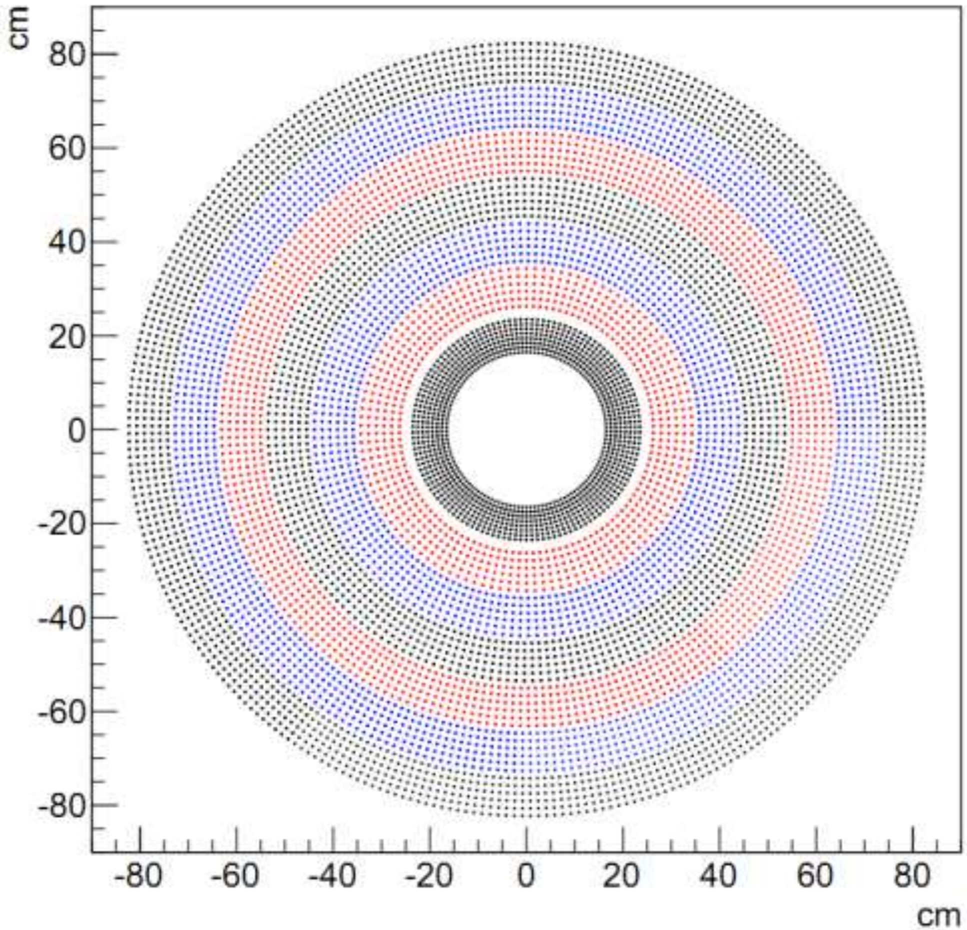


$$\sigma_x \sim 130\mu m$$

$$\frac{\sigma_P}{P} \sim 0.5\%@1GeV/C$$

$$\frac{\sigma_{\frac{dE}{dx}}}{\frac{dE}{dx}} \sim 6\%$$

A Drift Chamber for STCF



- Rin = 15 cm, Rout = 85 cm, L = 2.4 m
- B = 1 T
- He/C_2H_6 (60/40)
- Cell size =1.0cm(inner),1.6cm(outer)
- Sense wire: 20 um W
- Field wire: 110 um Al
- # of layers = 44
- Layer configuration: 8A-6U-6V-6A-6U-6V-6A
- Carbon fiber for both inner and outer walls
- Expected spatial resolution: <130μm
- Expected dE/dx resolution: <7%

Combination of inner/outer trackers

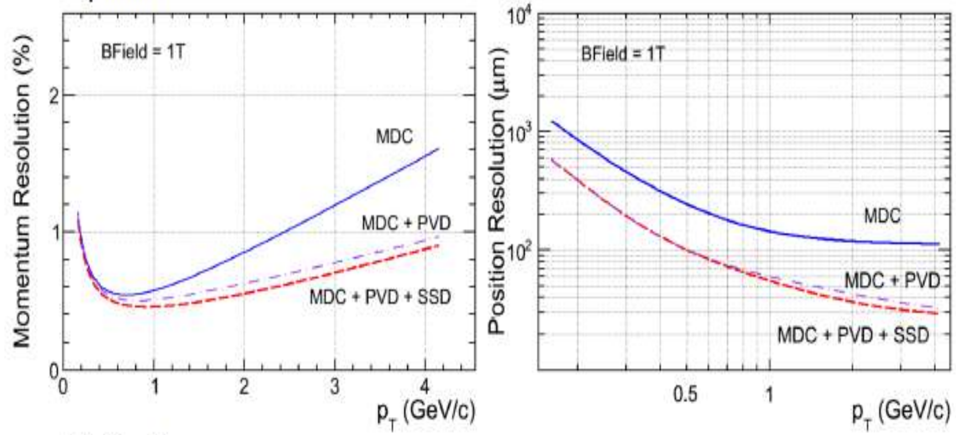
Option I: MDC + STAR HFT (geometry is not optimized)

Detector	radius (cm)	material (%X_0)	resolution (μm)
MDC Outer 9-48	23.5-82	0.0045 /layer	130
MDC Inner 1-8	15-22	0.0051 /layer	130
SSD	10	1.5	250
PXD 2 layers	3/6	0.37 /layer	30
Beam pipe	2	0.15	-

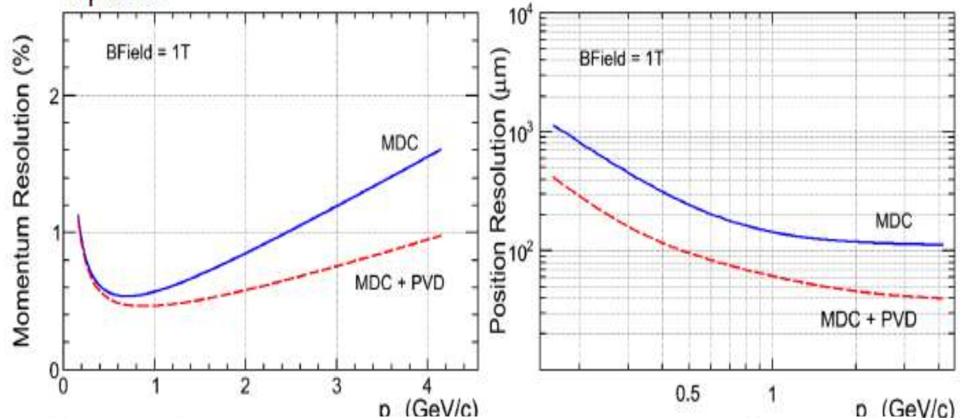
Option II: MDC + Belle-II PXD (geometry is not optimized)

Detector	radius (cm)	material (%X_0)	resolution (μm)
MDC Outer 9-48	23.5-82	0.0045 /layer	130
MDC Inner 1-8	15-22	0.0051 /layer	130
PXD 3rd layer	10	0.15	50
PXD 2 layers	3/6	0.15 /layer	50
Beam pipe	2	0.15	-

Option1



Option2



$$\frac{\sigma_{P_t}}{P_t} pos. = \frac{3.3 \times 100 \times \sigma_x}{BL^2} P_t \sqrt{\frac{720}{N+5}}$$

$$\left.\frac{\sigma_{P_t}}{P_t}\right|_{MS} = \frac{5.7}{BL} \times \frac{1}{\beta} \times \sqrt{\frac{LP}{X_0 P_t}}$$

PID Detector

Key Features of PID System

- Enable π/K (and K/p) $3\text{-}4\sigma$ separation up to 2GeV/c
- Suitable for high luminosity run – fast detector
- Radiation hard, especially in the endcap region
- Compact – reduce costs of the outer detectors
- Modest material budget - $<0.5X_0$

Low Momentum PID

- Specific energy loss (dE/dx) in MDC can be used for low momentum PID
- Better dE/dx resolution for longer track length
- BESIII MDC (~6%, track length ~0.7m)
  - clean $\pi/K/p$ ID for p<0.8/1.1 GeV/c

High Momentum PID

- TOF can not identify π/K to p=2GeV/c
- Cherenkov detector is necessary
- Two catalogs
  - Threshold Cherenkov – simple to build
  - Imaging Cherenkov: RICH (large momentum range)/ DIRC / TOP (most compact)

PID Detector

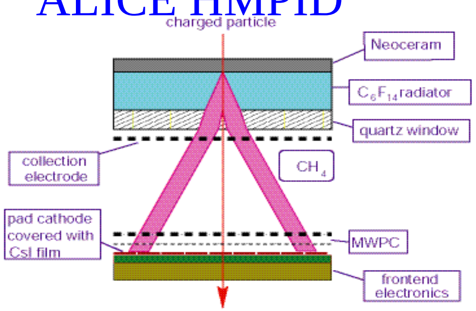
Baseline Design

- PID by RICH at $0.8<p<2$GeV/c, no TOF
- Proximity RICH, similar to ALICE HMPID design, but with PHENIX HBD (CsI coated GEM) readout
- n~1.3 (liquid C_6F_{14}), UV detection
- Already proven
- Immune to B field → same structure at both the endcap and the barrel

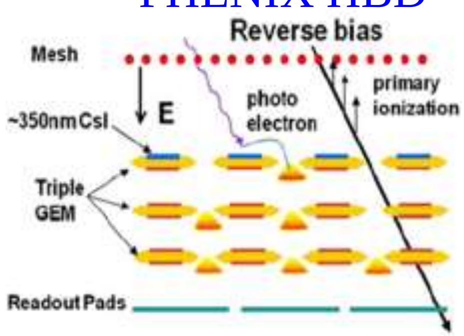
Alternative Design

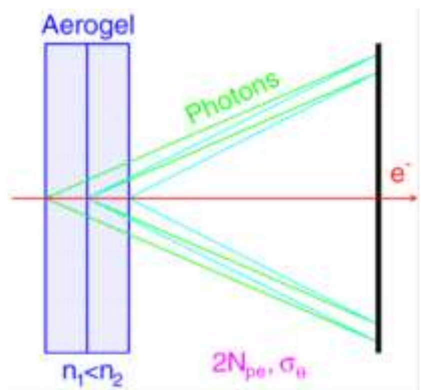
- No TOF, PID by RICH only
- Similar to BELLE-II ARICH design, Aerogel + Position Sensitive Photon Detector
- n~1.13 (Below threshold for proton at p<2GeV/c)
- Already proven at the BELLE-II endcap, how about the barrel part?
- Need R&D

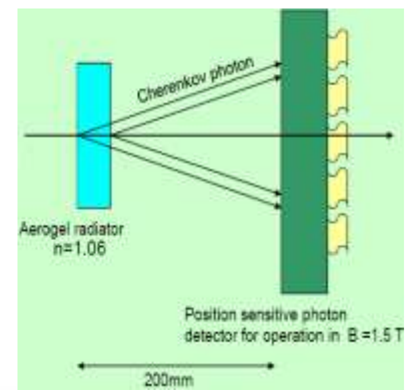
ALICE HMPID



PHENIX HBD

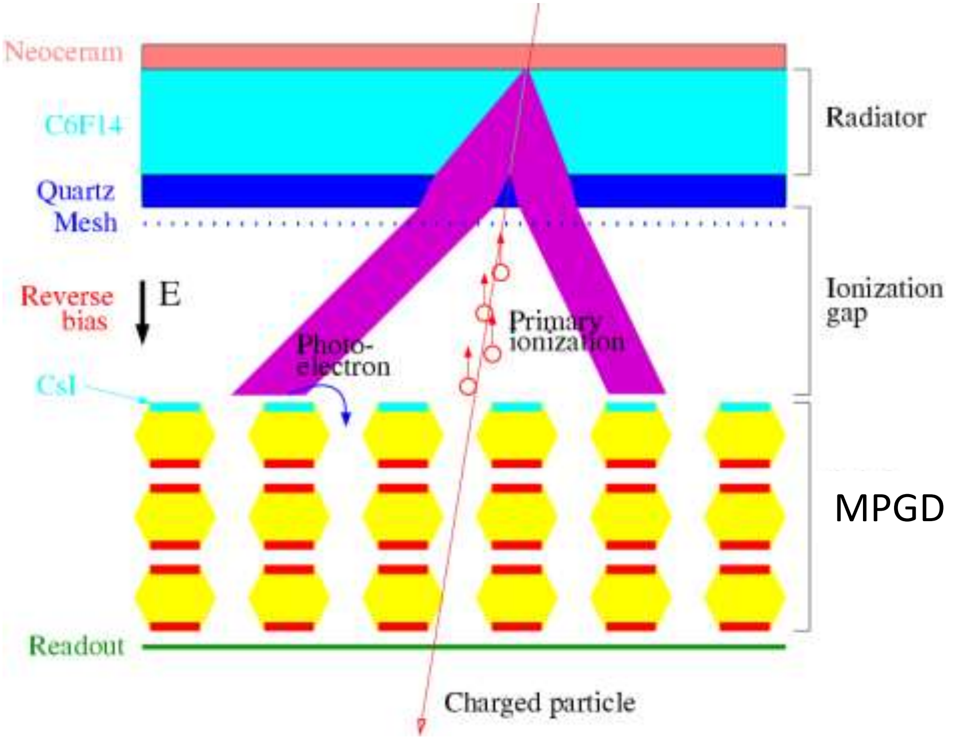




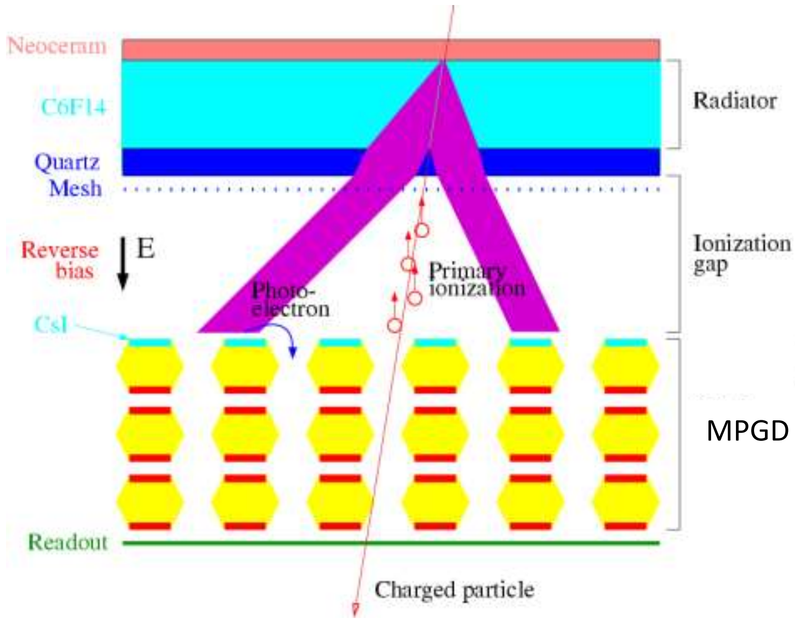


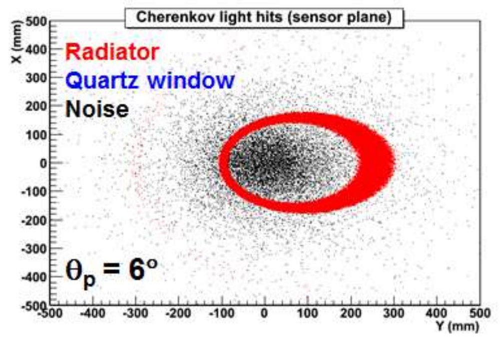
A RICH Design for HIEPA

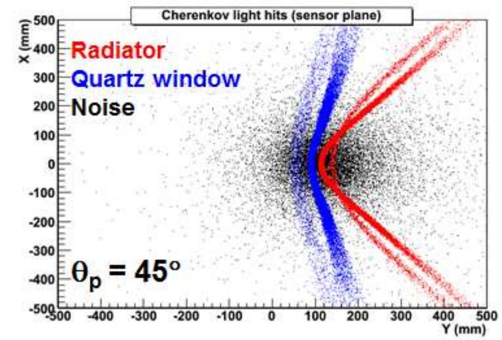
- Proximity focusing RICH, similar to ALICE HMPID design, but with CsI-coated MPGD readout
  - avoid photon feedback
  - less ion backflow to CsI
  - Fast response, high rate capacity
  - Radiation hard
- Proximity gap ~10cm
- Radiator: liquid C_6F_{14}, n~1.3, UV detection

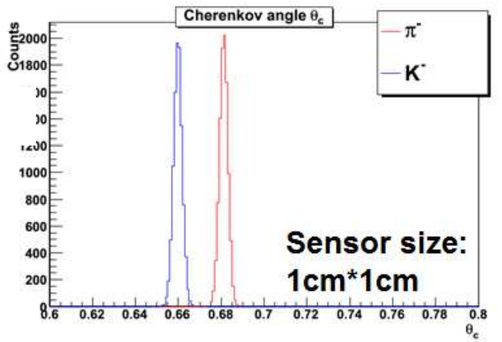


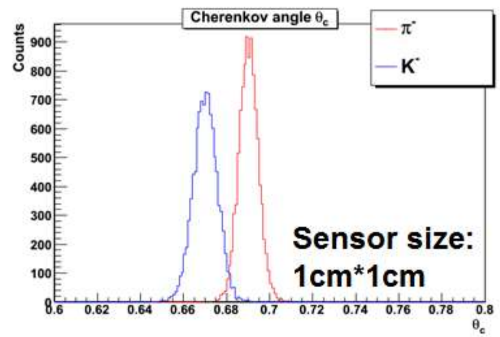
Performance Simulation

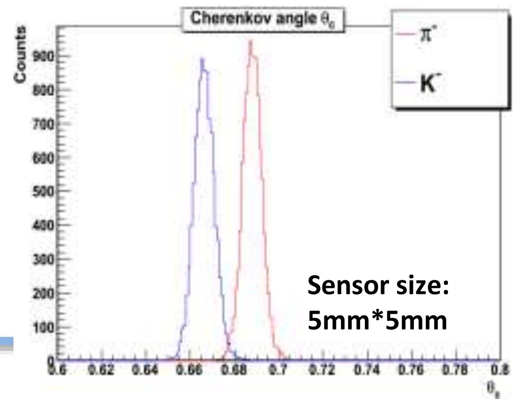








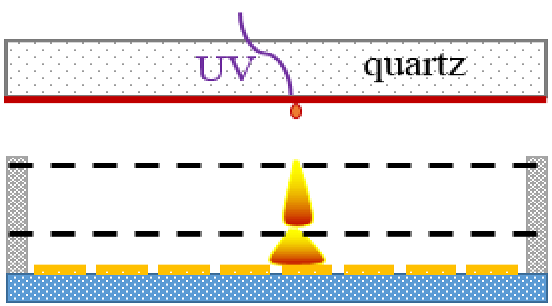




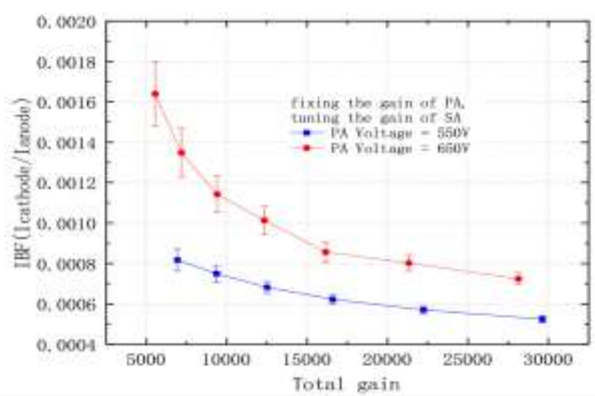
The π/K separation requirement can be met with a RICH detector.

MPGD Photon Detector R&D

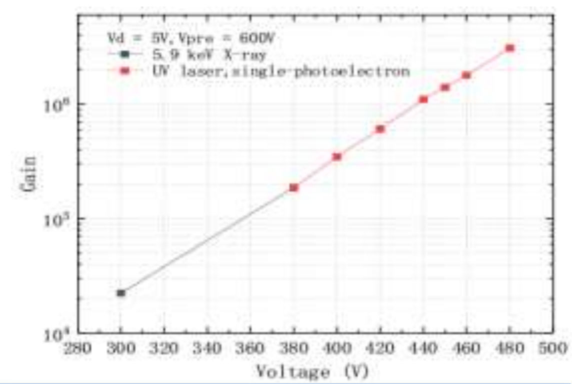
- A double-mesh Mircromegas detector is being developed at USTC
  - High gain and very low ion backflow
  - Very suitable for single photon detection (with a proper photon-electron converter)
  - A promising photon detector option for RICH



IBF ~ 0.05%

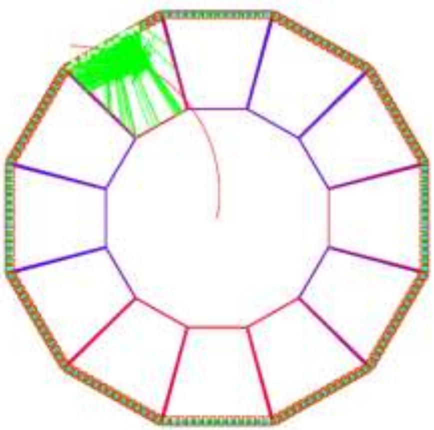


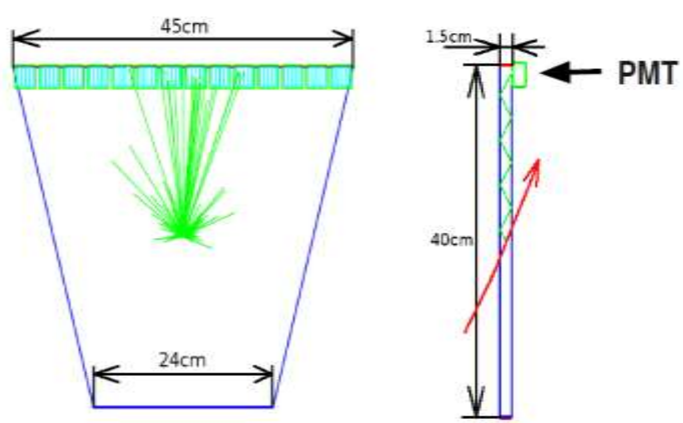
Gain ~ 3×10^6



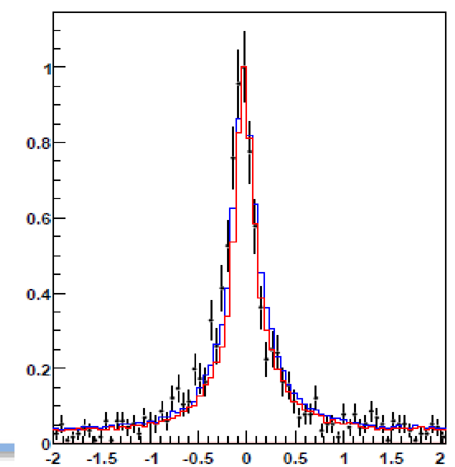
DIRC-like TOF for Endcaps

- DIRC-like forward TOF detector (FTOF: quartz + MCP-PMT) was developed at LAL for the SuperB factory project.
- Also an endcap PID option for HIEPA.
  - Flight length ~ 1.4 m for endcaps. ~30ps time resolution is required for pi/K separation to reach 2GeV.





~ 80ps per PE



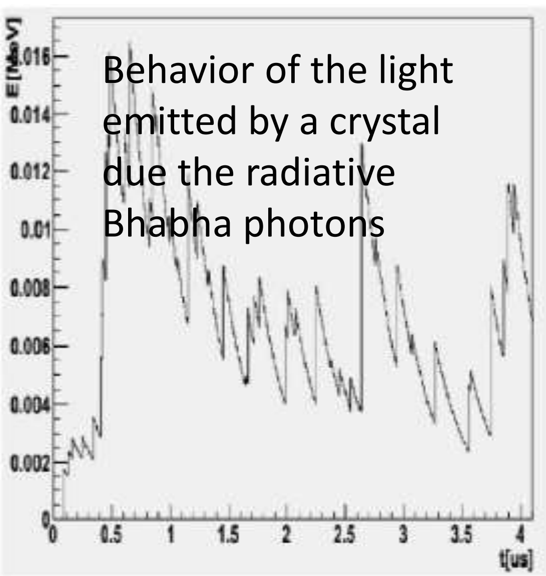
Electromagnetic Calorimeter

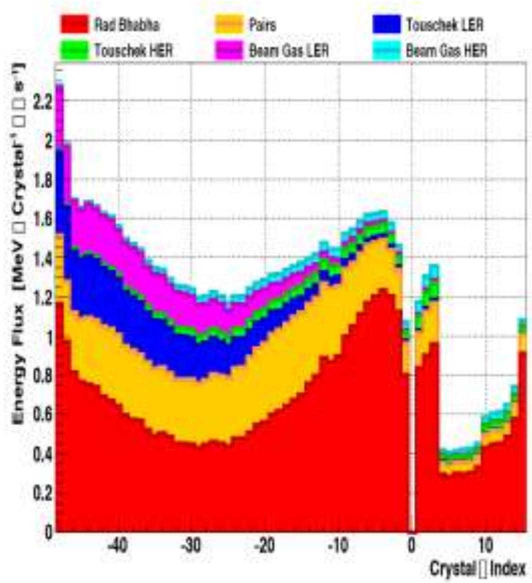
EMC Requirements

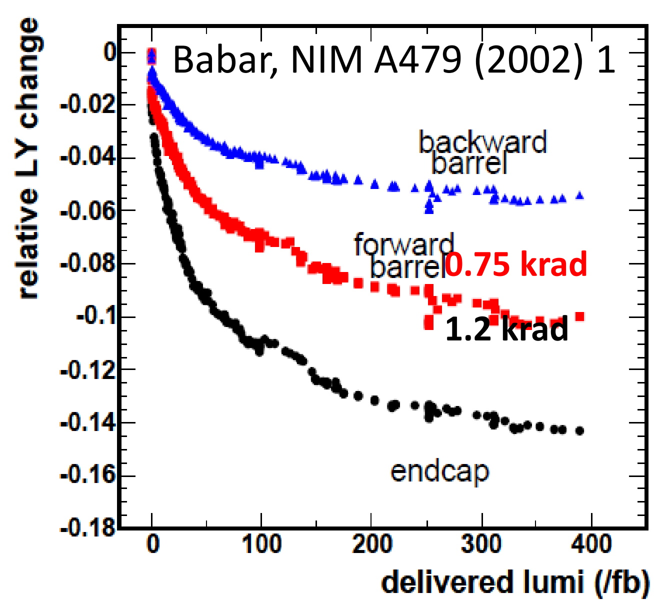
- Good energy resolution
- Good position/angular resolution
- Good timing resolution if possible

Challenging

- Radiation damage
  - Decrease light yield
  - A function of run time
- High photon background rate
  - Produce pile-up
  - Degrade energy and angular resolution





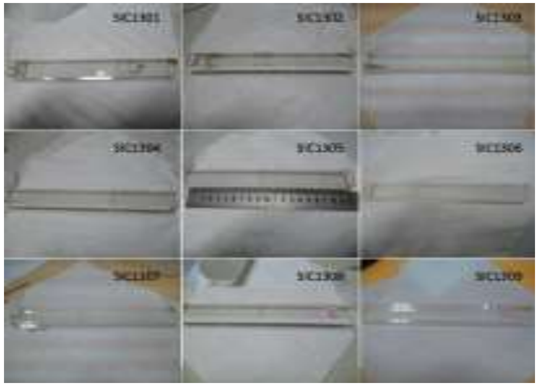


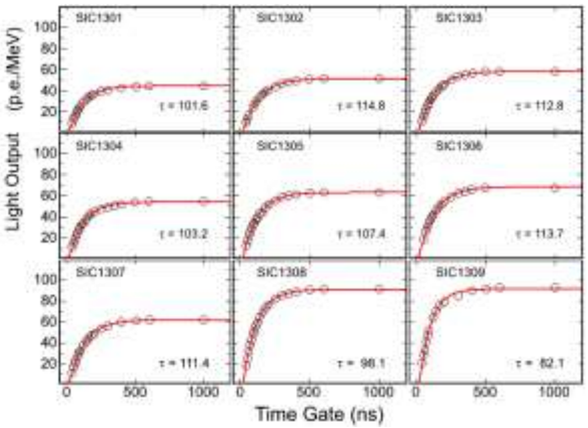
Crystal Options

Crystal	CsI(Tl)	CsI	BSO	$PbWO_4$	LYSO(Ce)
Density (g/cm^3)	4.51	4.51	6.8	8.3	7.40
Melting Point (°C)	621	621	1030	1123	2050
Radiation Length (cm)	1.86	1.86	1.15	0.89	1.14
Molière Radius (cm)	3.57	3.57	2.2	2.0	2.07
Interaction Len. (cm)	39.3	39.3	23.1	20.7	20.9
Hygroscopicity	Slight	Slight	No	No	No
Peak Luminescence (nm)	550	310	480	425/420	420
Decay Time [b] (ns)	1220	30 6	100 26,2.4	30 10	40
Light Yield [b,c] (%)	165	3.6 1.1	3.4 0.5/0.25	0.30 0.077	85
LY in 100 ns	13	4.6	2.9	0.37 *(2-3x↑)*	78
LY in 30 ns	4	3.3	1.5	0.26 (2-3x↑)	45
d(LY)/dT [b] (%/ °C)	0.4	-1.4	-2.0	-2.5	-0.2
Radiation hardness (rad)	10^3	10^{4-5}	10^{6-7}	10^{6-7}	10^8
Dose rate dependent	no	no	yes	yes	
Experiment	CLEO, *BABAR*, Belle, BES III	KTeV, E787 Belle2 1st SuperB 2nd	Belle2 3rd	CMS, ALICE PANDA Belle2 2nd	SuperB 1st (Hybrid)

Different options for barrel and endcaps

R&D on BSO

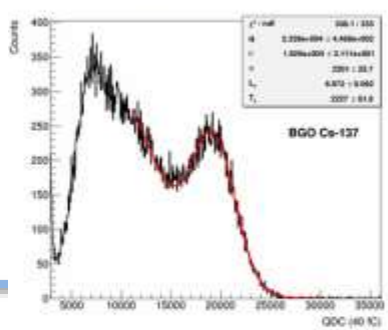


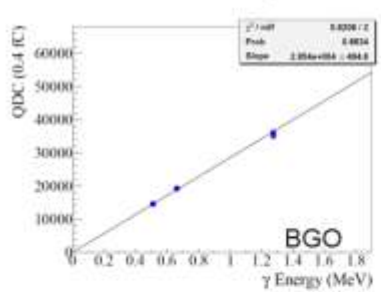


SiPM Technology

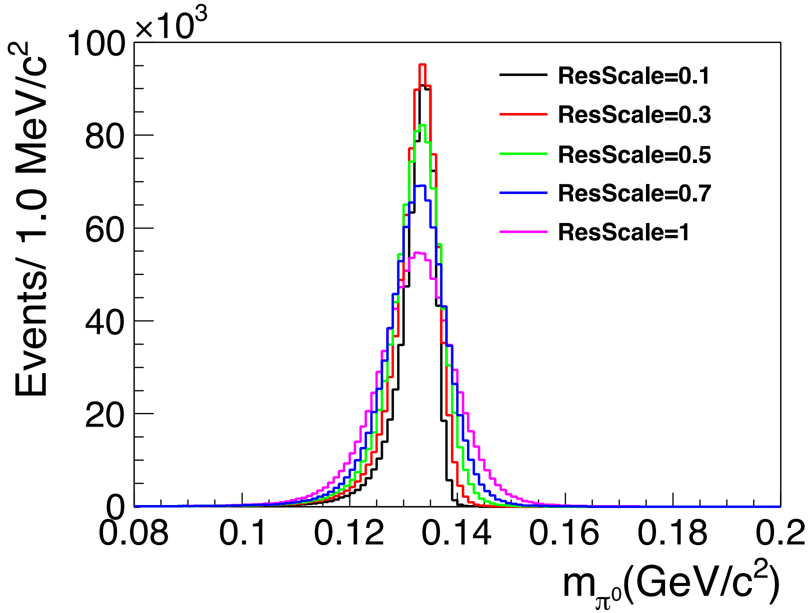
- SiPM: a novel and rapidly-developing photo-sensor technology
  - High gain, low equivalent noise, B-field resistant, good time resolution
- R&D at USTC

Hamamatsu S10362-33-050C, 3x3 mm^2

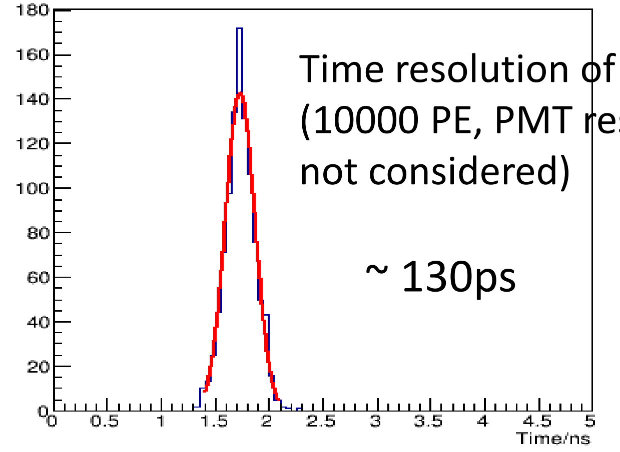




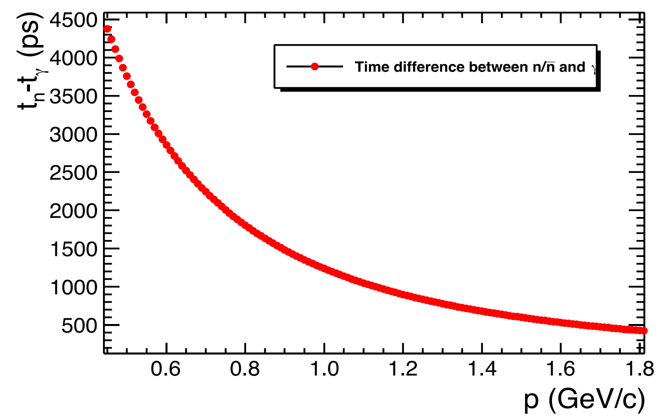
Aspects Other Than Energy



A timing ECAL !



Difference in TOF of n and γ

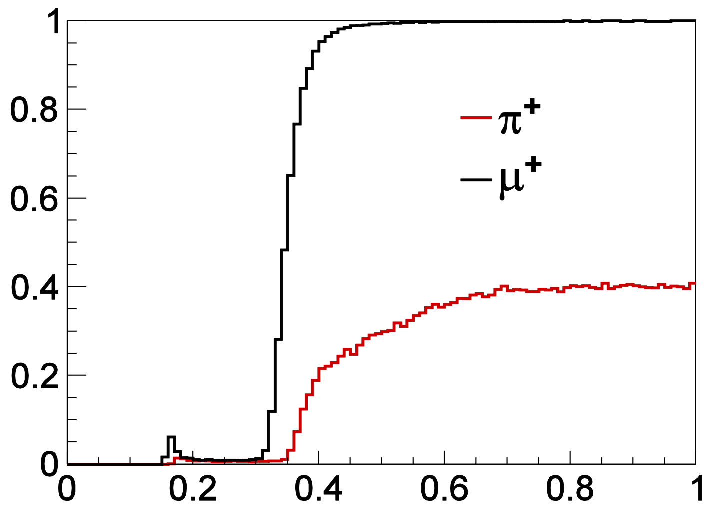


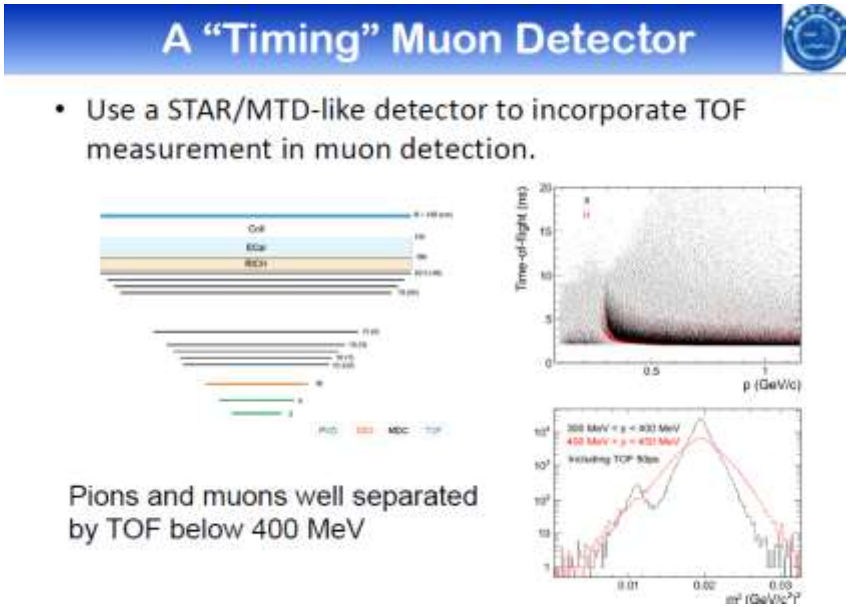
The position resolution of ECAL has a significant impact on object/event reconstruction involving γ .

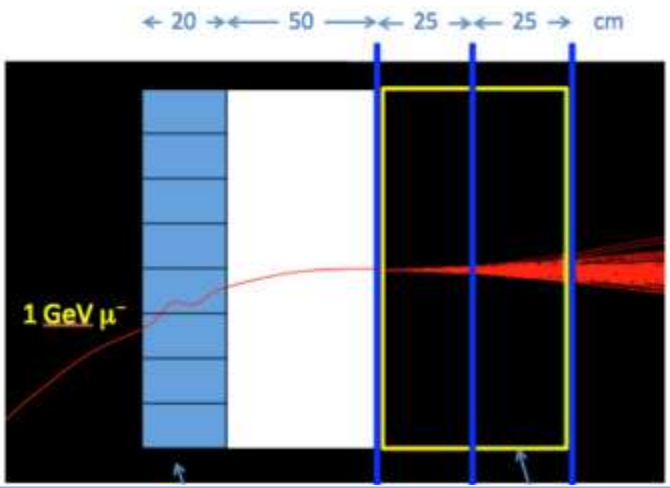
→ Energy resolution is not everything, position resolution is also important.

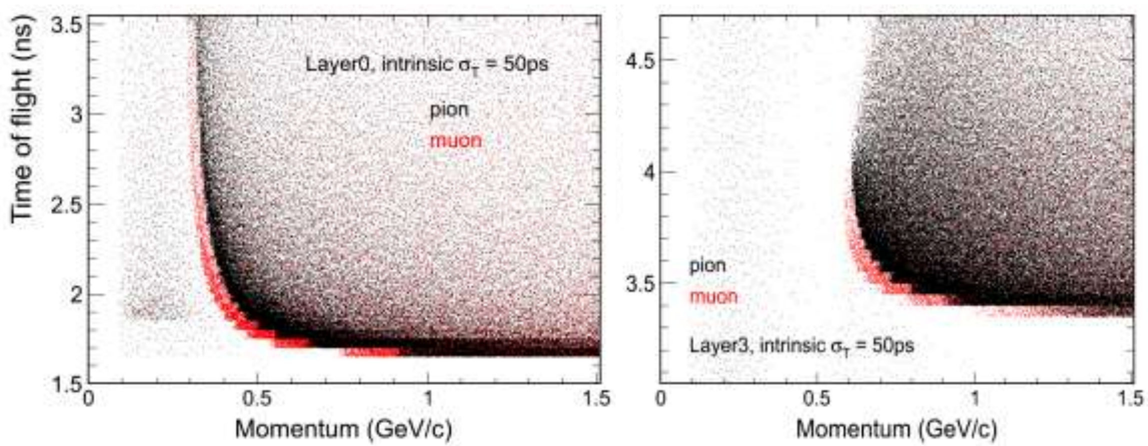
Precise ECAL timing is very useful in suppressing γ background

Muon Detector







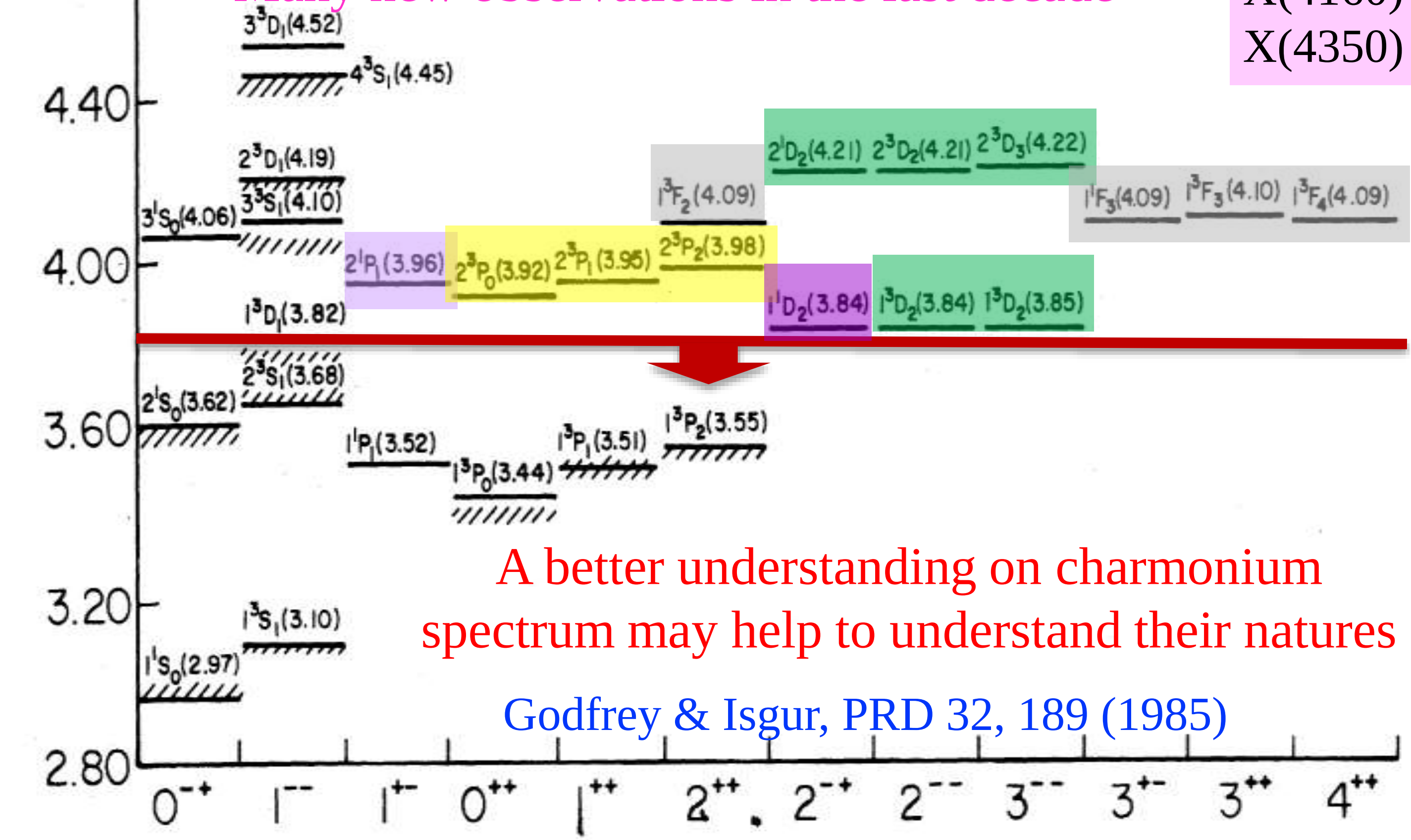


Charmonium (like) Spectroscopy

Key Science question : Is there any exotic hadron exist

- States below charm threshold are all well observed
- Many missing states above charm threshold
- Many new observations in the last decade

X	Y	Z
X(3872)	Y(3940)	Z(3900)
X(3940)	Y(4008)	Z(4020)
X(4160)	Y(4260)	Z(4050)
X(4350)	Y(4360)	Z(4200)
	Y(4660)	Z(4250)
		Z(4430)



A better understanding on charmonium spectrum may help to understand their natures

Godfrey & Isgur, PRD 32, 189 (1985)

Nature unclear

- Charmonium?
- Hybrid?
- Tetraquark?
- Molecule?
- Non-resonance?

Summary of τ Physics

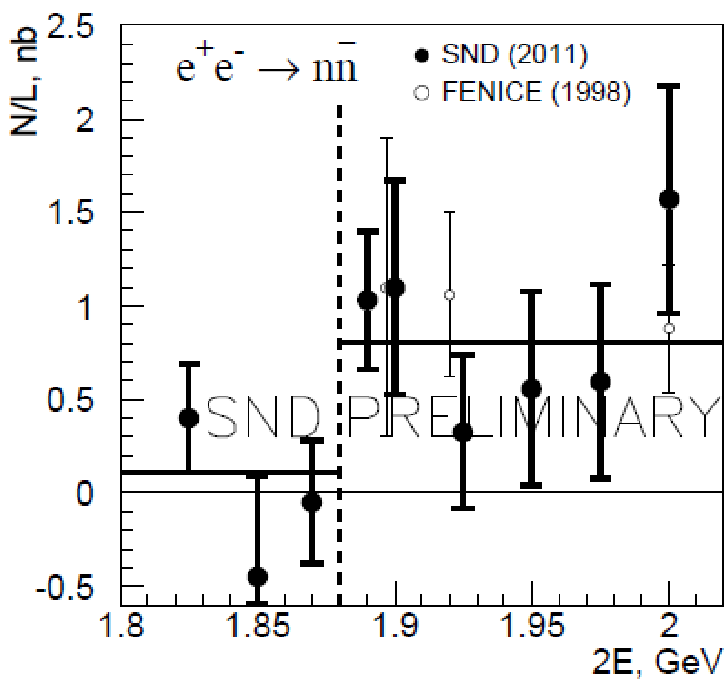
With 1ab^{-1} near tau threshold:

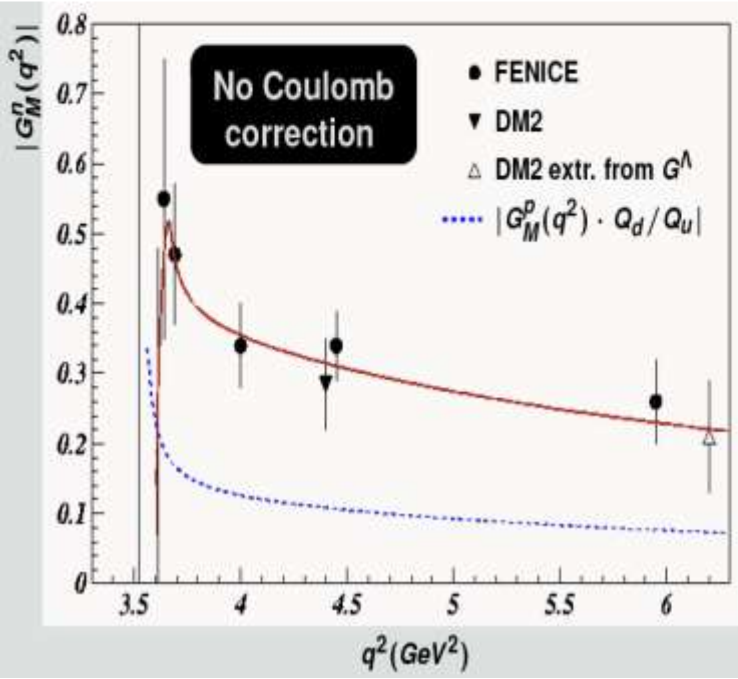
- LFV: 10^{-9}
- Lepton universality: 10^{-4}
- CP violation in decay: 10^{-4}
- CPT tests: 10^{-4}
- Tau mass
- Vus: (0.1-0.5)%

A super-tau-charm and a BELLEII will be complementary machines for tau physics

Nucleons FF

- 中子数据更稀缺，只有Fenice结果(74个$e^+e^- \to n\bar{n}$事例, 0.4 pb^{-1})
- 现有数据表明中子的形状因子是质子的2倍，需要实验验证!





提高中子形状因子的测量精度在实验和理论方面都具有重要意义！

意大利曾计划对**DAΦNE/FINUDA**做重大专门改进来测量核子形状因子

Search for $\eta_{c2}(1^1D_2)$ and $\chi_{c1}(2^3P_1)$

Simple estimations

$L_{peak} = 10^{35}cm^{-1}s^{-1}$, 1 year running = $10^6 pb^{-1}$ = $1ab^{-1}$

A BESIII-Like detector

Detail MC studies are ongoing

$\eta_{c2}(1^1D_2)$

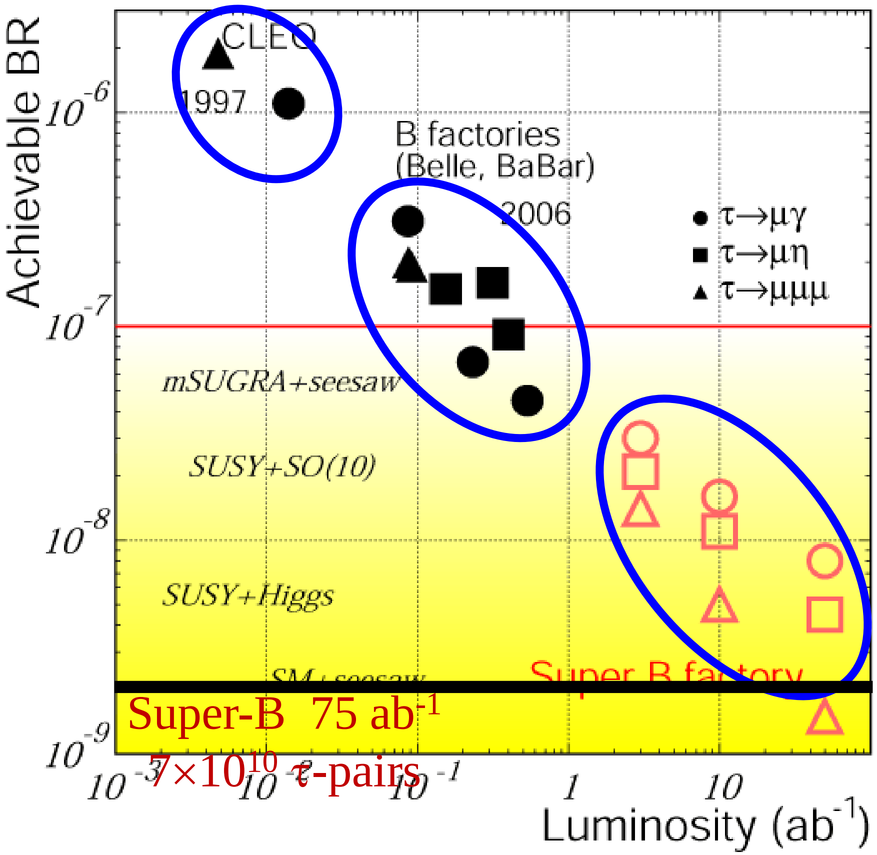
- $\sigma(e^+e^- \to \pi^+\pi^- h_c(2P)) \sim 20$ pb @ Ecm=??GeV
- $B(h_c(2P) \to \gamma\eta_{c2}) \sim 3\times10^{-4}$ [E1 trans., Barnes′ 05]
- $B(\eta_{c2} \to \gamma h_c) \sim (44\text{–}54)\%$ [E1 trans., Fan′ 09]
- $B(h_c \to \gamma\eta_c) \sim 54\%$ [E1 trans., BESIII′10]
- $\varepsilon B(\eta_c \to \text{hadrons}) \sim 1.5\%$ at BESIII
- $N^{obs}=2\times10^{-5}\times L$ (L is int. lumi. in pb^{-1})
- $N^{obs}=20$ events /year,
- Bkg is low for narrow h_c and η_c

$\chi_{c1}(2^3P_1)$

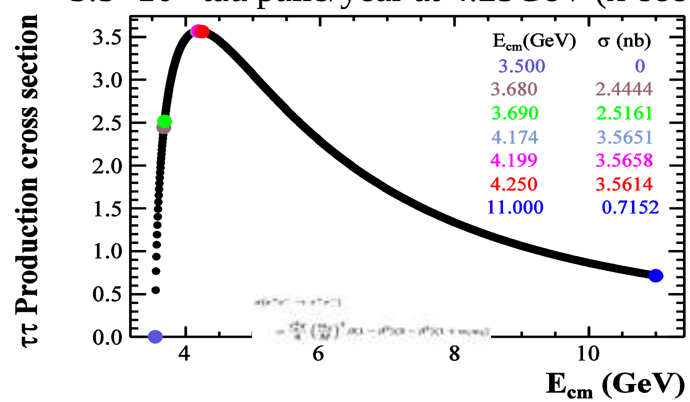
- $\sigma(e^+e^- \to \psi(nS)/\psi(mD)) \sim (3\text{-}7)$ nb @ for n>1, m>2
- $B(\psi \to \gamma\chi'_{c1}) \sim 3\times10^{-4}$ [E1 trans., Barnes′ 05]
- $B(\chi'_{c1} \to \gamma\psi') \sim 1\times10^{-3}$ [E1 trans., Barnes′ 05]
- $B(\chi'_{c1} \to \gamma J/\psi) \sim 1\times10^{-4}$ [E1 trans., Barnes′ 05]
- $\varepsilon B \sim (1\text{–}5)\%$ at BESIII
- $N^{obs} = (1\text{–}10)\times10^{-5}\times L$ (L is int. lumi. in pb^{-1})
- $N^{obs} = (10\text{–}100)$ events /year,
- Bkg is low for narrow ψ' and J/ψ

cLFV Decay τ→μγ @ B Factory

From A. Bondar, Charm2010



- **Current limit : ~ 4×10^{-8}** (5×10^{8} τ-pairs)
  - BABAR : $516 fb^{-1}$ [PRL, 104, 021802]
  - BELLE : $545 fb^{-1}$
- **At Υ(4S) :**
  - ISR background e+e-→$\tau^+\tau^-\gamma$
  - Upper Limit ∝ $1/\sqrt{L}$
  - Expected limit : 3×10^{-9}@$75ab^{-1}$ (7×10^{10} τ-pairs)
- **Belle-II Factory with $L=10^{36}cm^{-2}s^{-1}$**
  - 10^{10} tau pairs per year (x-sec=1nb)
- **HIEPAF with $L=10^{35}cm^{-2}s^{-1}$**
  - 10^{8} tau pairs per year at threshold (x-sec=0.1nb)
  - 3.5×10^{9} tau pairs/year at 4.25GeV (x-sec = 3.5nb)



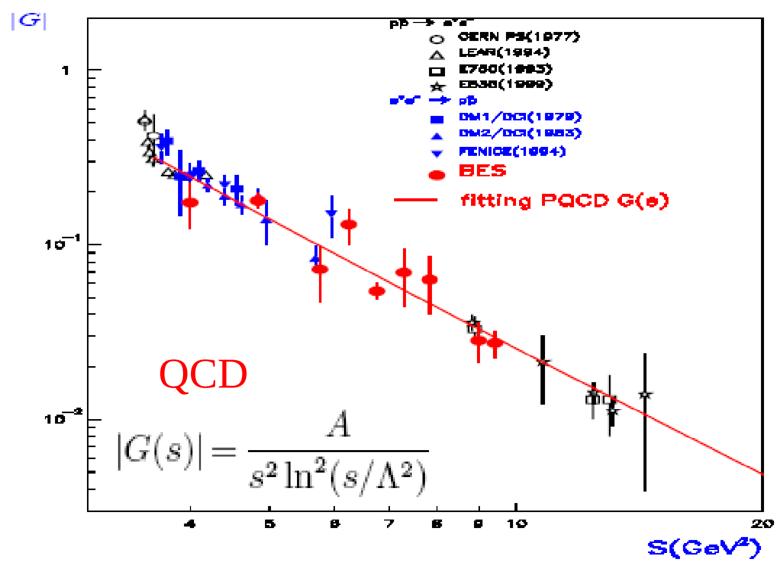
What can HIEPA have with 3×10^{9} ττ pairs / year?

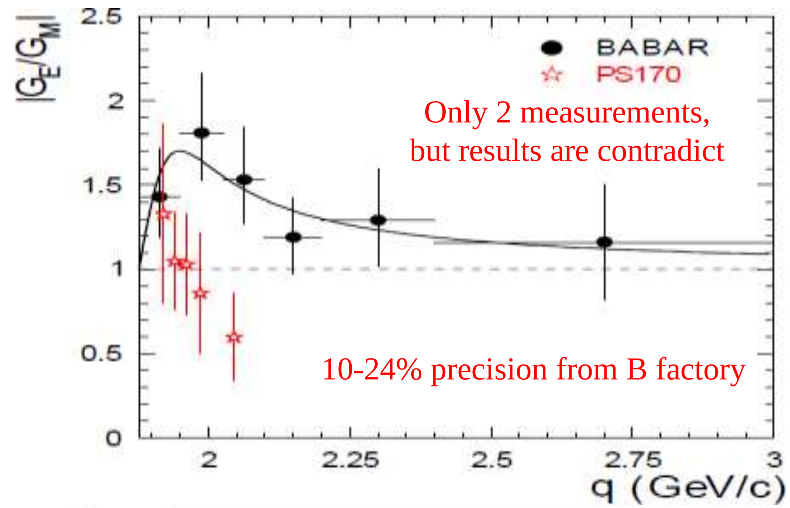
Proton FF : Time-Like

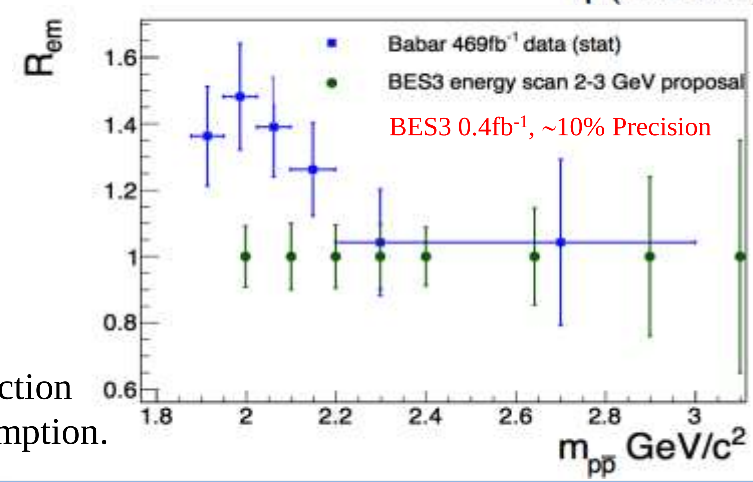
$$\sigma_{e^+e^-\to N\bar{N}} = \frac{4\pi\alpha^2\beta}{3s} C_N(s) \left[|G_M^N(q^2)|^2 + \frac{2M_N^2}{s} |G_E^N(q^2)|^2 \right]$$

$$|G_M(q^2)| = [1 + (q^2 - 4M_p^2)/q_2^2]^{-2}$$
$$|G_E(q^2)| = |G_M(q^2)|[1 + (q^2 - 4M_p^2)/q_1^2]^{-1}$$

Assume $G_M = G_E$ $\quad \sigma_0 = \frac{4\pi\alpha^2\beta}{3s}(1 + \frac{2M^2}{s})|G(s)|^2$







$\delta|R_{EM}|/|R_{EM}| \sim 9\% - 35\%$

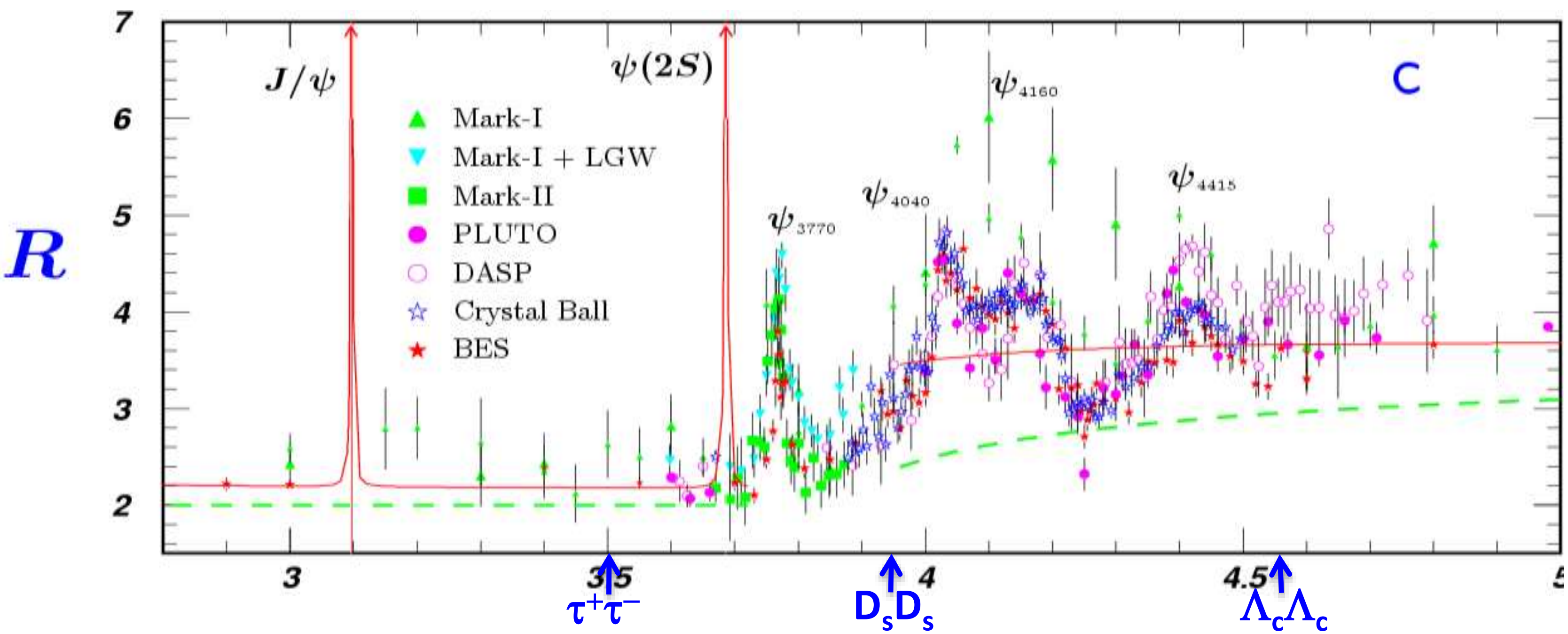
$\delta|G_M|/|G_M| \sim 3\% - 9\%$

$\delta|G_E|/|G_E| \sim 9\% - 35\%$

first time extraction without any assumption.

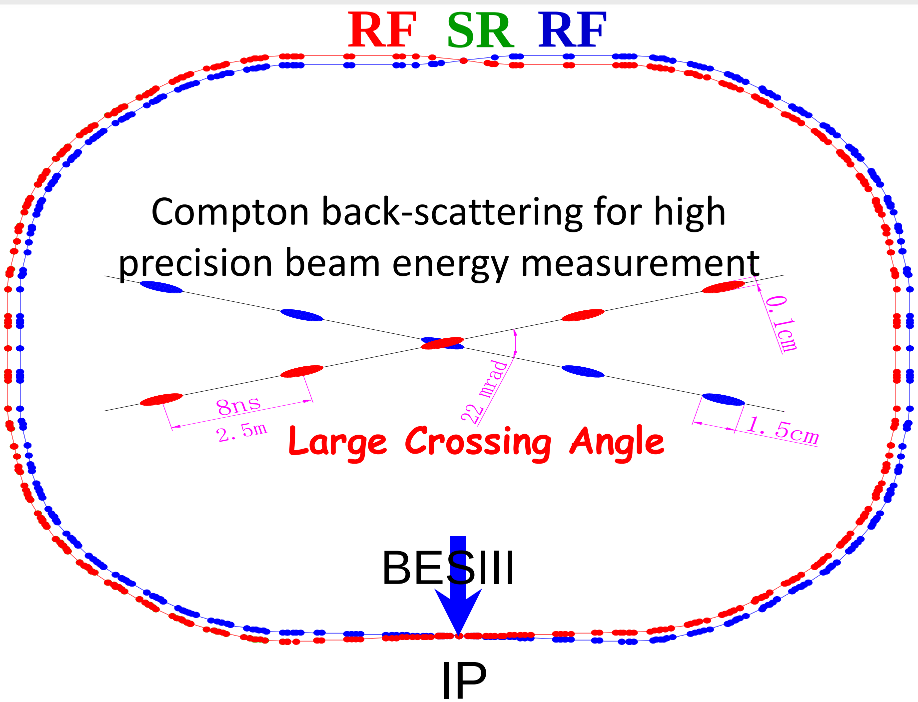
Features of the τ-c Energy Region

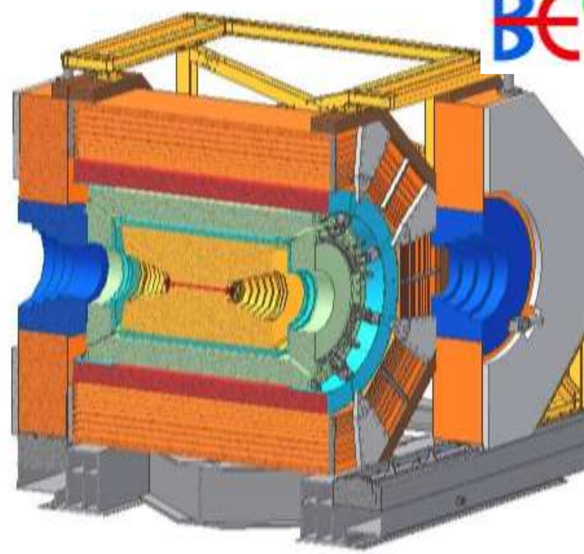
Why Physics on τ-c energy region



- Rich of resonances, charmonium and charmed mesons.
- Threshold characteristics (pairs of τ, D, D_s, charmed baryons…).
- Transition between smooth and resonances, perturbative and non-perturbative QCD.
- Mass location of the exotic hadrons, gluonic matter and hybrid.

Status of BEPCII/BESIII





Sub-detectors			Performance
MDC	Momentum resolution		0.5%@1GeV
	dE/dx resolution		6%
EMC	Energy resolution		2.5%@1GeV
	Spatial resolution		6 mm
TOF	Time resolution	Barrel	80 ps (Bhabha)
		Endcap	110 ps (Di-muon)
MUC	9 layers RPC, 8 layers for endcap		

- Beam energy : 1.0-2.3 GeV
- Energy spread : 5.16 $\times 10^{-4}$
- Optimum ene. : 1.89 GeV
- Luminosity : 1×10^{33} $cm^{-2}s^{-1}$
- No. of bunches : 93
- Bunch length : 1.5 cm
- Total current : 0.91 A
- SR mode : 0.25A@2.5GeV

Unique machine running on tau-charm region in the world

Achieved $1.0\times10^{33}cm^{-2}s^{-1}$ on April

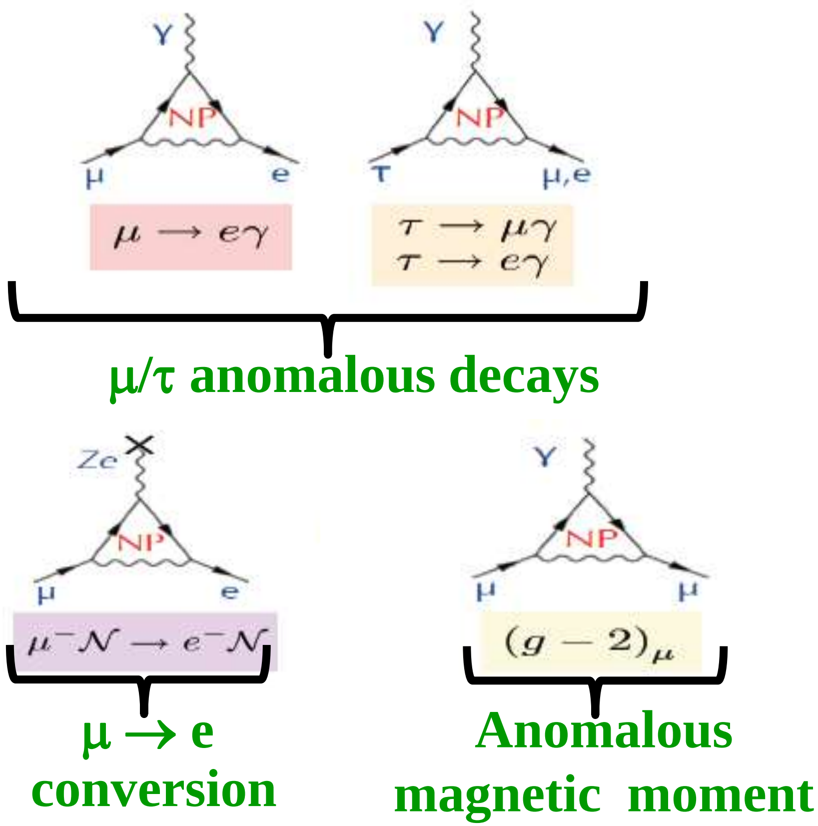
cLFV Decay $\tau \to \ell\gamma$

- No evidence of new physics been found at high energy frontier.
- important and complementary to search for new physics in the precision frontier.

	AC	RVV2	AKM	δLL	FBMSSM	LHT	RS
$D^0 - \bar{D}^0$	★★★	★	★	★	★	★★★	?
ϵ_K	★	★★★	★★★	★	★	★★	★★★
$S_{\psi\phi}$	★★★	★★★	★★★	★	★	★★★	★★★
$S_{\phi K_S}$	★★★	★★	★	★★★	★★★	★	?
$A_{CP}(B \to X_s\gamma)$	★	★	★	★★★	★★★	★	?
$A_{7,8}(B \to K^*\mu^+\mu^-)$	★	★	★	★★★	★★★	★★	?
$A_9(B \to K^*\mu^+\mu^-)$	★	★	★	★	★	★	?
$B \to K^{(*)}\nu\bar{\nu}$	★	★	★	★	★	★	★
$B_s \to \mu^+\mu^-$	★★★	★★★	★★★	★★★	★★★	★	★
$K^+ \to \pi^+\nu\bar{\nu}$	★	★	★	★	★	★★★	★★★
$K_L \to \pi^0\nu\bar{\nu}$	★	★	★	★	★	★★★	★★★
$\mu \to e\gamma$	★★★	★★★	★★★	★★★	★★★	★★★	★★★
$\tau \to \mu\gamma$	★★★	★★★	★	★★★	★★★	★★★	★★★
$\mu + N \to e + N$	★★★	★★★	★★★	★★★	★★★	★★★	★★★
d_n	★★★	★★★	★★★	★★	★★★	★	★★★
d_e	★★★	★★★	★★	★	★★★	★	★★★
$(g-2)_\mu$	★★★	★★★	★★	★★★	★★★	★	?

Table 8: "DNA" of flavour physics effects for the most interesting observables in a selection of SUSY and non-SUSY models ★★★ signals large effects, ★★ visible but small effects and ★ implies that the given model does not predict sizable effects in that observable.

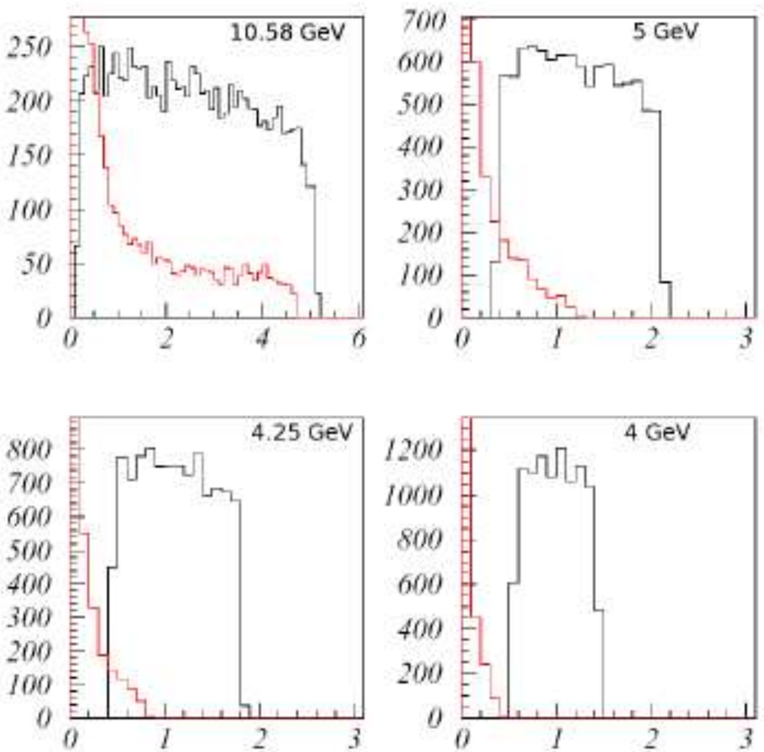
W. Altmannshofer et al. arXiv : 0909.1333



In τ-charm factory, τ→μγ decay is a golden mode to search for NP

STCF .VS. BF : $\tau \to \mu\gamma$ background

Background $e^+e^- \to \tau^+\tau^-\gamma$



Dominant BKG @ B Factory

- Dominant source at $\Upsilon(4S)$: $e^+e^- \to \tau^+\tau^-\gamma$
- Does not contribute below $\sqrt{s} \approx 4m_\tau/\sqrt{3} \approx$ 4.1 GeV.

Dominant BKG @ STCF

- τ decays : [arXiv:1206.1909]

  direct ($\tau^+ \to \pi^+\pi^0\nu_\tau$) and combinatorial
- QED processes :

  $e^+e^- \to \mu^+\mu^-\gamma\gamma$, $e^+e^- \to e^+e^-\mu^+\mu^-\gamma$
- Continuum hadron production $e^+e^- \to qq$
- $\psi(2S)$ and D-meson decays

Polarized beam may further suppress background and increase the sensitivity for the new physics significantly

Expected $\tau \to \mu\gamma$ Br upper limit

E(GeV)	σ(nb)	L(ab^{-1})	$N_{\tau\tau}(10^{10})$
3.686	5.0	1.5	0.75
3.77	2.9	3.5	1.03
4.17	3.6	2.0	0.71
Total		7.0	2.49

Results from Vladimir Druzhinin, (BINP, Novosibirsk) at Workshop on Tau Charm at High Luminosity 26-31 May, 2013, La Biodola, Italy

Fast simulation for NP sensitivity and detector optimization is ongoing

	σ_E/E=1.5%	σ_E/E=2.5%
Signal (Br=10^{-9})	17	15
Muon background	7	11
Pion background	83	271
Expected 90% CL upper limit for Br	1.1×10^{-9}	3.0×10^{-9}
Expected 90% CL upper limit for Br with pion suppression by a factor of 30	3.3×10^{-10}	5.1×10^{-10}

Supper-B Expected limit : 3x10^{-9}@75ab^{-1} (7×10^{10} τ-pairs)