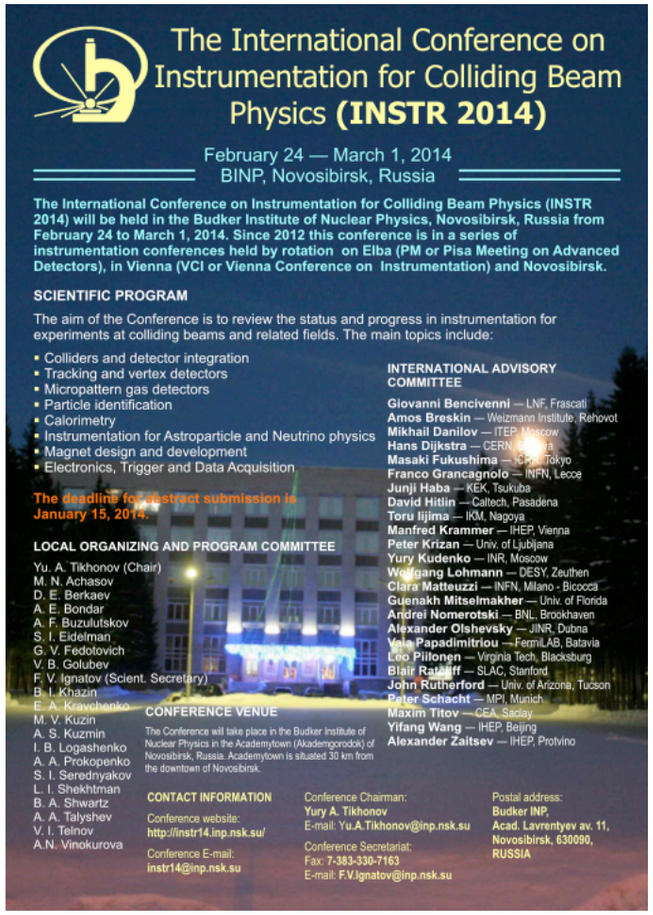
# Status of Belle II and SuperKEKB

Ichiro Adachi
KEK

INSTR2014
BINP
Feb.24, 2014



The International Conference on Instrumentation for Colliding Beam Physics **(INSTR 2014)**

February 24 — March 1, 2014
BINP, Novosibirsk, Russia

**The International Conference on Instrumentation for Colliding Beam Physics (INSTR 2014) will be held in the Budker Institute of Nuclear Physics, Novosibirsk, Russia from February 24 to March 1, 2014. Since 2012 this conference is in a series of instrumentation conferences held by rotation on Elba (PM or Pisa Meeting on Advanced Detectors), in Vienna (VCI or Vienna Conference on Instrumentation) and Novosibirsk.**

**SCIENTIFIC PROGRAM**

The aim of the Conference is to review the status and progress in instrumentation for experiments at colliding beams and related fields. The main topics include:

- Colliders and detector integration
- Tracking and vertex detectors
- Micropattern gas detectors
- Particle identification
- Calorimetry
- Instrumentation for Astroparticle and Neutrino physics
- Magnet design and development
- Electronics, Trigger and Data Acquisition

**The deadline for abstract submission is January 15, 2014.**

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**CONFERENCE VENUE**

The Conference will take place in the Budker Institute of Nuclear Physics in the Academytown (Akademgorodok) of Novosibirsk, Russia. Academytown is situated 30 km from the downtown of Novosibirsk.

**CONTACT INFORMATION**

Conference website:
**http://instr14.inp.nsk.su/**

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**Budker INP,**
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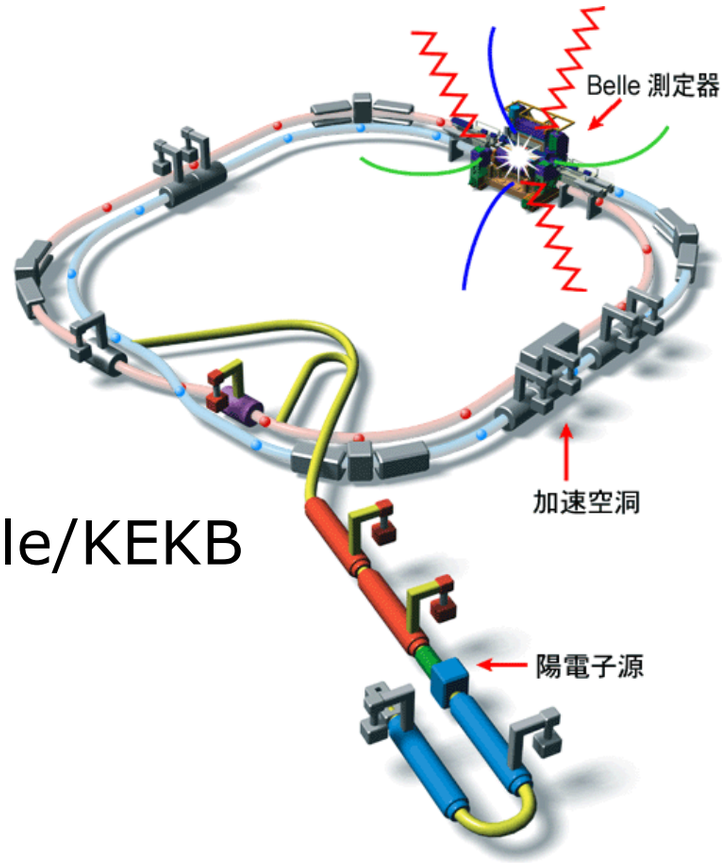
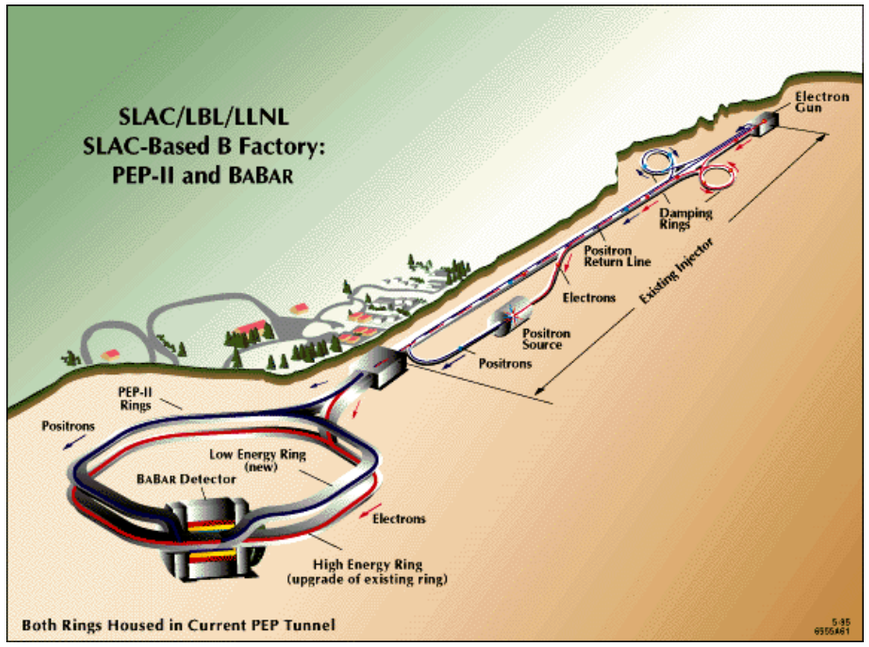
**Novosibirsk, 630090,**
**RUSSIA**

# Achievements at B-Factory Experiments

- Belle/KEKB and BaBar/PEP-II were built to observe CP violation in B-meson system as a prime physics target.




Belle/KEKB



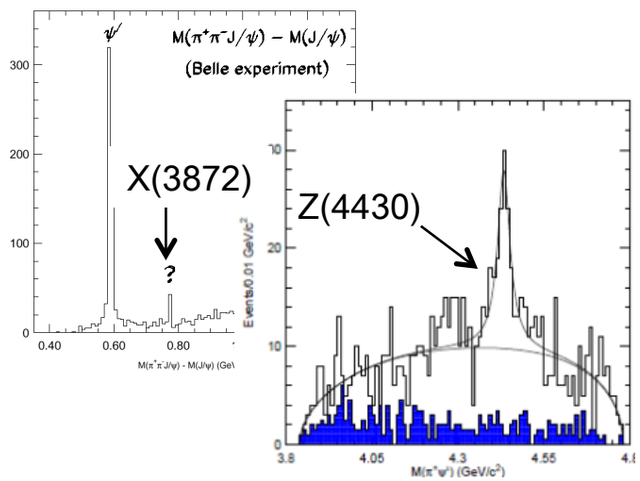

BaBar/PEP-II

Two experiments led 2008 Nobel Prize in physics to Profs. Kobayashi and Maskawa.

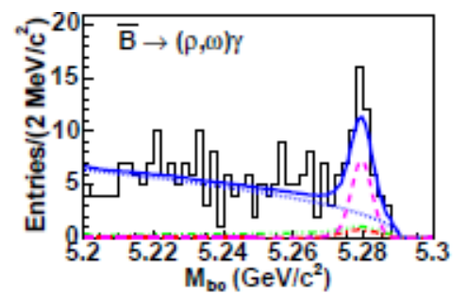
*Not only for this, but....*

# Fruitful Results from Broad Physics Topics

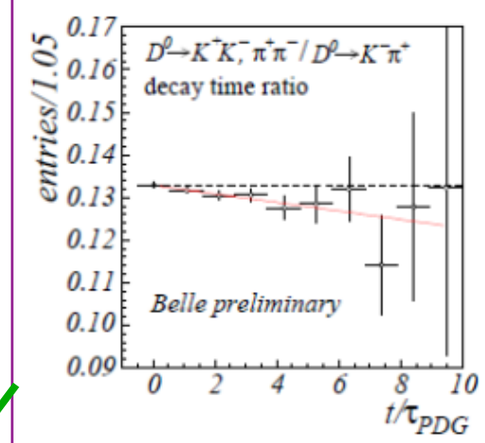
Exotic hadrons observed



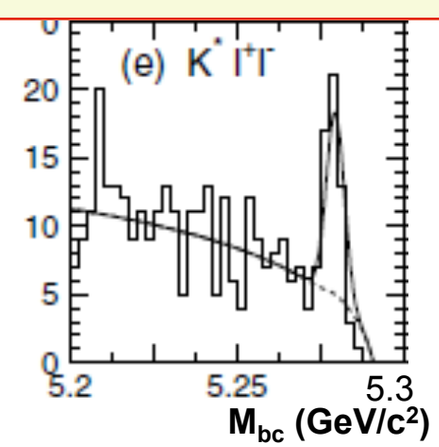

$B \to d\gamma$ detected

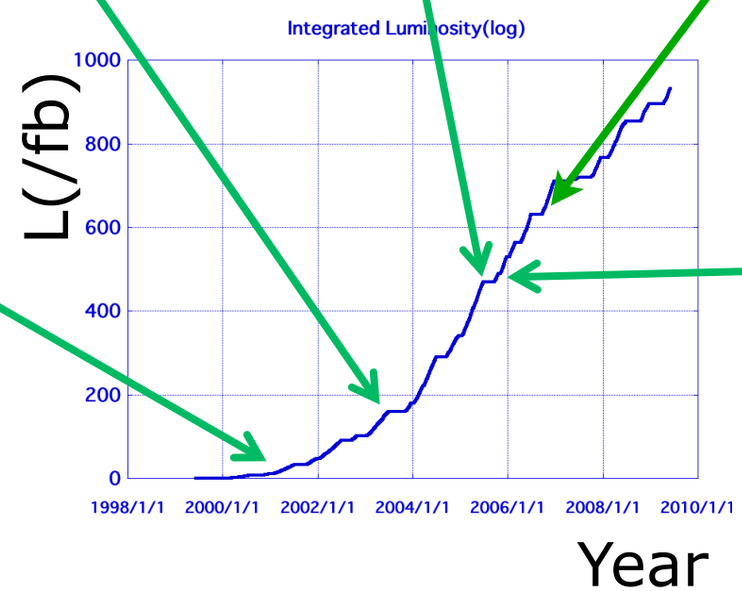



$D^0\overline{D}^0$ mixing found

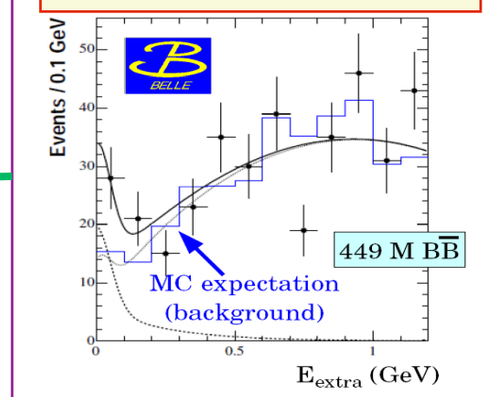



Observation of $B \to K^* l^+ l^-$




$B \to \tau\nu$ observed




$17.2\ ^{+5.3}_{-4.7}$ events

# Fruitful Results from Broad Physics Topics

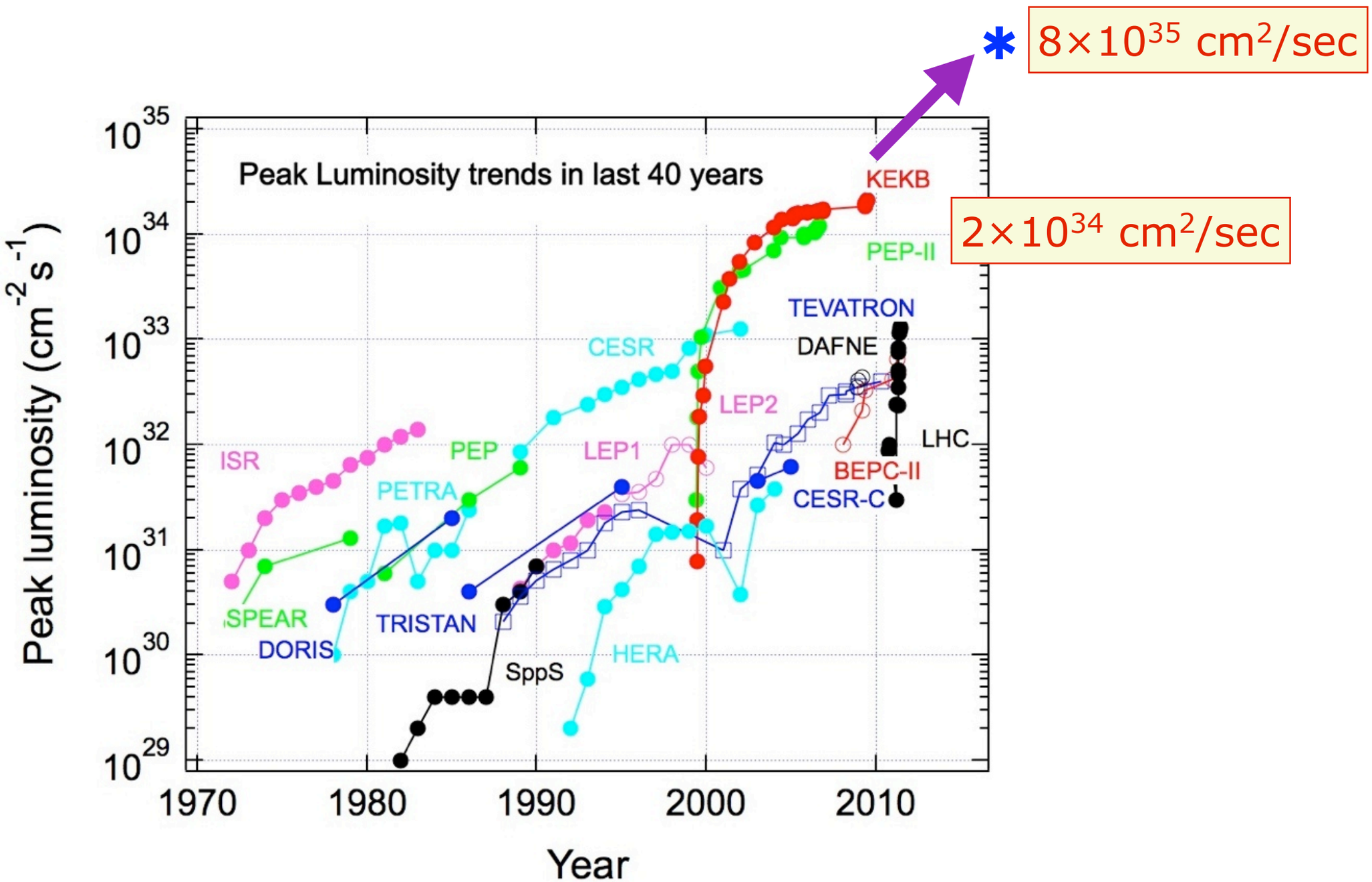
Many parties !

**<u>Excellent detector (+accelerator)</u> allows us to attack various fields of physics !!**

# SuperKEKB Accelerator

# Next Generation B-Factory Accelerator

## How to get 40 times higher luminosity ?



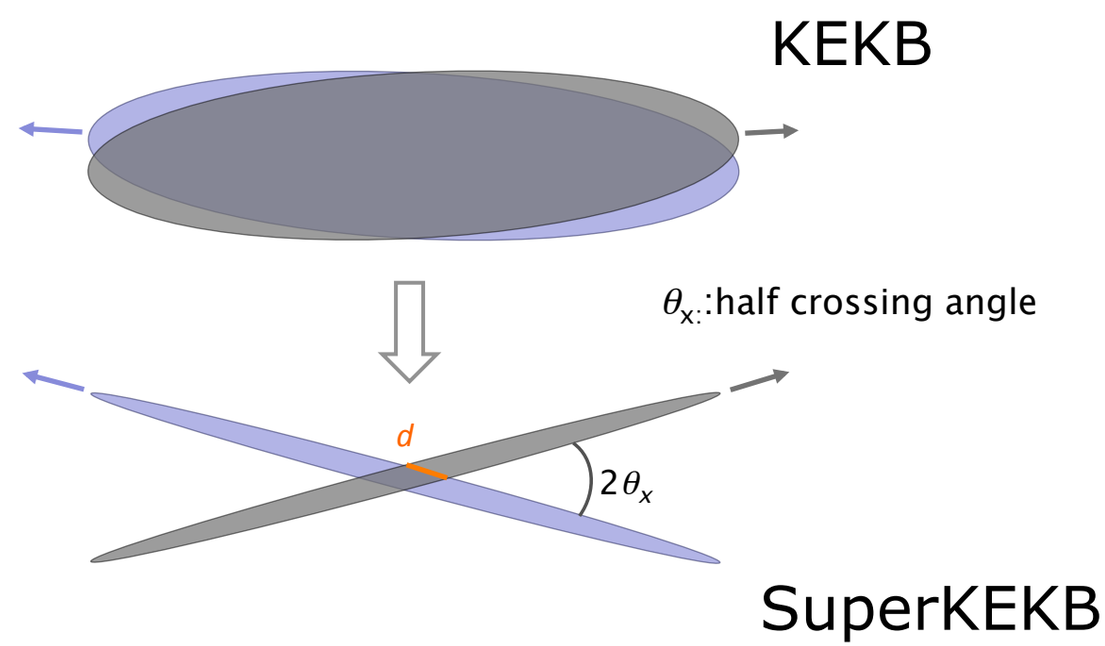
# SuperKEKB Accelerator

## Low emittance ("nano-beam") scheme employed

Machine parameters

| | SuperKEKB LER/HER | KEKB LER/HER |
|---|---|---|
| E(GeV) | 4.0/7.0 | 3.5/8.0 |
| $\varepsilon_x$ (nm) | 3.2/4.6 | 18/24 |
| βy at IP(mm) | 0.27/0.30 | 5.9/5.9 |
| βx at IP(mm) | 32/25 | 120/120 |
| Half crossing angle(mrad) | 41.5 | 11 |
| I(A) | 3.6/2.6 | 1.6/1.2 |
| Lifetime | ~10min | 130min/ 200min |
| L($cm^{-2}s^{-1}$) | $80\times10^{34}$ | $2.1\times10^{34}$ |

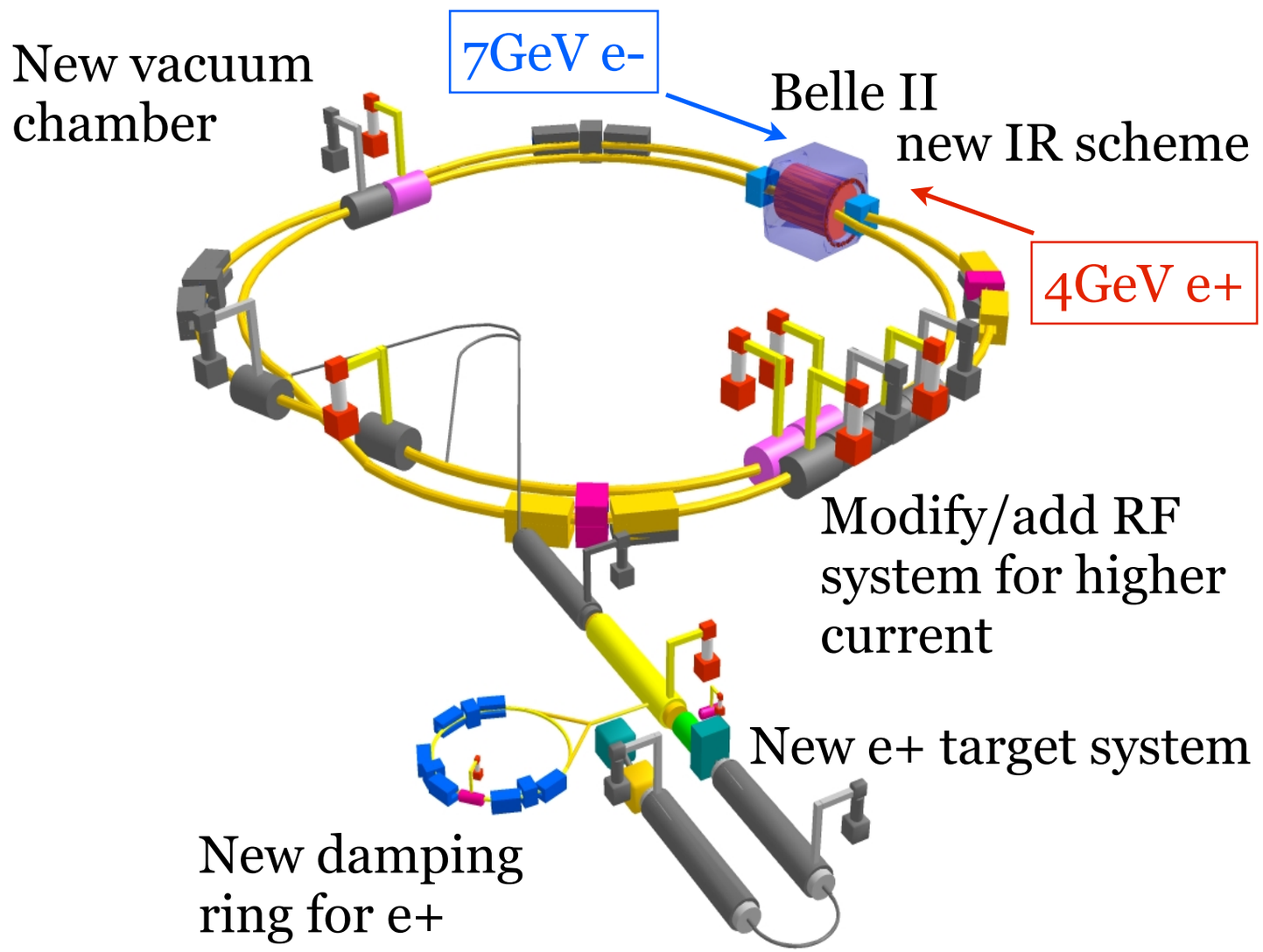
proposed by P.Raimondi



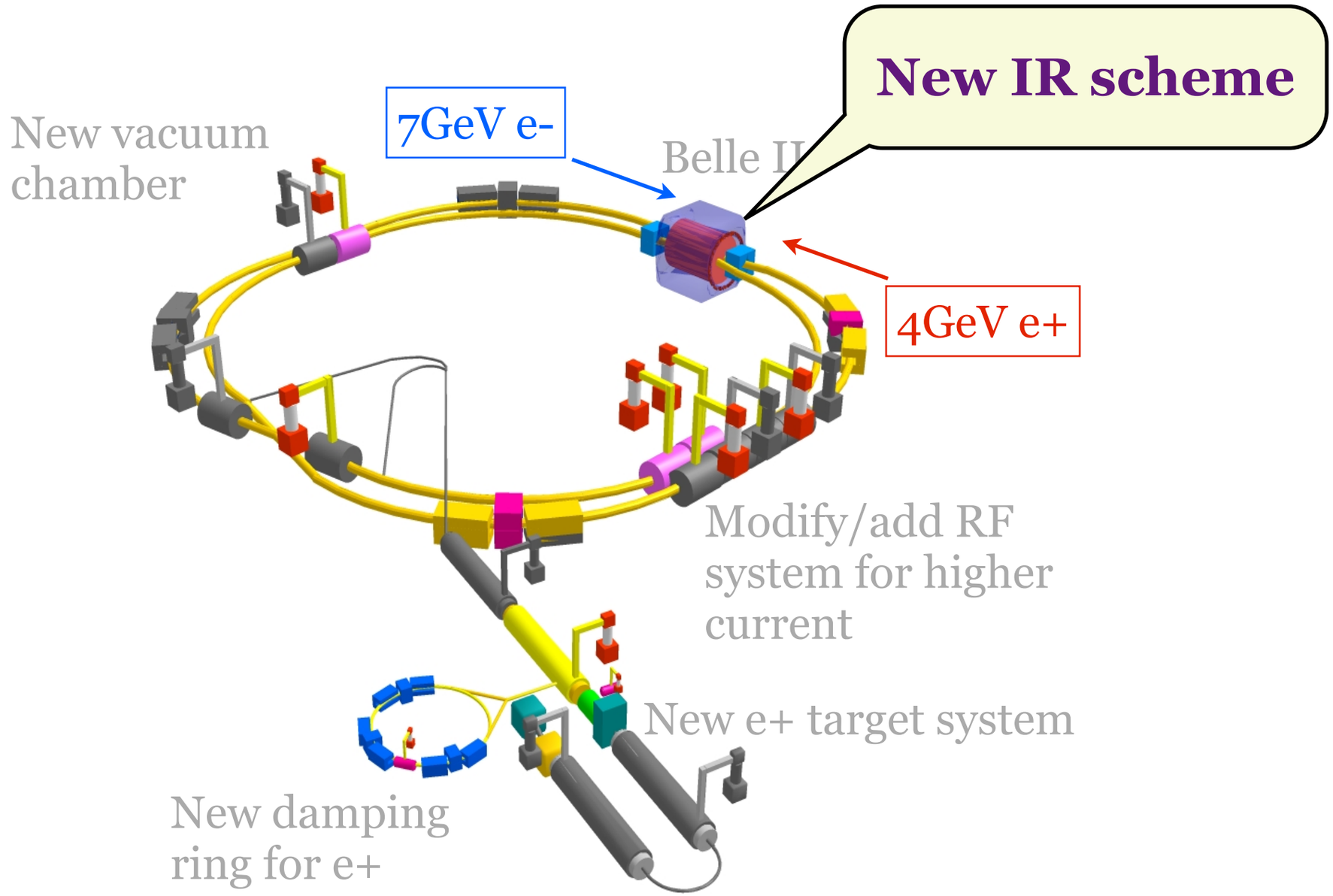

**Beam at IP will be squeezed by 1/20.**

**Beam currents will be doubled.**

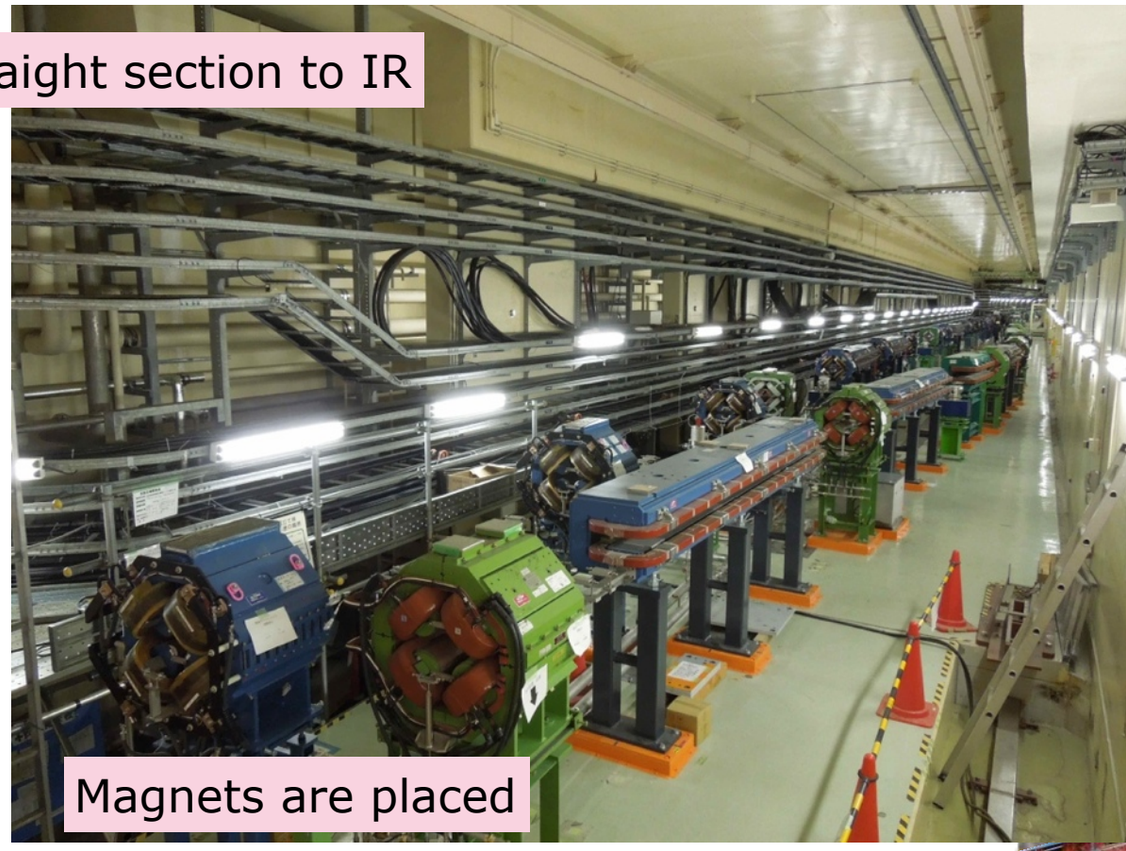
# SuperKEKB Components

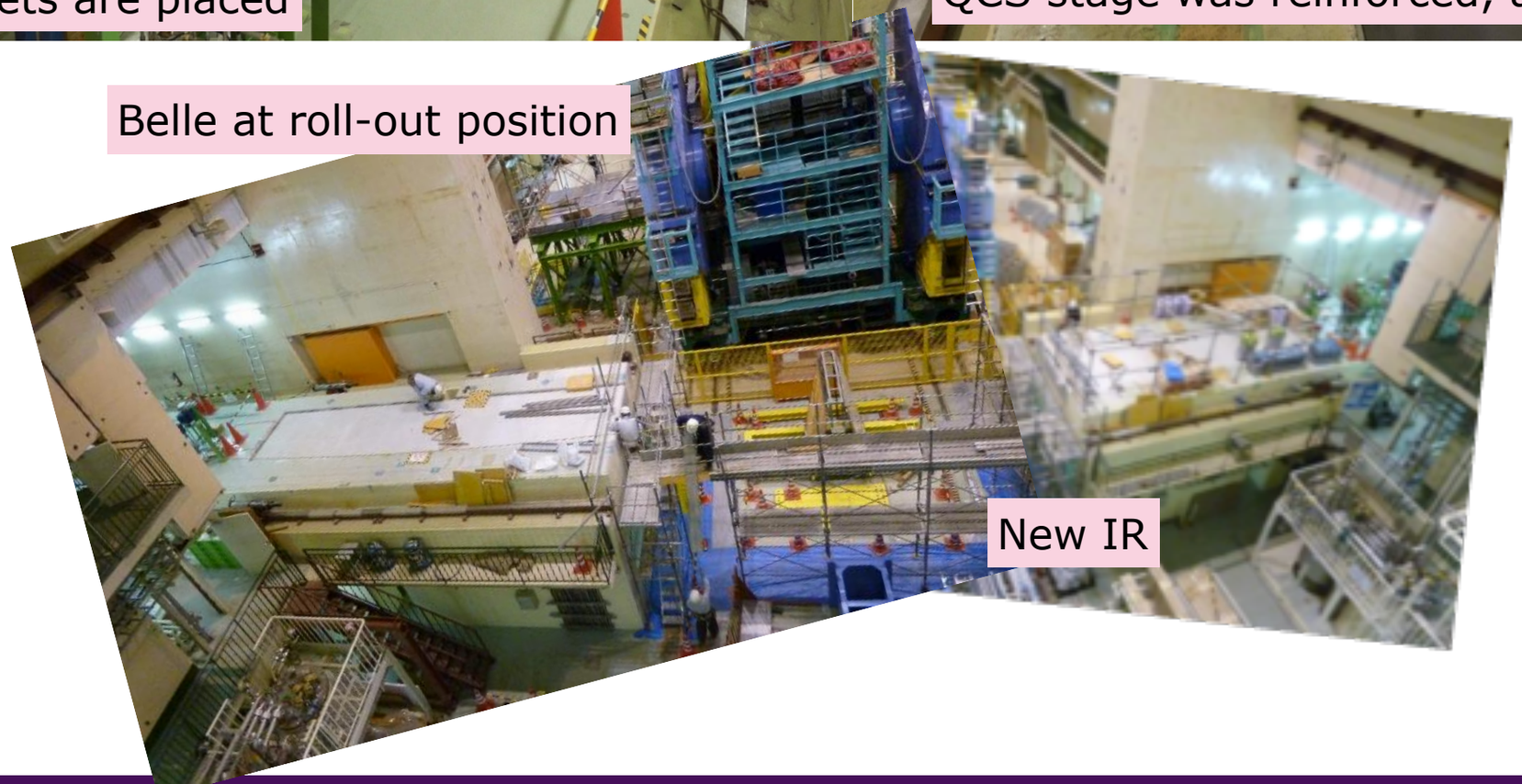


# SuperKEKB Components

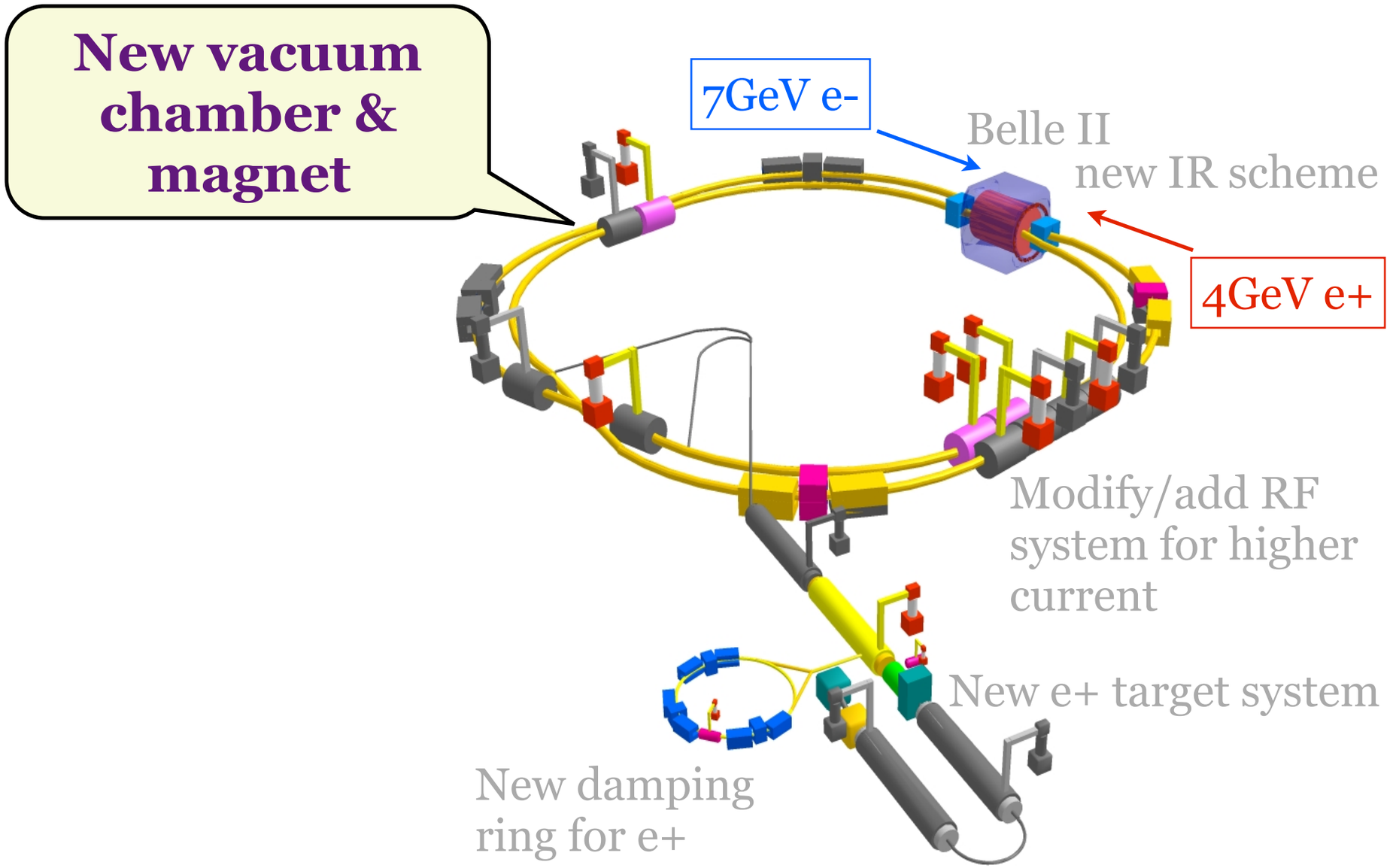


# New IR Status





# SuperKEKB Components



# Magnets & Vacuum Components

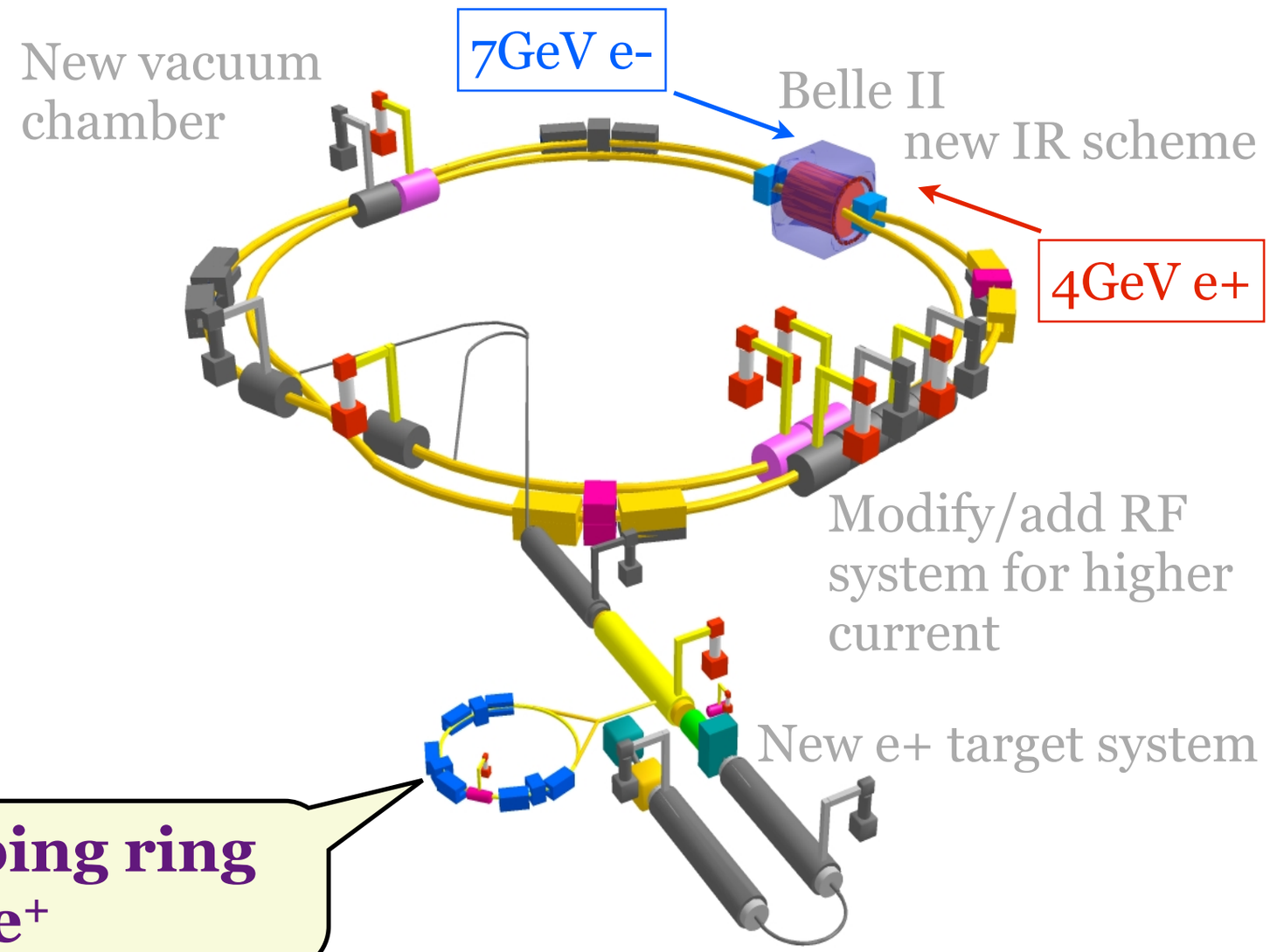
North tunnel

LER Gate valve in West tunnel

LER Oho wiggler downstream

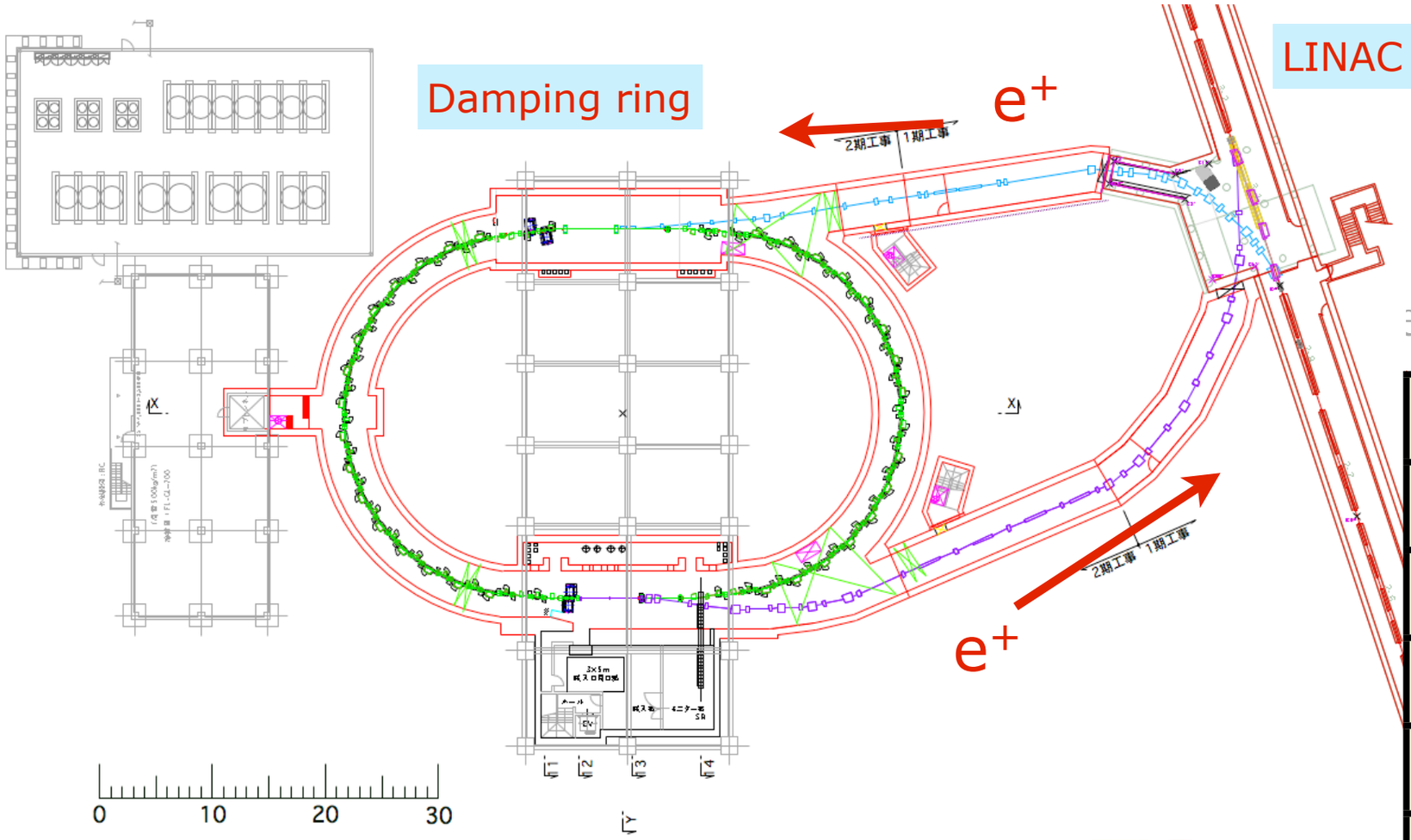
LER Nikko wiggler downstream

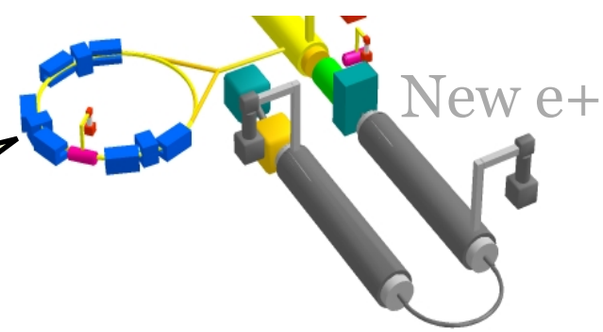
# SuperKEKB Components




**New damping ring for $e^+$**

# SuperKEKB Components



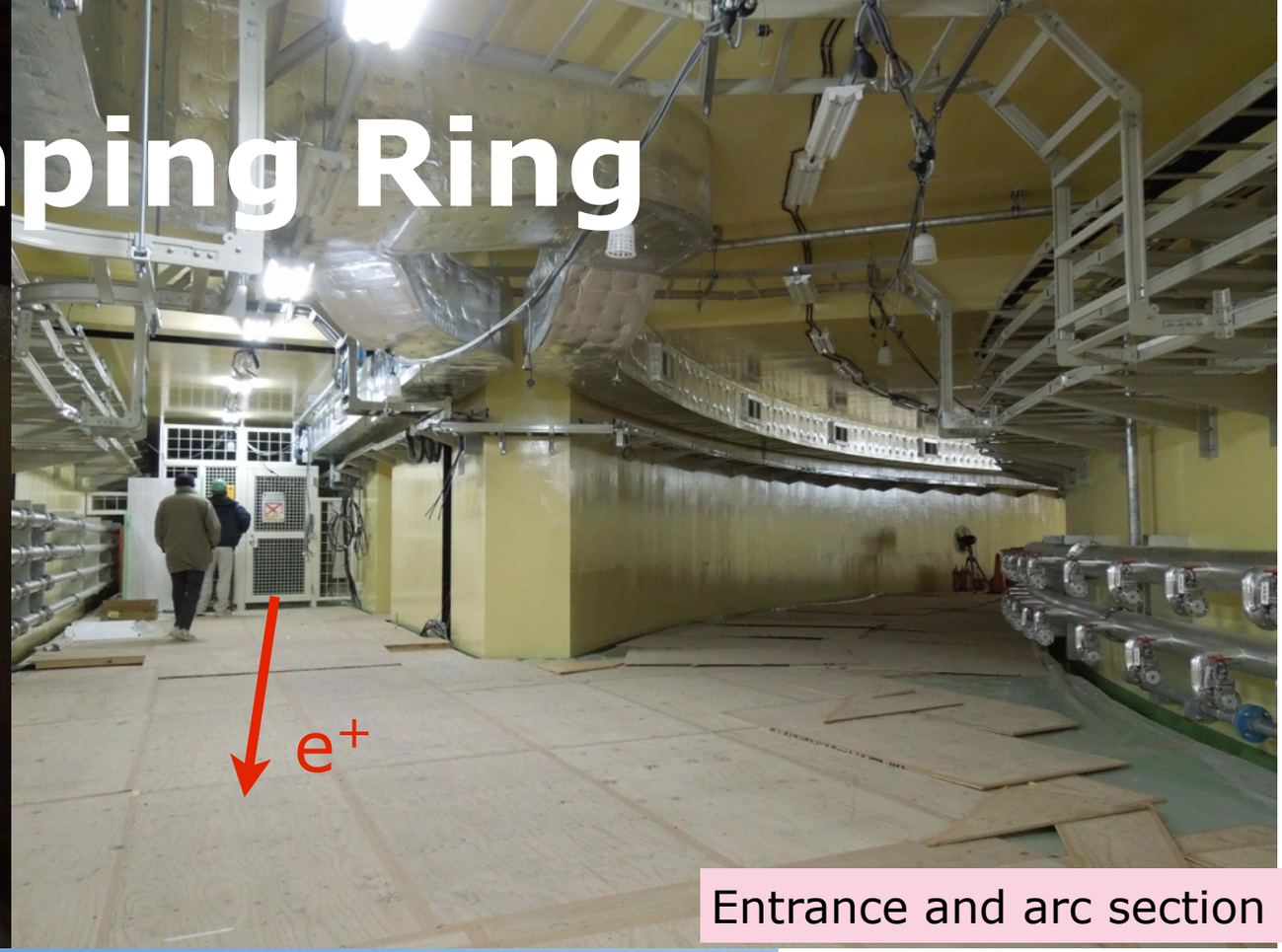

**New damping ring for e+**

New Damping ring parameters

| Parameter | Value |
|---|---|
| Energy | 1.1 GeV |
| Bunches | 2x2 |
| Circumference | 135.5 m |
| H. damping | 10.87 ms |
| Ext. emittance (H/V) | 42.5/3.15 nm |
| Max. current | 70.8 mA |

# New Damping Ring

View from LINAC

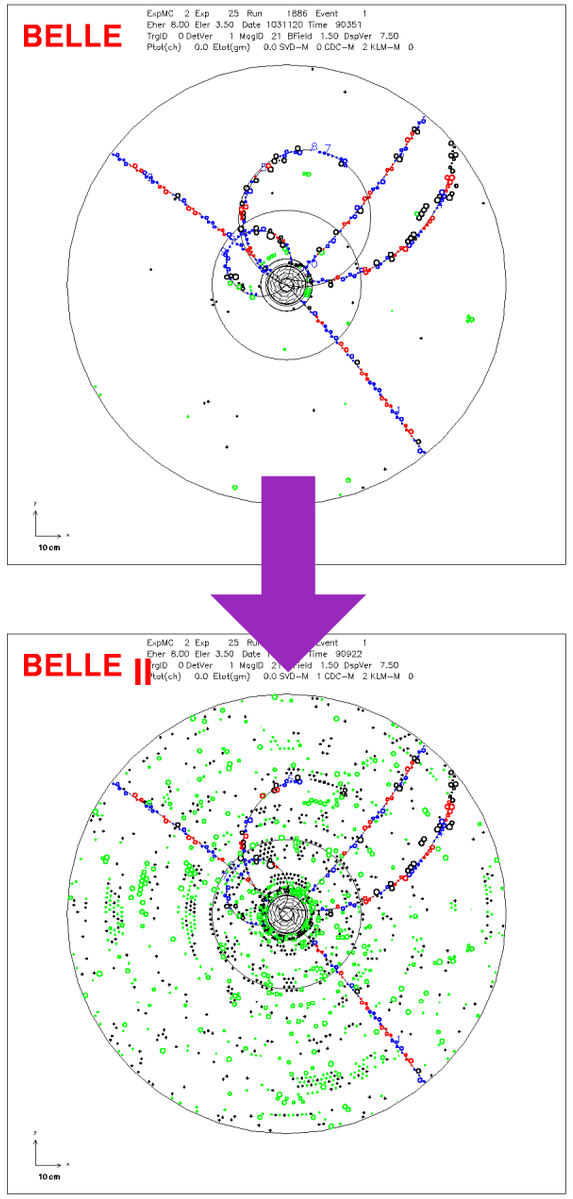



Entrance and arc section

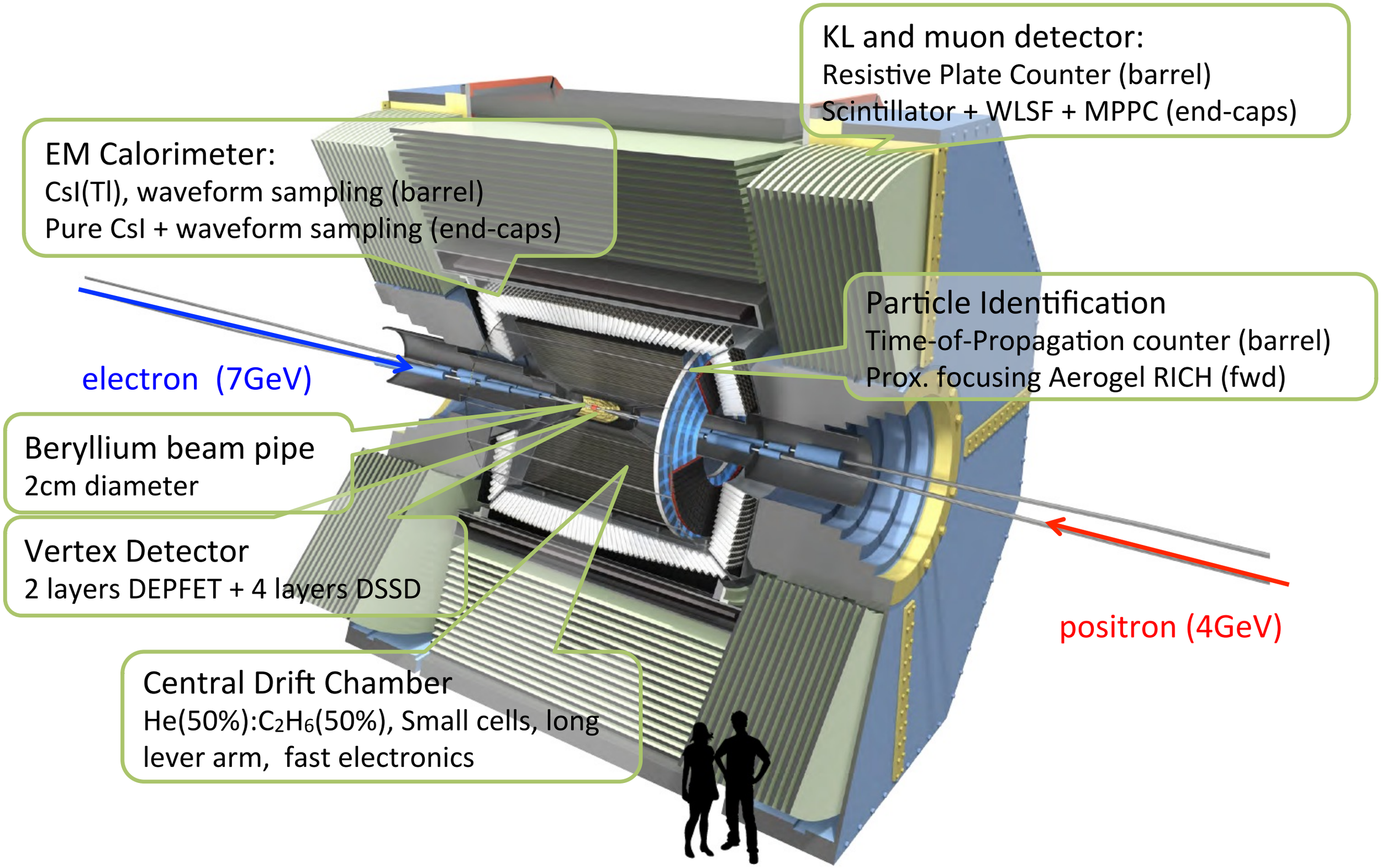
# Belle II Detector

# Experimental Challenges

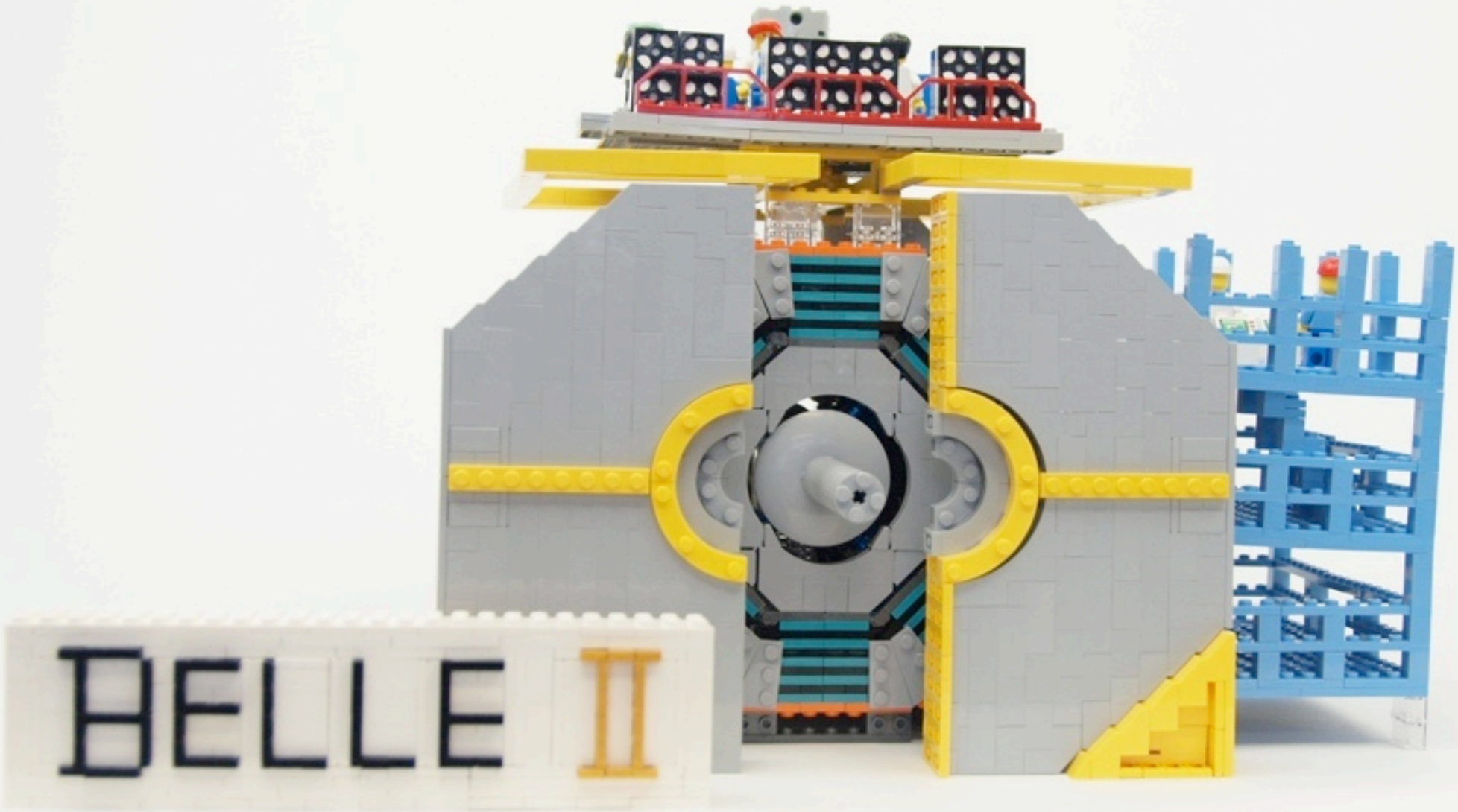
- 10-20 times higher beam-related backgrounds
  - Pile-up noise.
  - Radiation damage.
- 10 times higher event rate
  - Seamless data acquisition system.
  - High level intelligent trigger.
- Further improved performance
  - Better vertex reconstruction.
  - High particle identification capability.
  - Hermetic coverage.



# Belle II Detector



# Belle II Already Completed in LEGO !



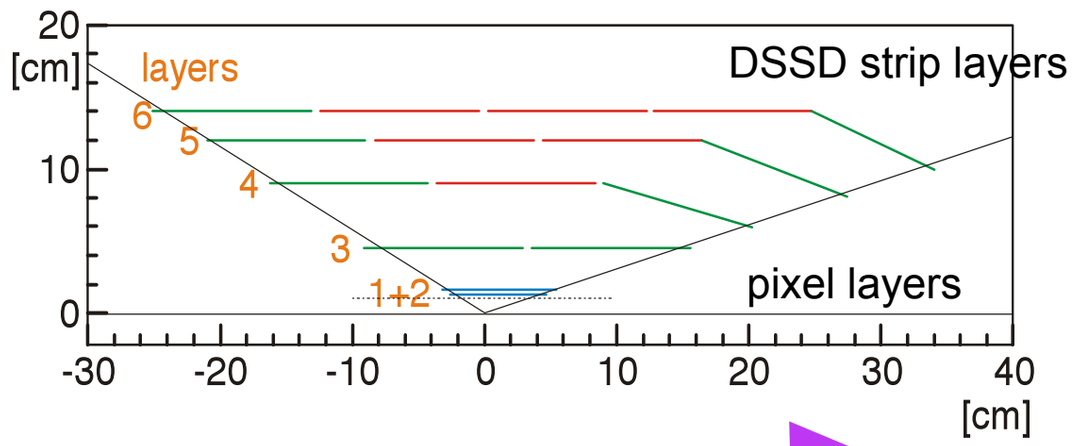

**We are in the middle of construction now !**

# Vertex Detector

Belle II vertex detector consists of
- 2 layers of DEPFET pixel sensors in the innermost part
- 4 layers of double-sided silicon strip sensors

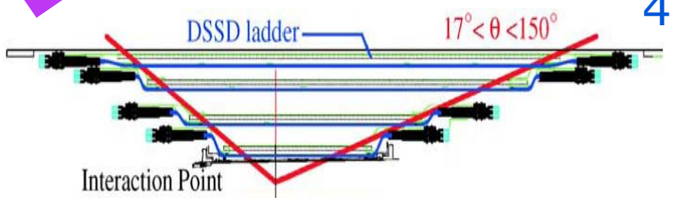
Belle II PXD+SVD

6-layer

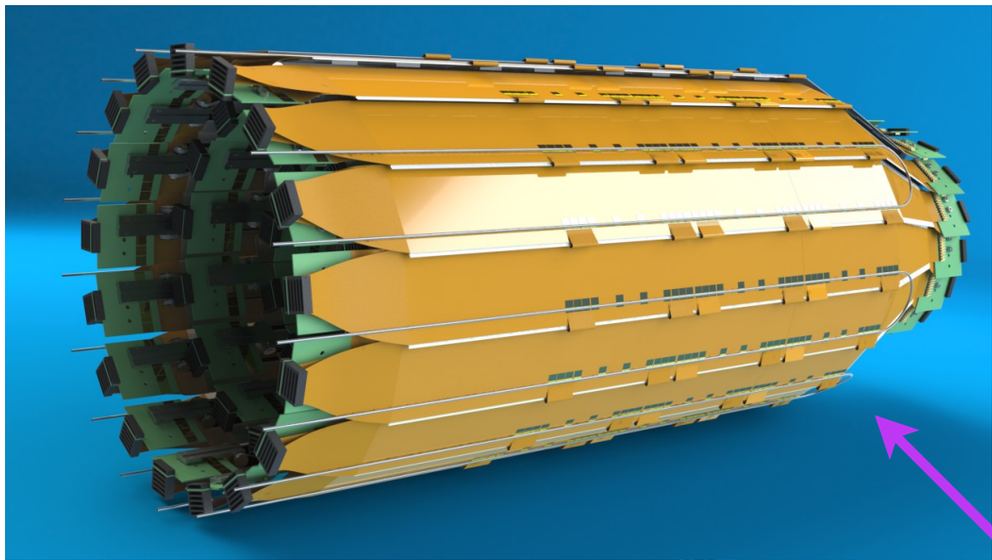



Belle SVD

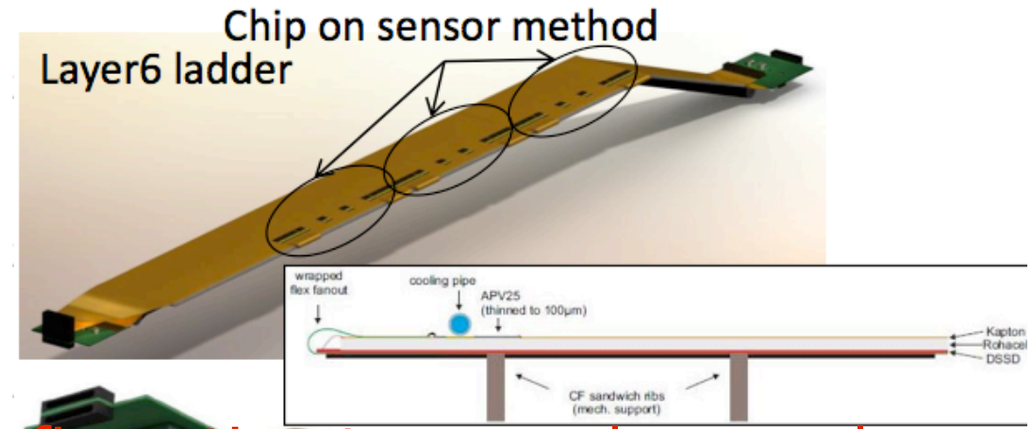
4-layer DSSD



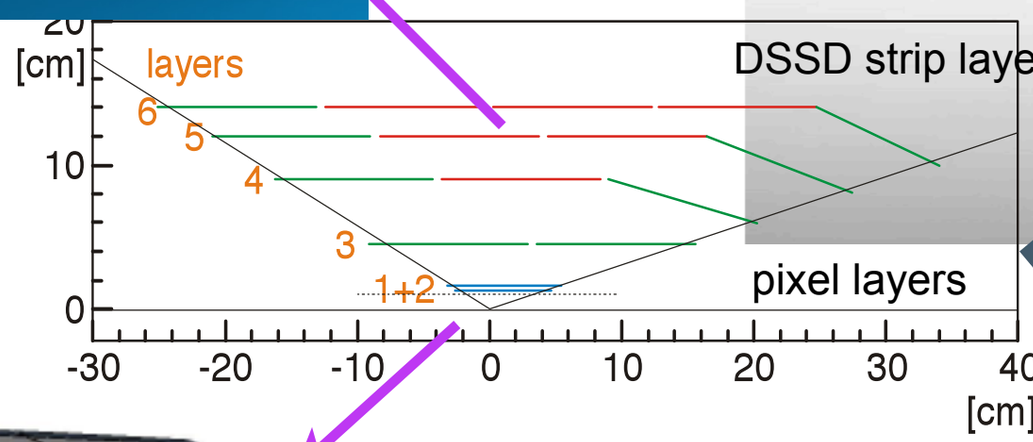
# Vertex Detector

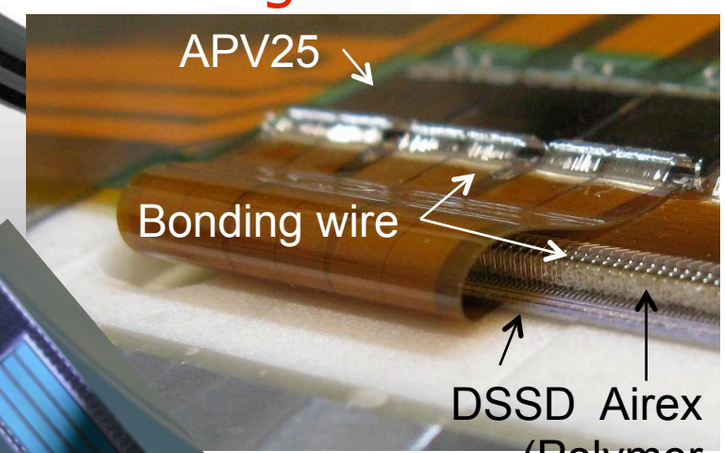


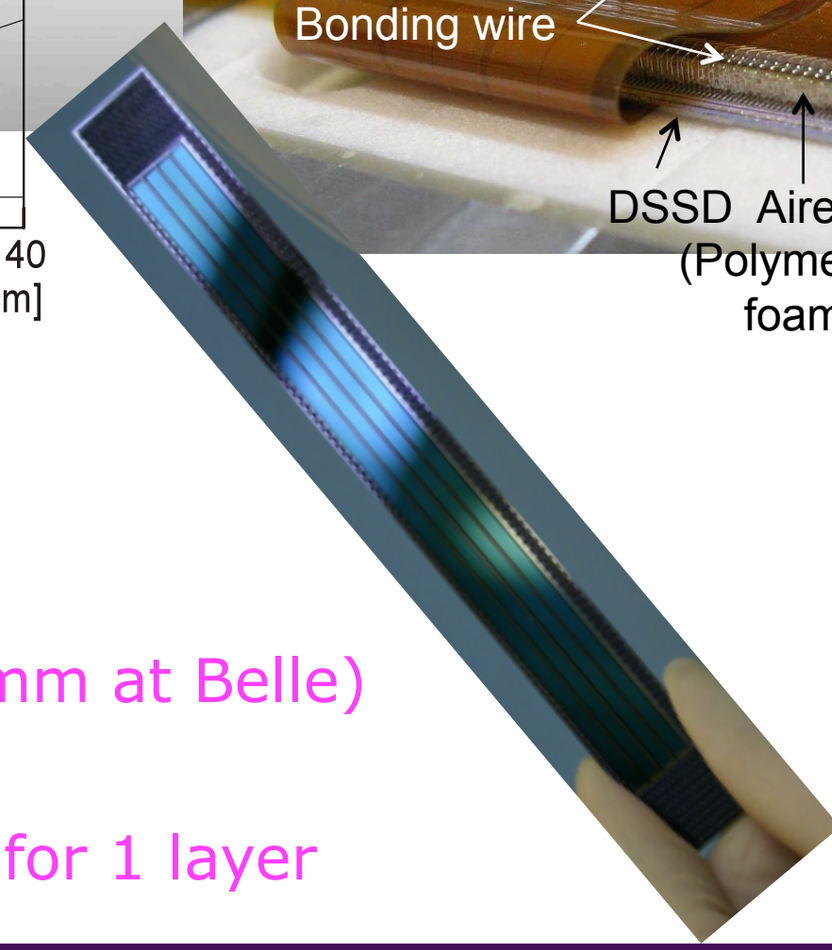
SVD



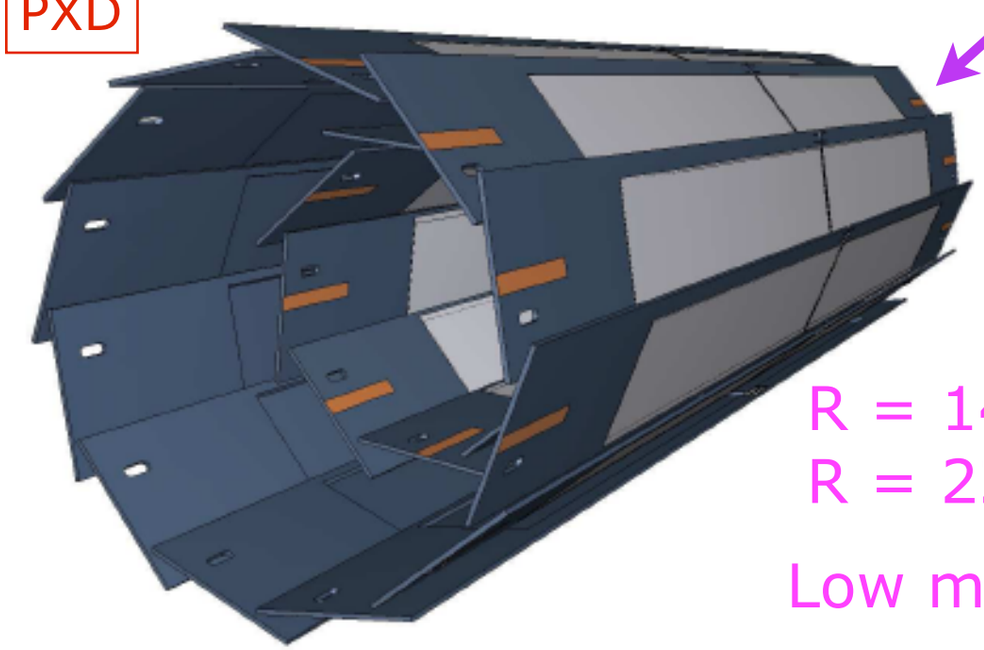

4-layer configuration to cover large volume



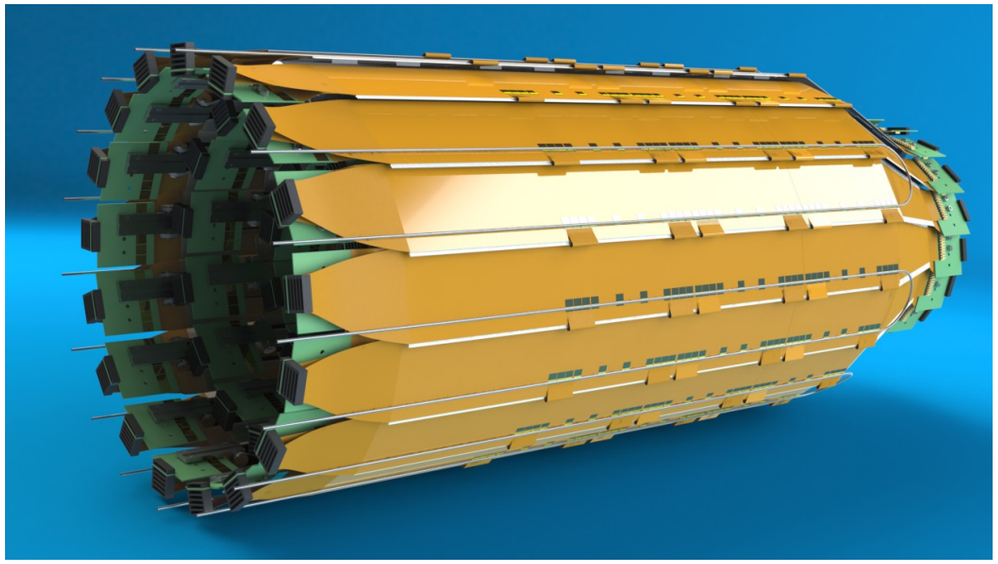
PXD



R = 14mm at 1st layer (18mm at Belle)
R = 22mm at 2nd layer

Low material of ~0.16% $X_0$ for 1 layer

# Vertex Detector



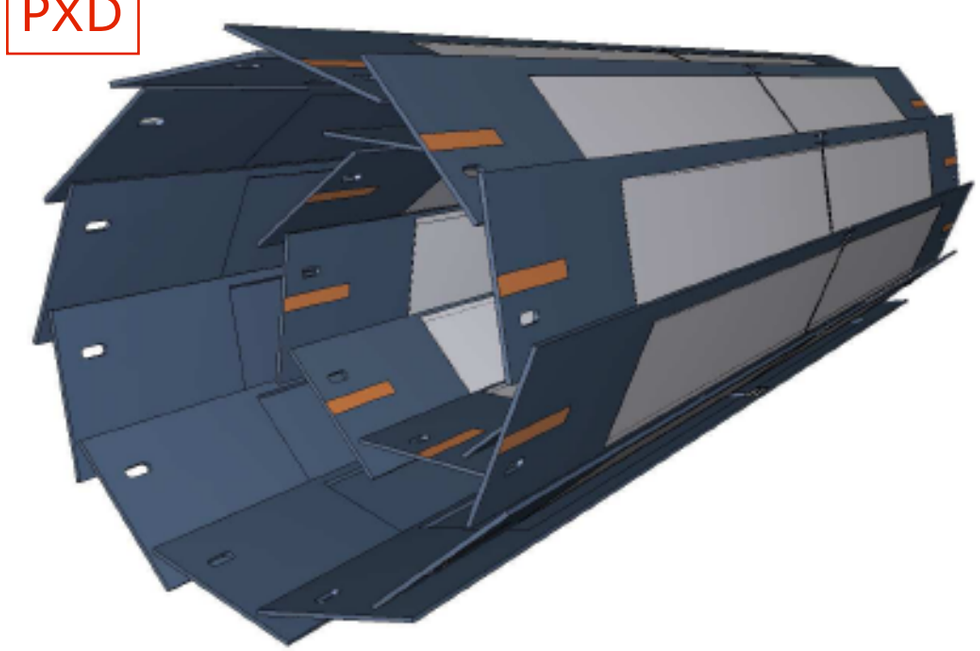
SVD

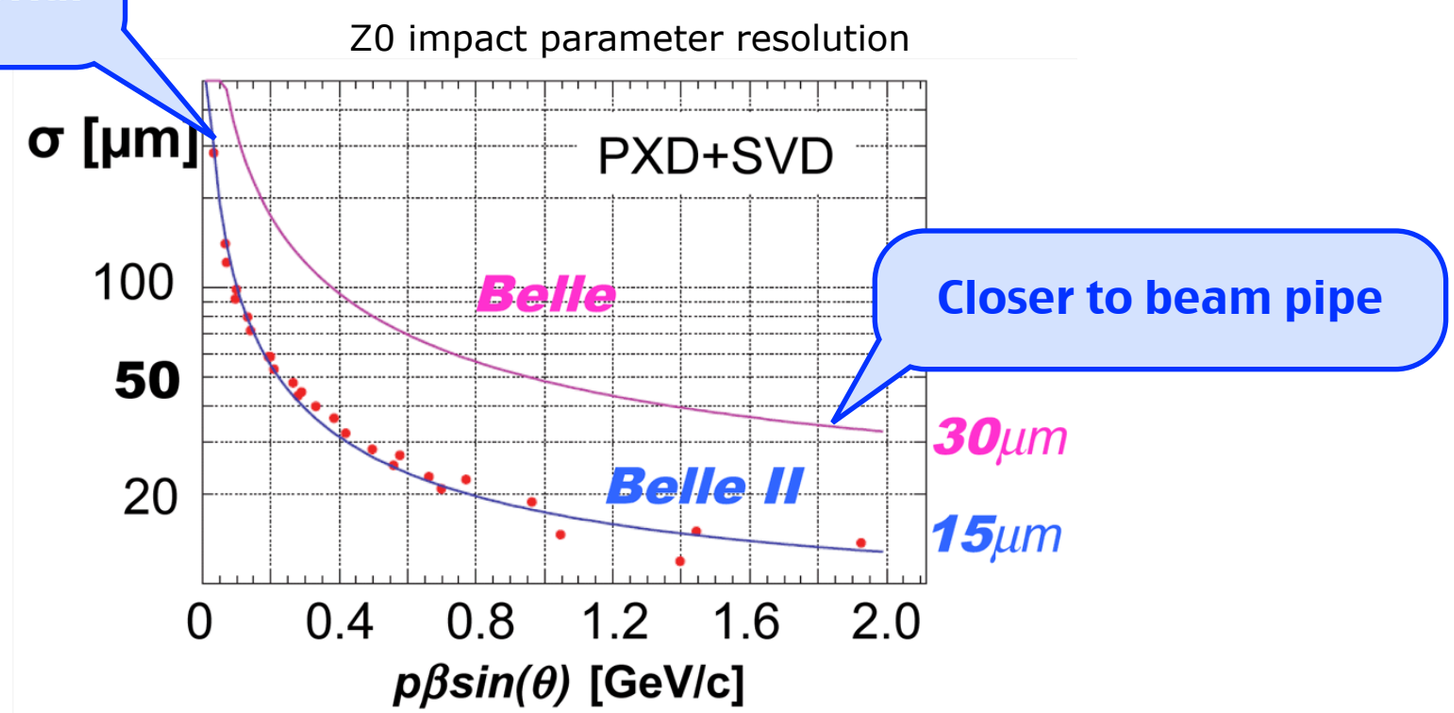
Low material VXD
Position detection closer to IP
More measurements for self-tracking capability with 6 layers

20% improved vertex resolution
30% more Ks detection efficiency

Less Coulomb scattering due to lower material

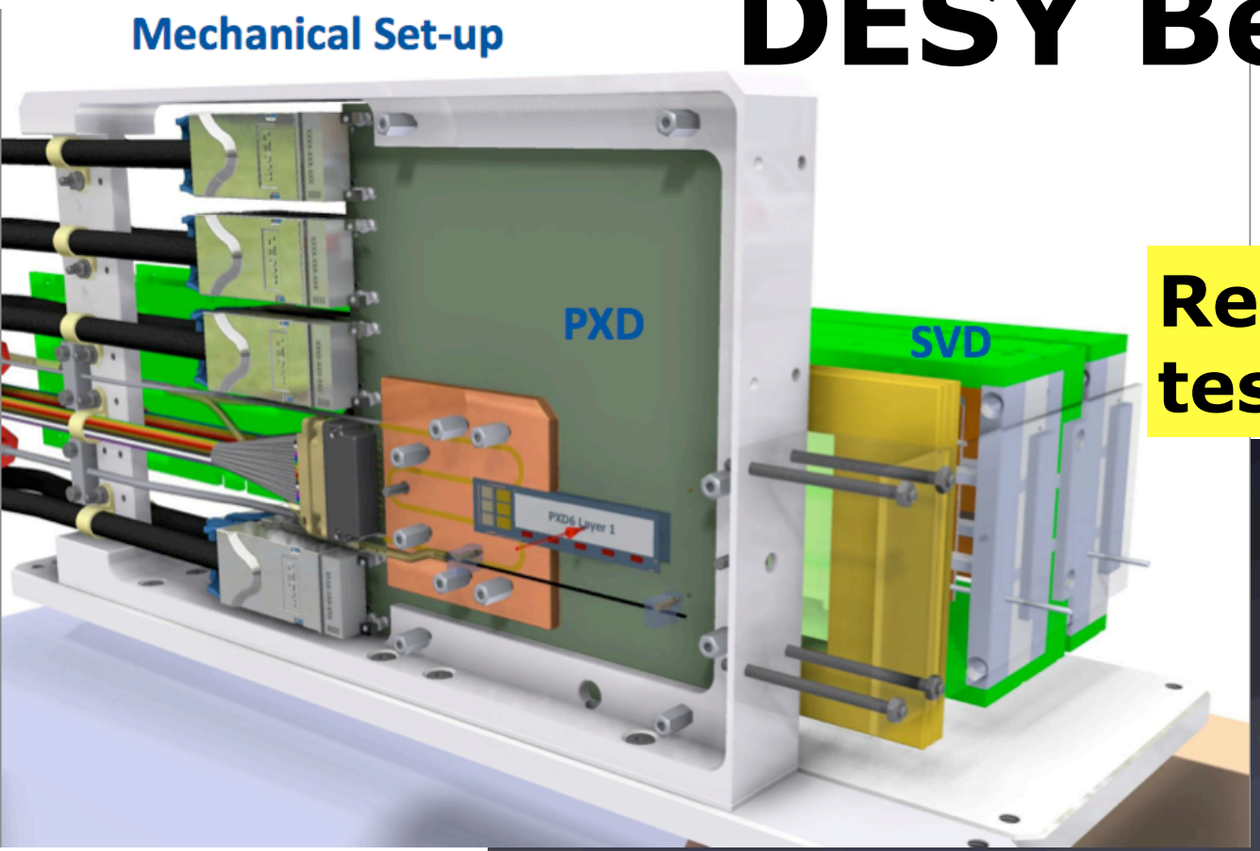
PXD





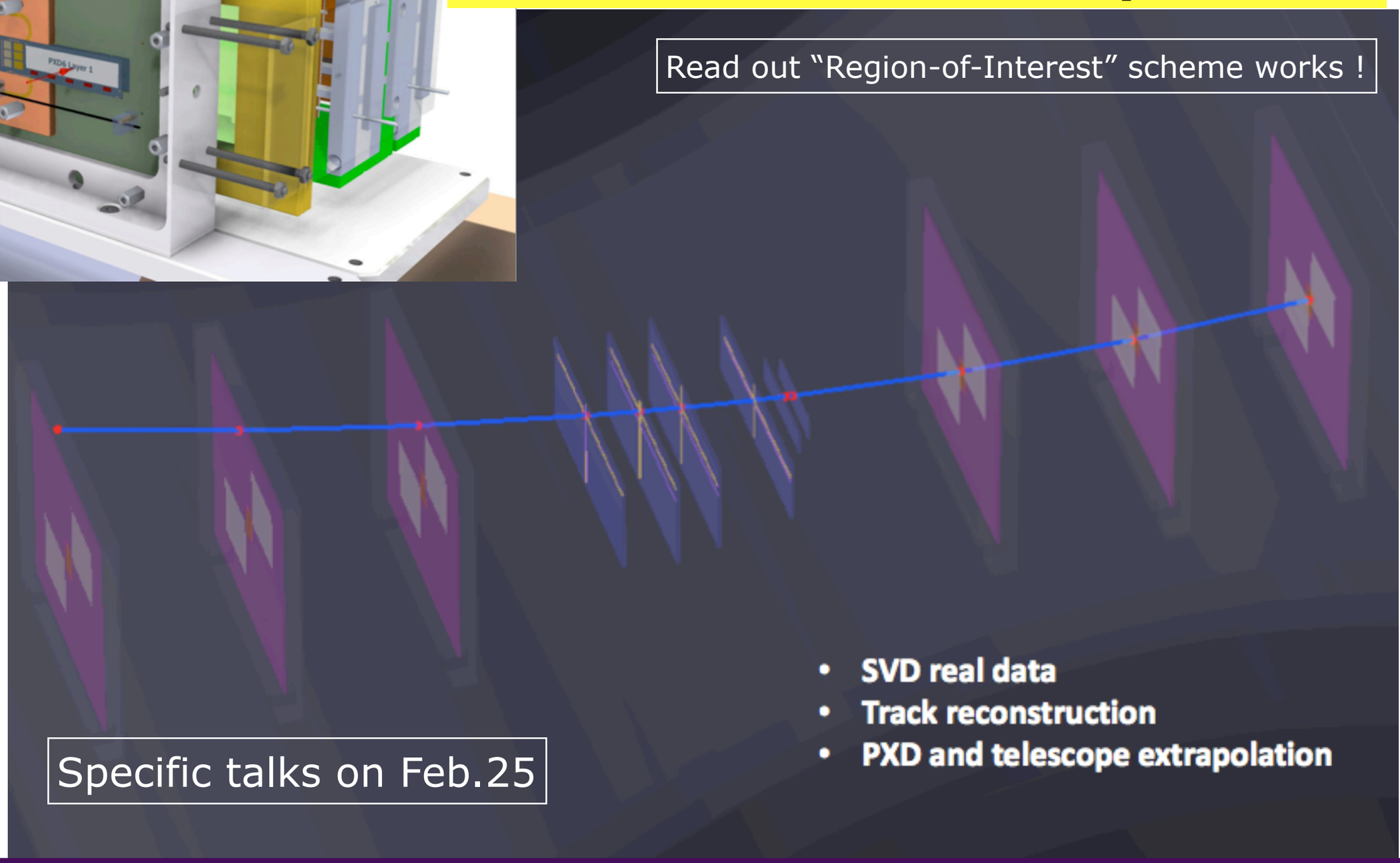

$$\sigma = a + b/(p\beta \sin^{\nu}\theta)$$

# DESY Beam Test



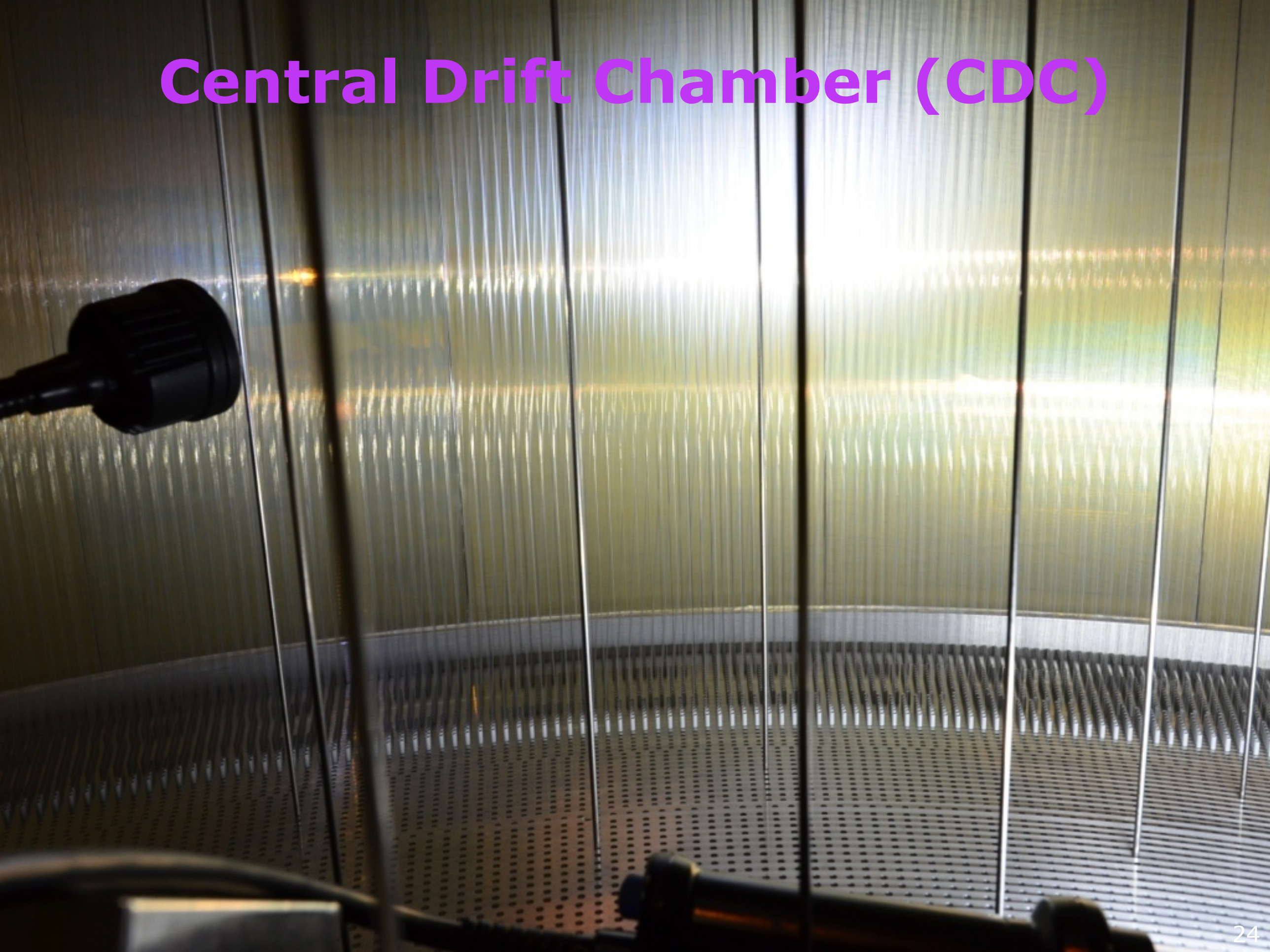

**Remarkable success of DESY beam test done at 2014 January.**

Read out "Region-of-Interest" scheme works !




Specific talks on Feb.25

# Central Drift Chamber (CDC)



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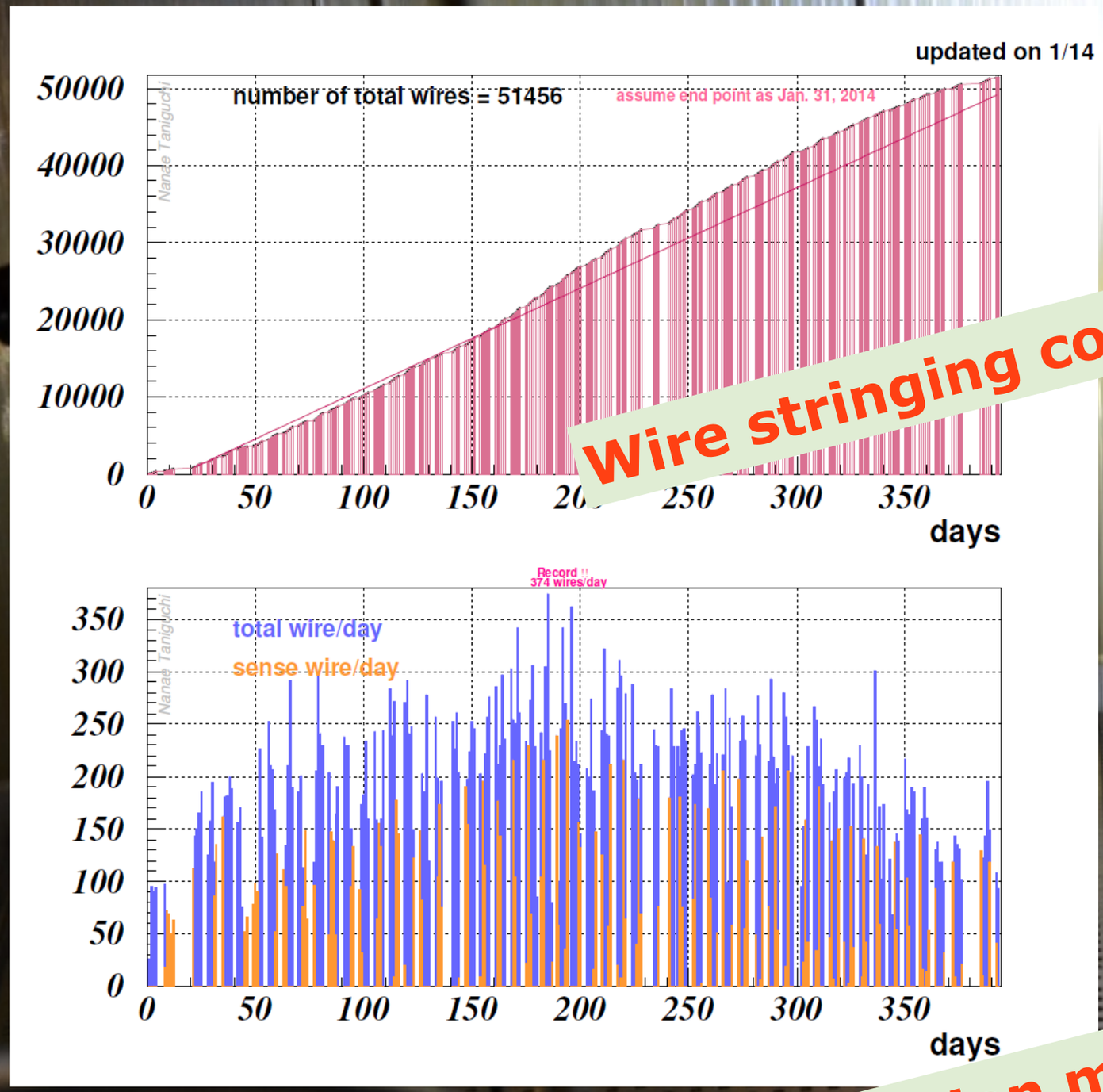
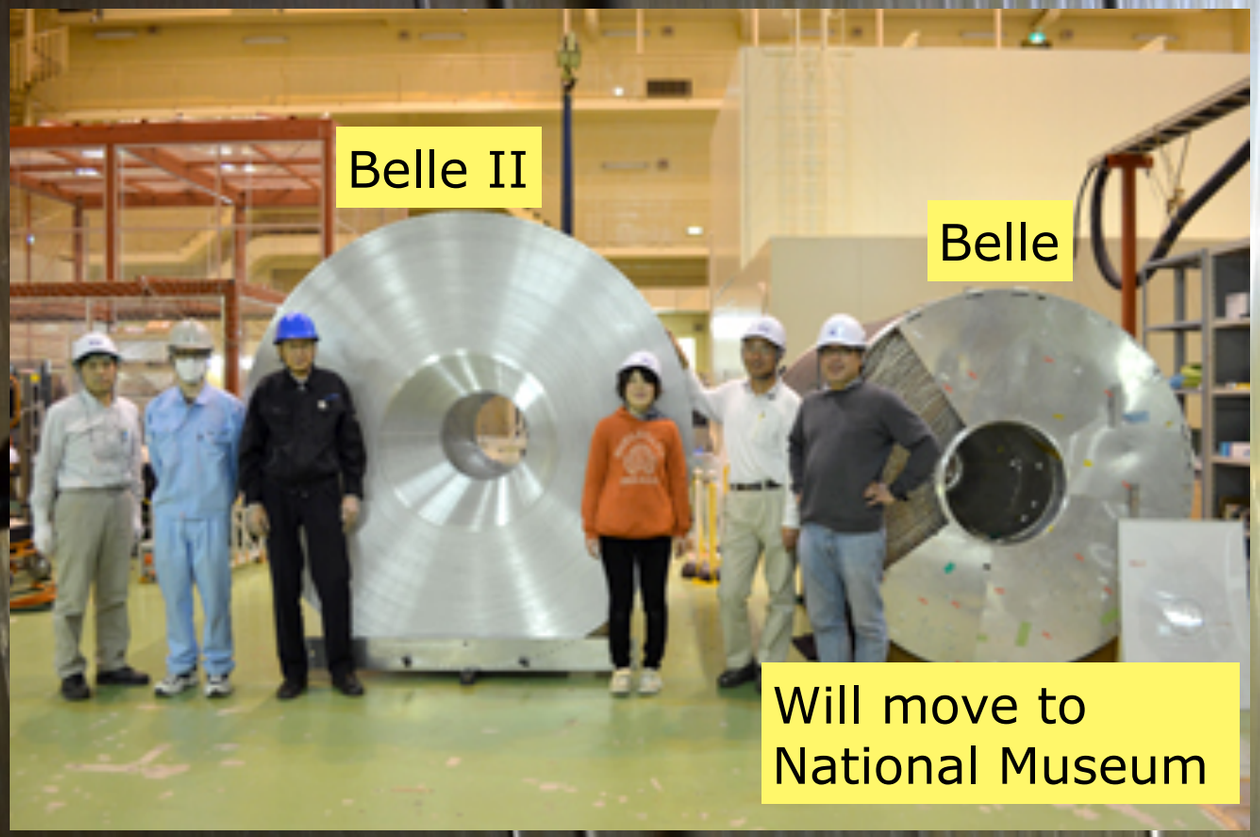


"Wire-stringers"

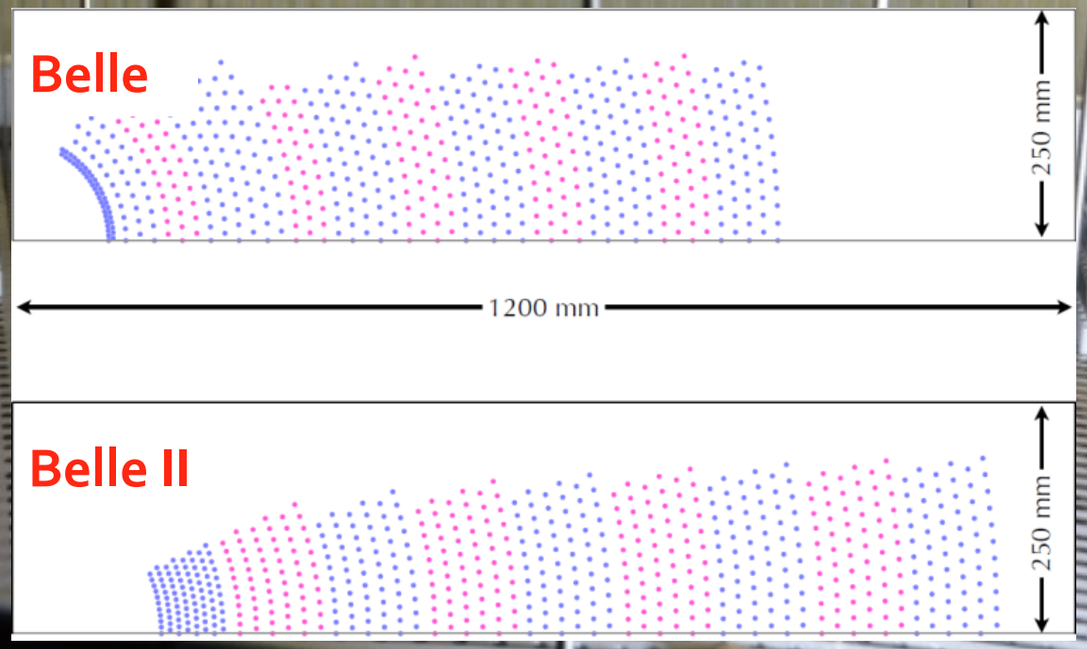
**Wire stringing completed on 2014.Jan.14 !!**

**Tension measurements are underway.**

# Central Drift Chamber (CDC)



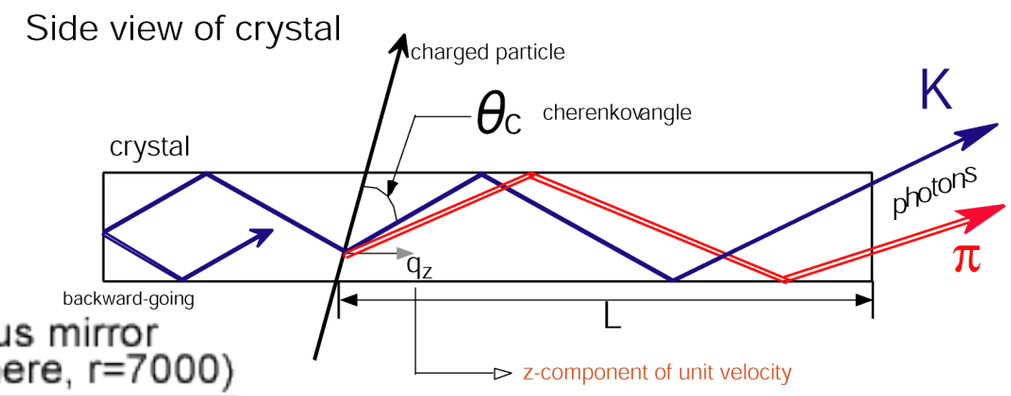

| | Belle | Belle II |
|---|---|---|
| Innermost sense wire | r=88mm | r=168mm |
| Outermost sense wire | r=863mm | r=1111.4mm |
| Number of layers | 50 | 56 |
| Total sense wires | 8400 | 14336 |
| Gas | $He:C_2H_6$ | $He:C_2H_6$ |
| Sense wire | W(Φ30μm) | W(Φ30μm) |
| Field wire | Al(Φ120μm) | Al(Φ120μm) |



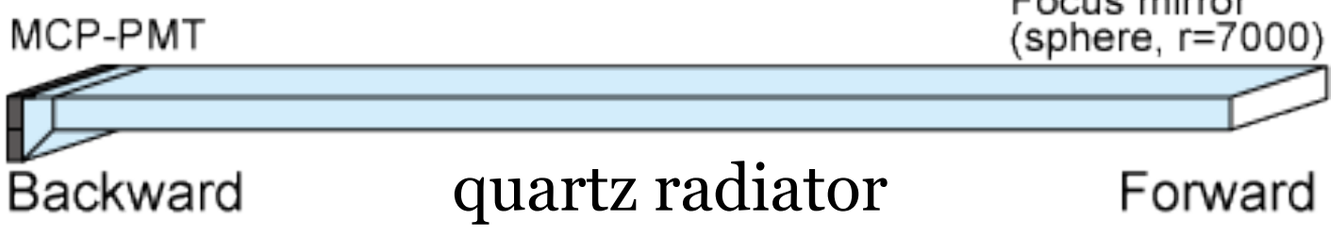

- 30% larger radius
  - Improve momentum & dE/dx resolutions
- Smaller cell size
  - Reduce occupancy
  - Shorter drift time

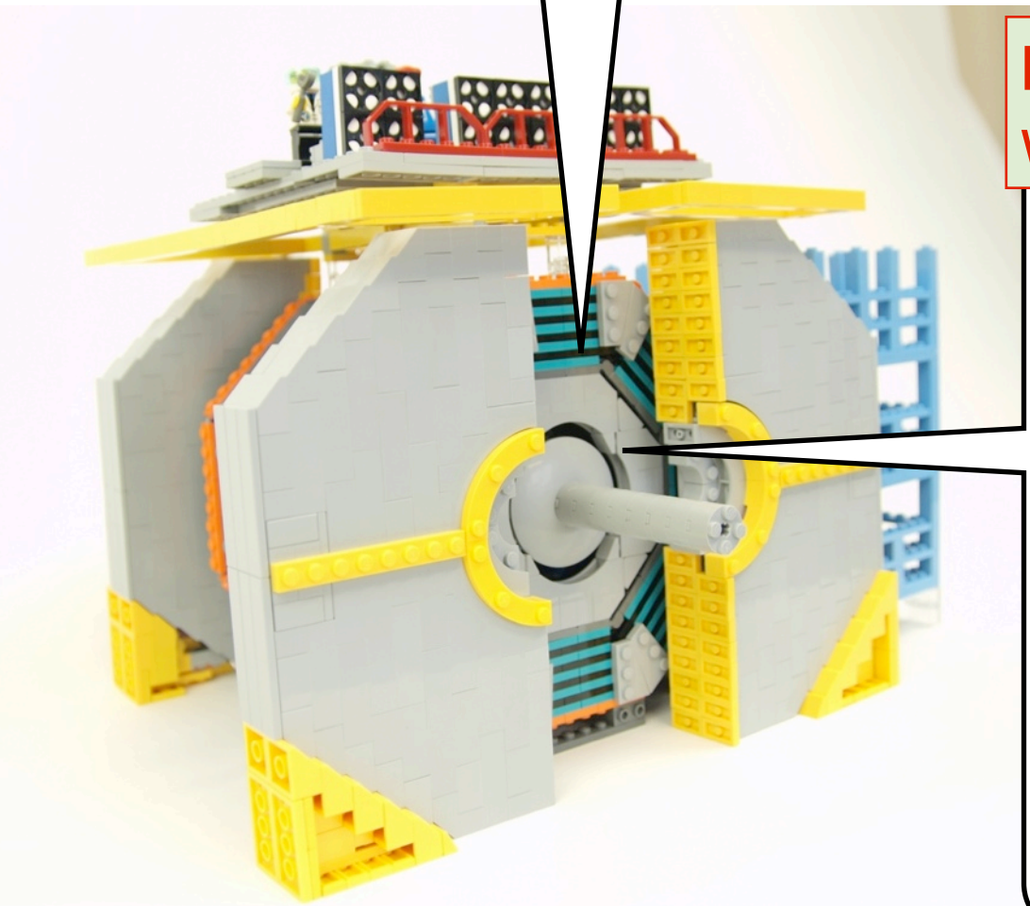
# Particle Identification Devices

Barrel : Time-of-Propagation (TOP) counter



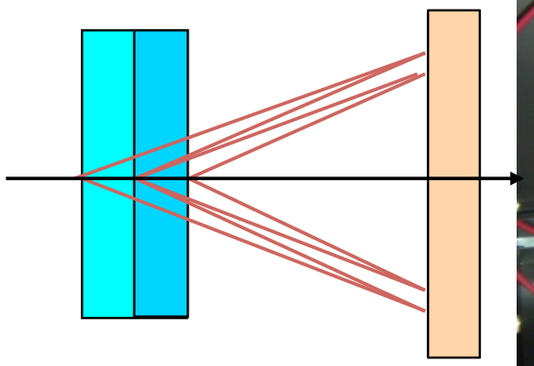

MCP-PMT+expansion block

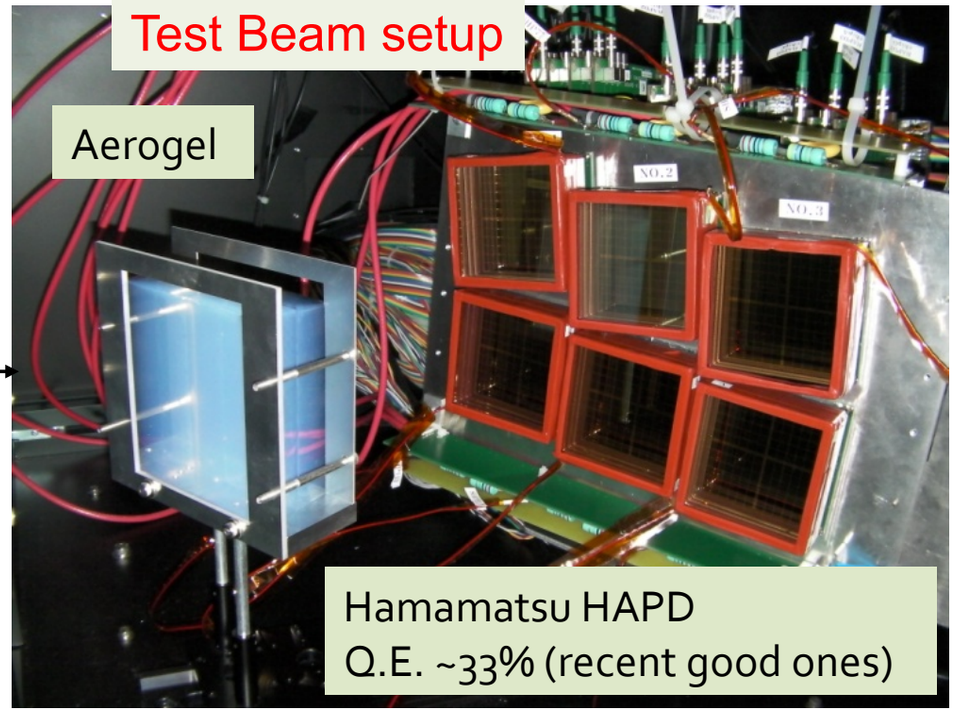


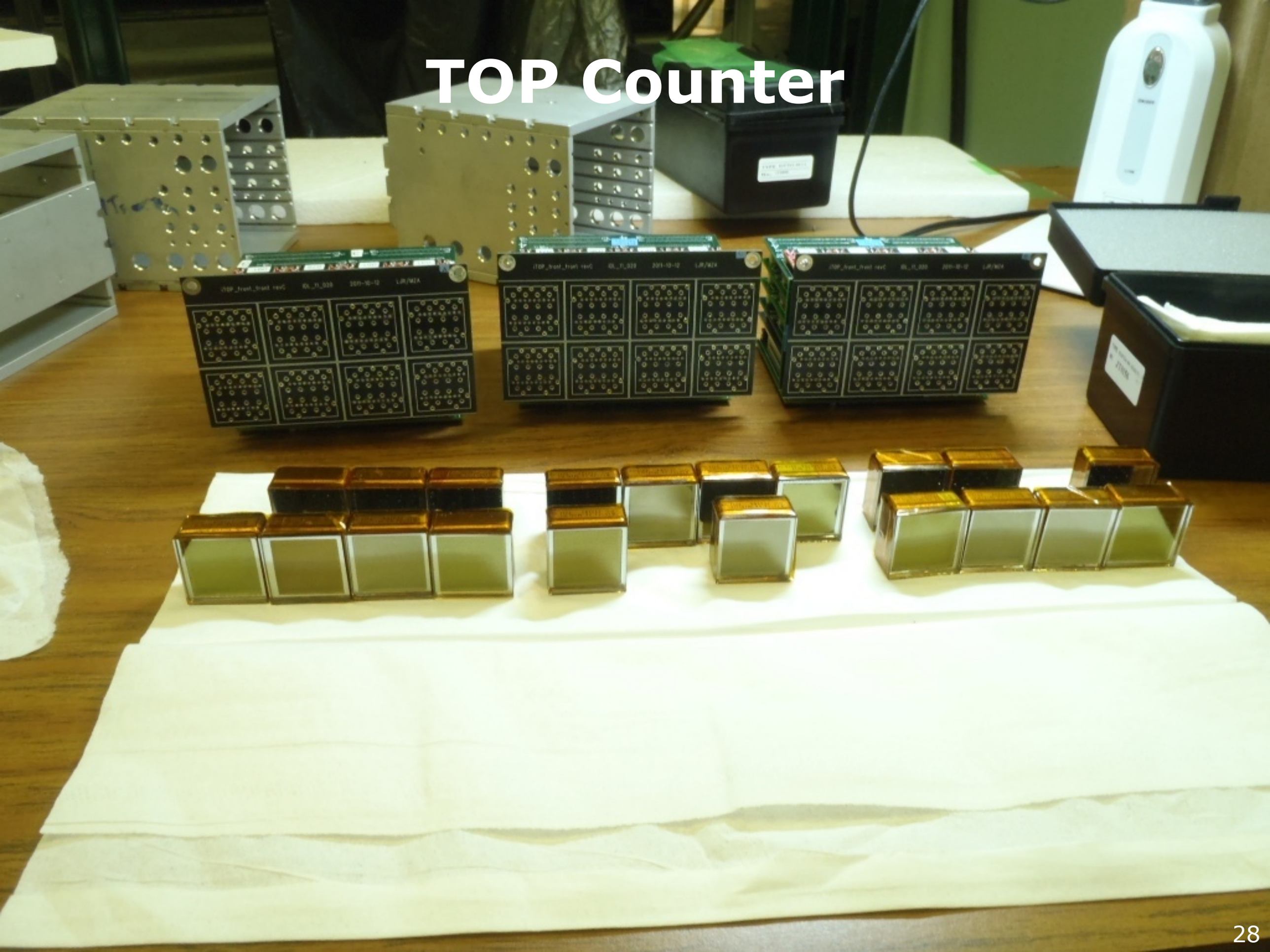
End-cap : Ring Imaging Cherenkov counter with Aerogel radiator (ARICH)

Two layer aerogel radiator





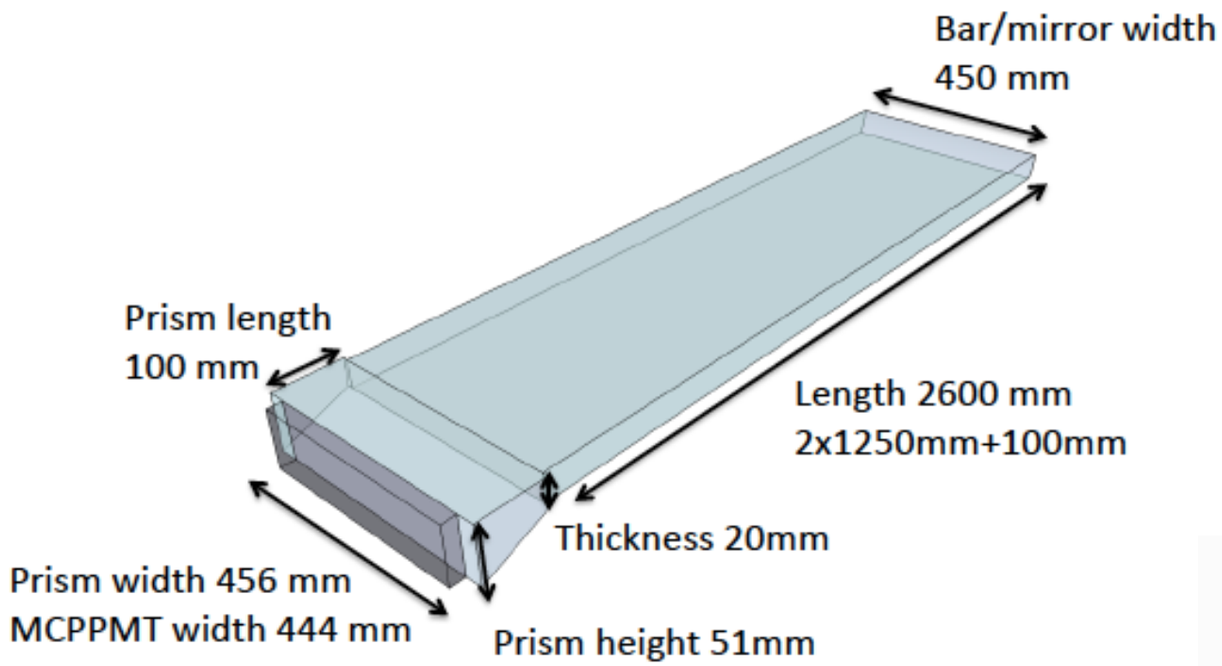
# TOP Counter



Specific talk on Feb.26

# TOP Counter

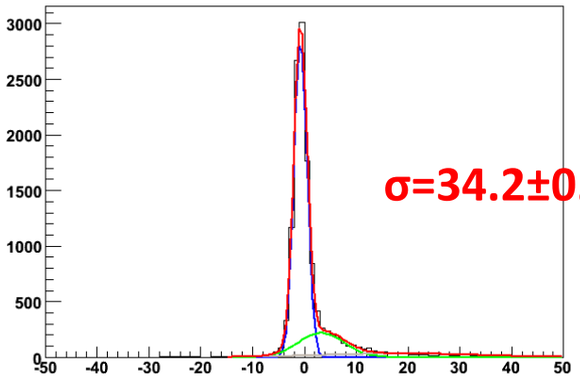
Extremely precise flatness of quartz bar
Excellent timing resolution ~100 picosec



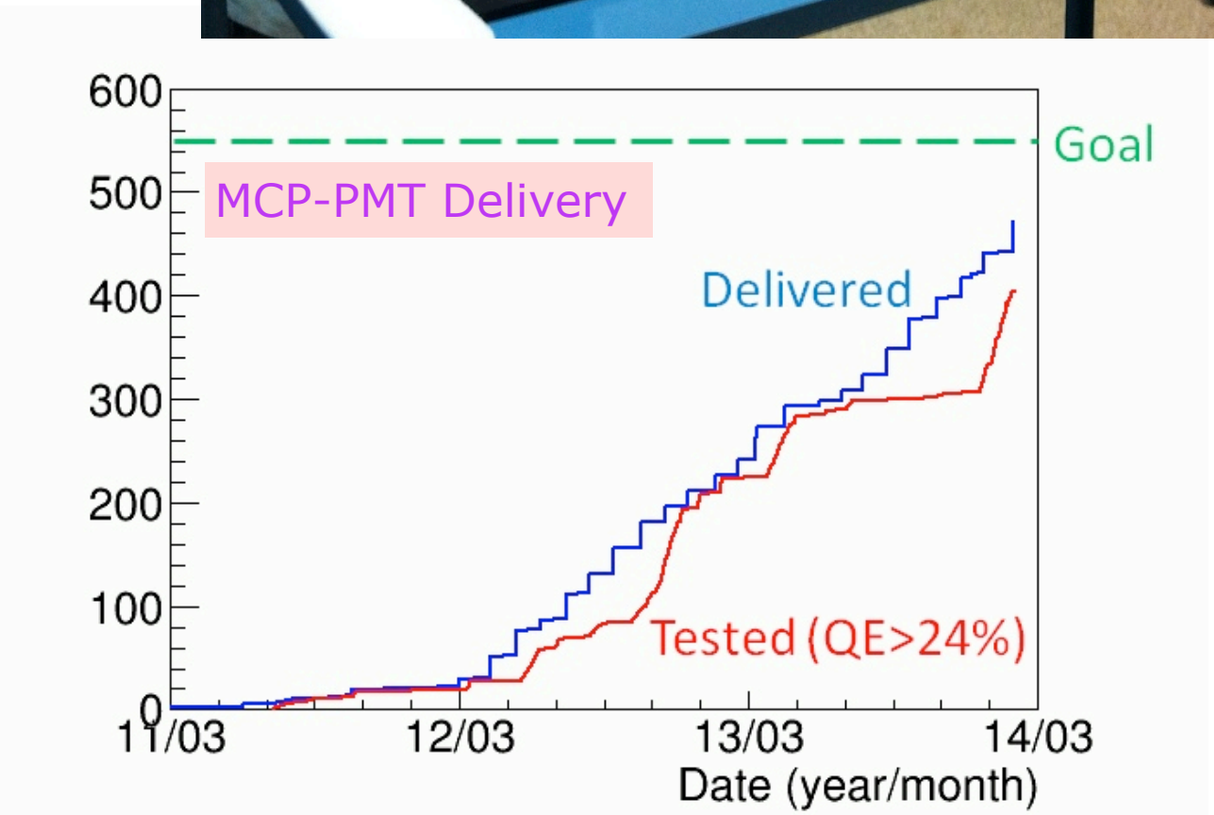
Zygo quartz bar : ultra-precise grinding

MCP-PMT from Hamamatsu

TTS<40psec




σ=34.2±0.4ps



# ARICH Counter

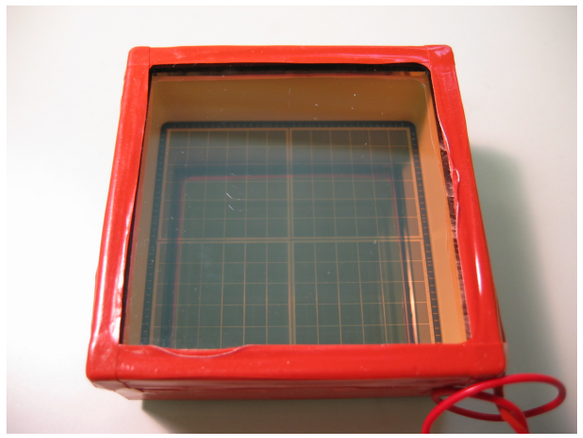
Specific talk on Feb.26

# ARICH Counter

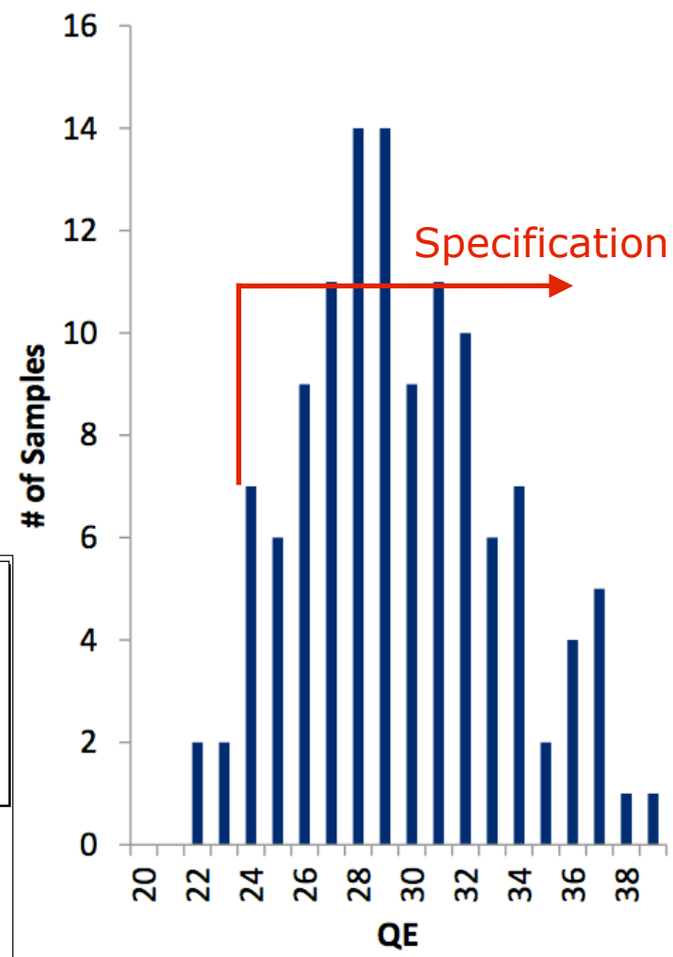
## Photon sensor

144-channel Hybrid Avalanche Photo-Detector (HAPD) developed with Hamamatsu

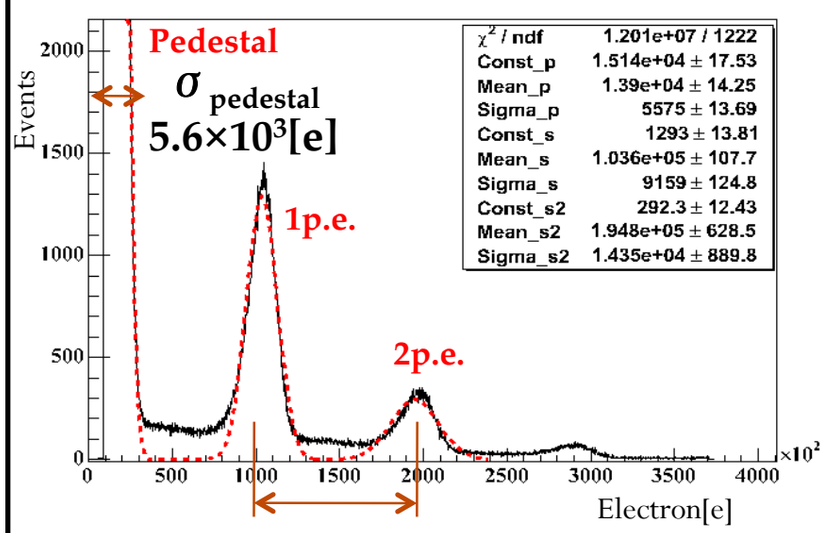
**Mass-productions underway**



QE measurements for HAPD samples



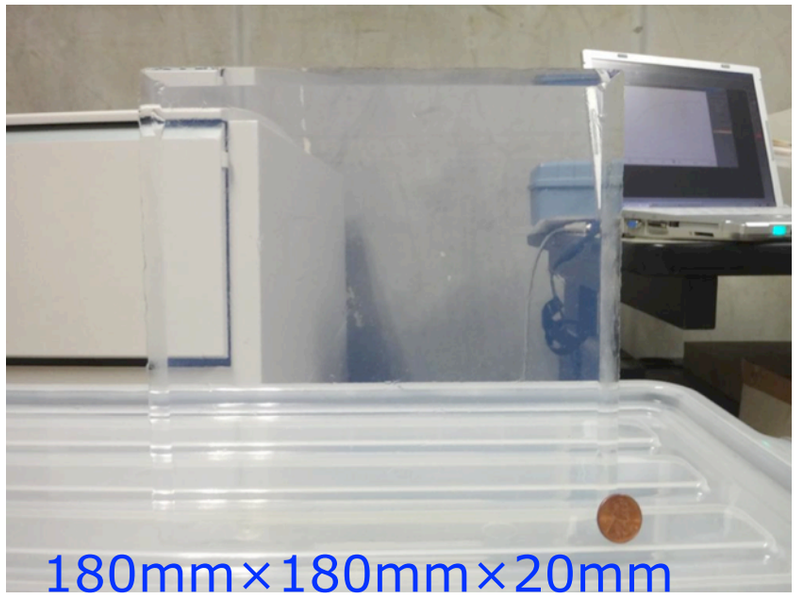

Clear single photon signal




## Cherenkov radiator

Two indices of 1.045 and 1.055: 125 tiles for each index are used.

Large aerogel tile produced




Transmission length ~50mm at λ=400 nm for n=1.045

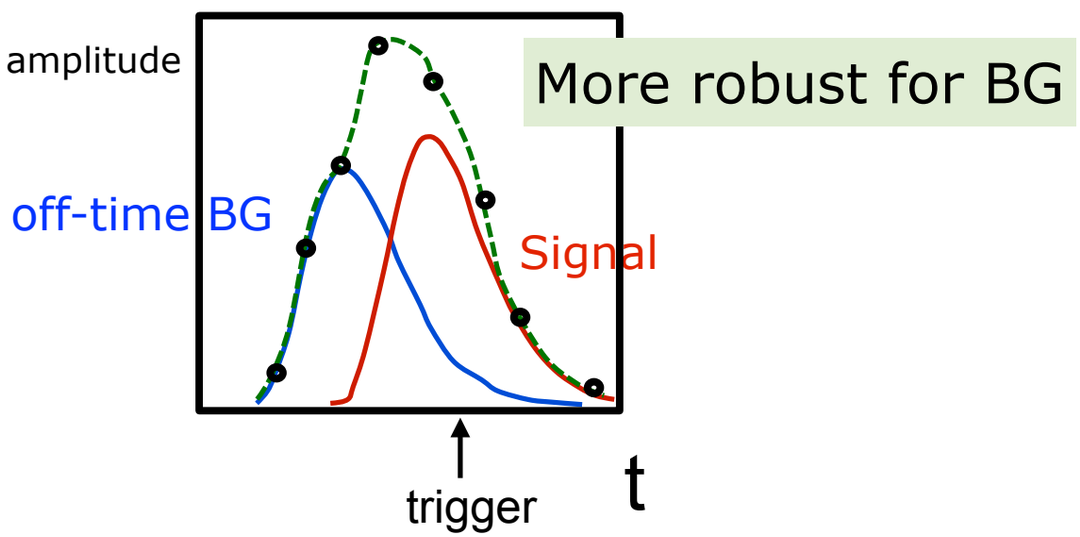
# CsI(Tl) Calorimeter

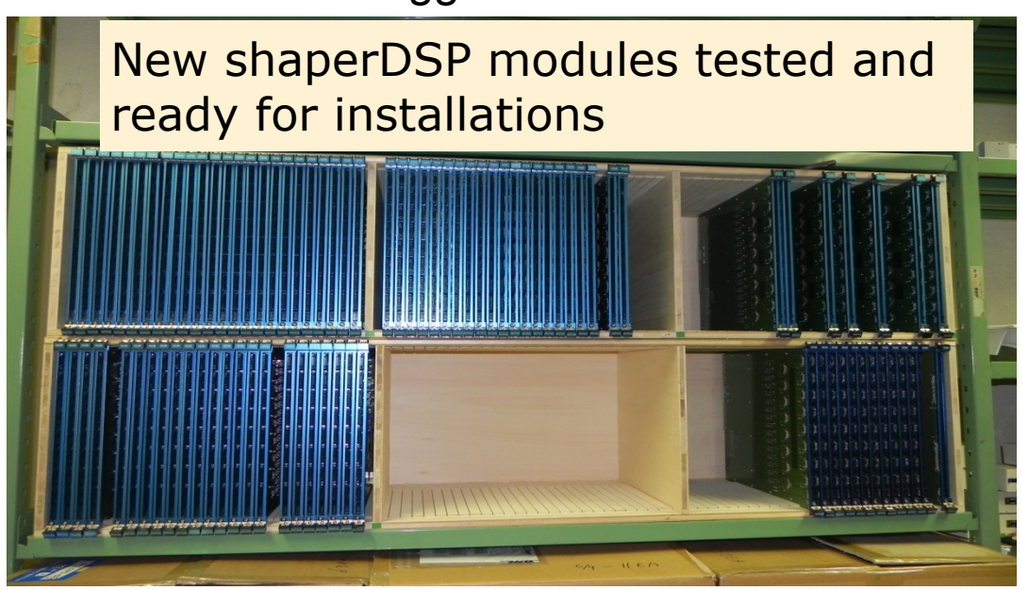
Specific talk on Feb.28

# CsI(Tl) Calorimeter

Two upgrade activities are going on.

## Install new 2MHz wave-form sampling readout at t=0




## Upgrade to pure CsI crystals for end-cap

Shorter time constant of 30 nsec can give a fundamental solution for pile-up

Photopentode for sensor ?

Active R&Ds for this purpose to be reported as a Technical Design Report

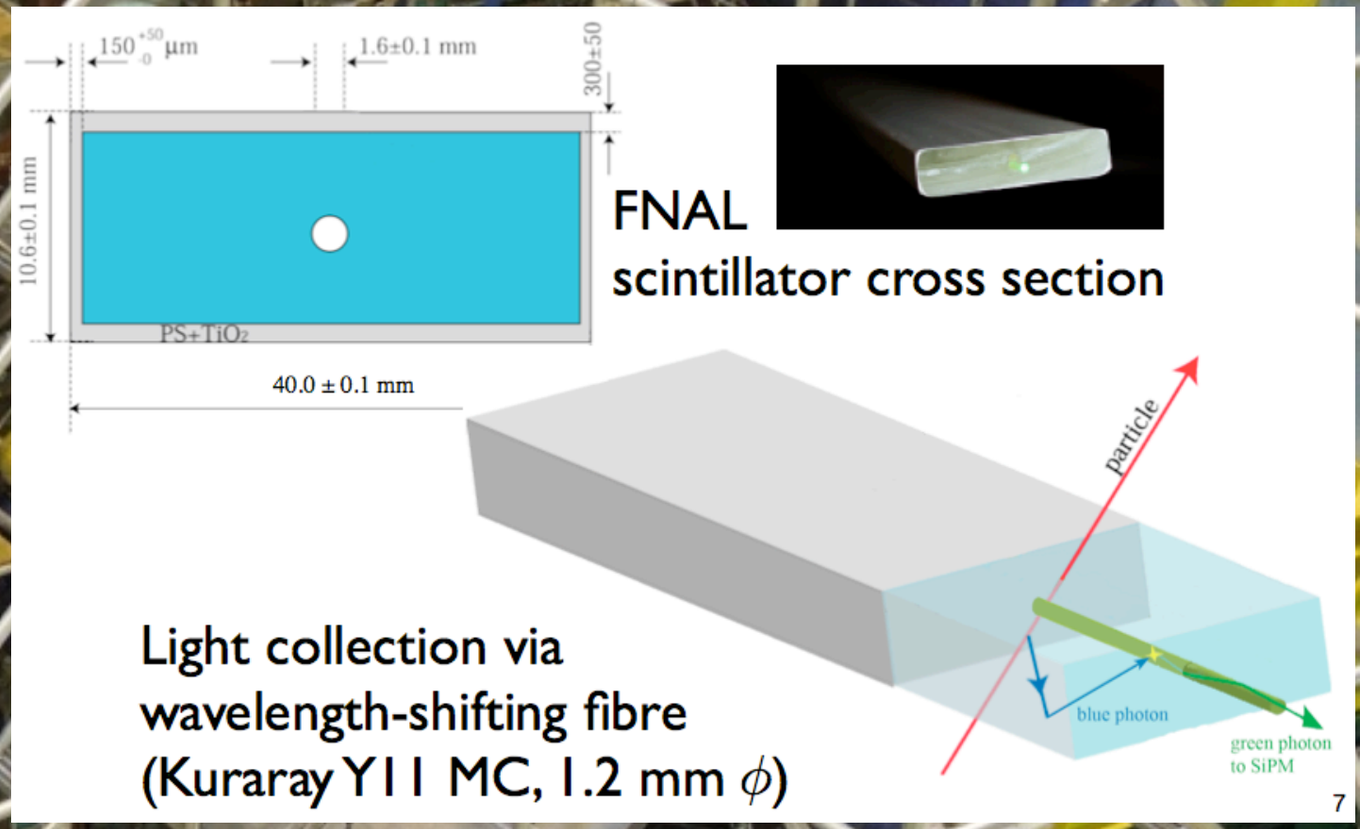
# KL & Muon Catcher (KLM)

**Barrel**

For innermost 2 layers, extract RPC modules and install new scintillator+WLSF+MPPC module

2 layers × 2 in Z-direction × 8 sectors = 32 modules to cope with beam background

# KL & Muon Catcher (KLM)

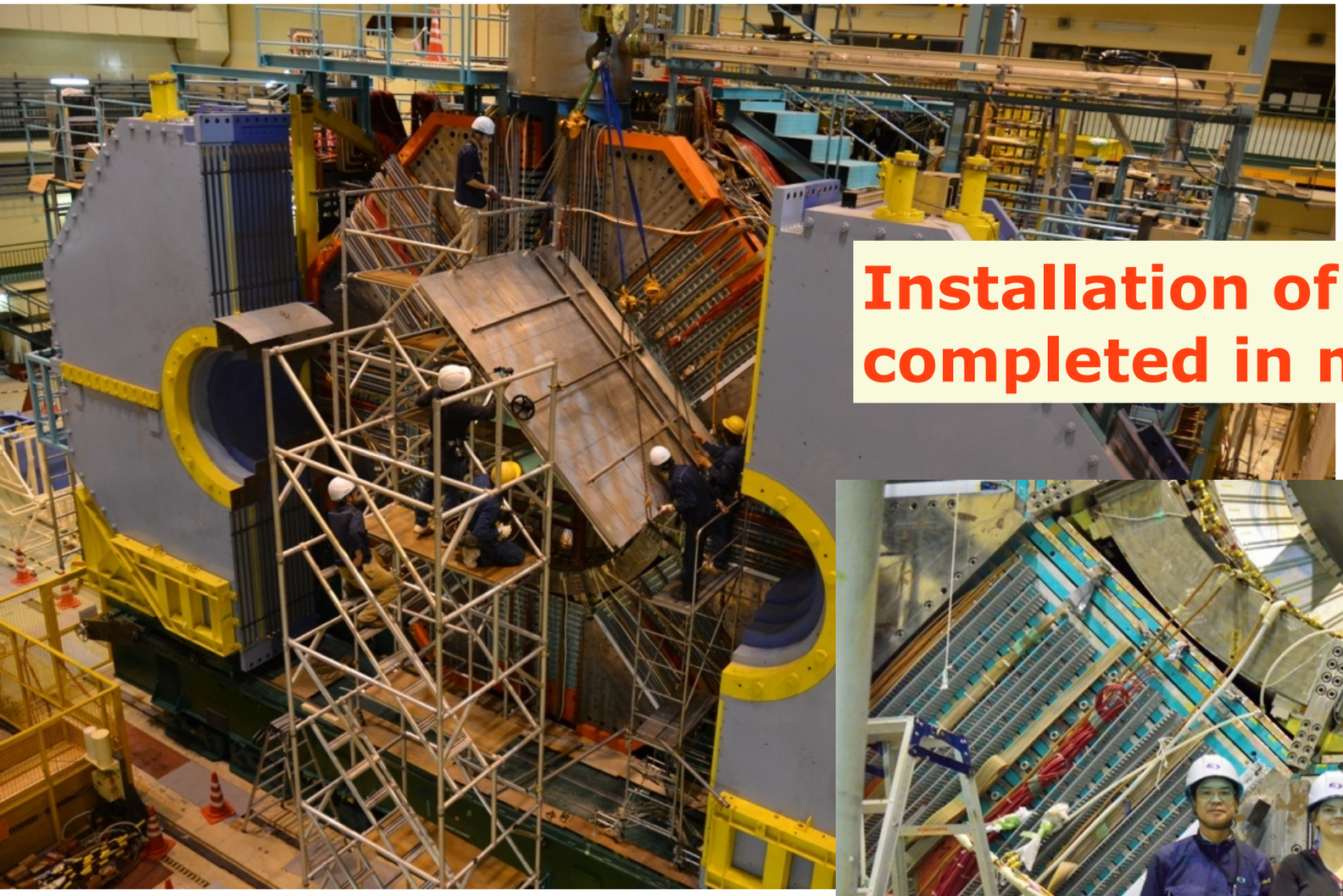



**Barrel**

For innermost 2 layers, extract RPC modules and install new scintillator+WLSF+MPPC module

2 layers × 2 in Z-direction × 8 sectors = 32 modules to cope with beam background

# Barrel KLM



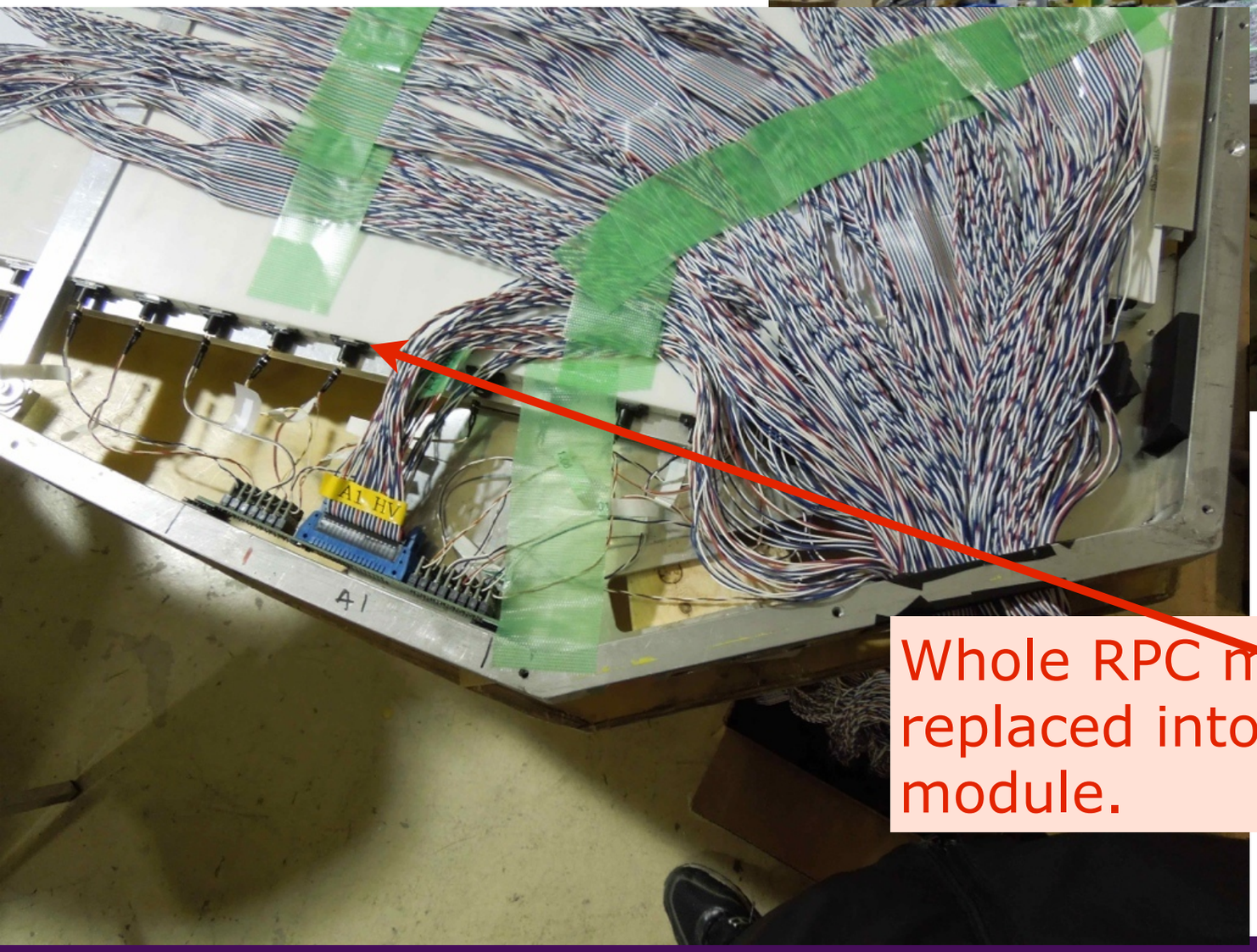
**Installation of barrel KLM has been completed in mid of November 2013.**

**DAQ integration being done**

# End-cap KLM

Whole RPC modules are removed and replaced into new scintillator+WLSF+MPPC module.

**Module assembly is underway. Installation will start this March.**

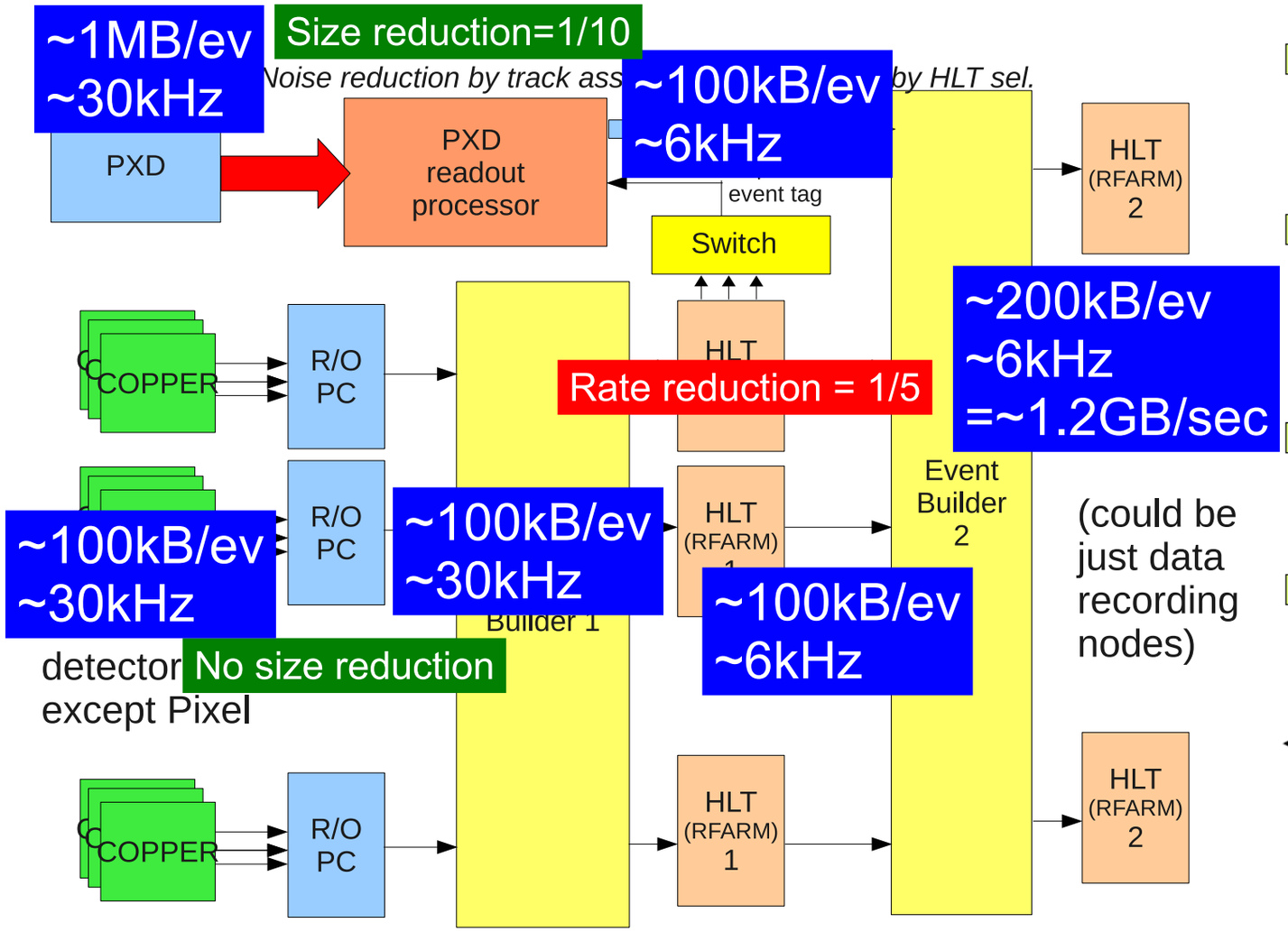


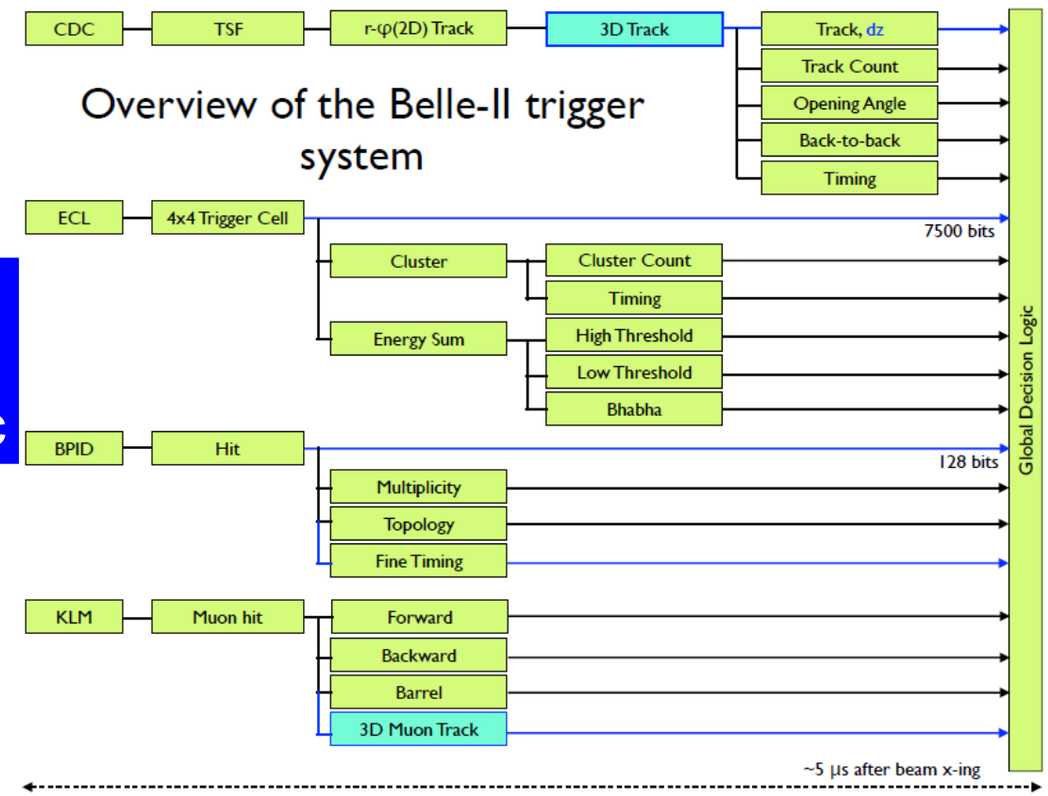

**End-cap**

Whole RPC modules are removed and replaced into new scintillator+WLSF+MPPC module.

Specific talks on Feb.28(ECL) & Mar.1(PXD)

# DAQ System and Trigger

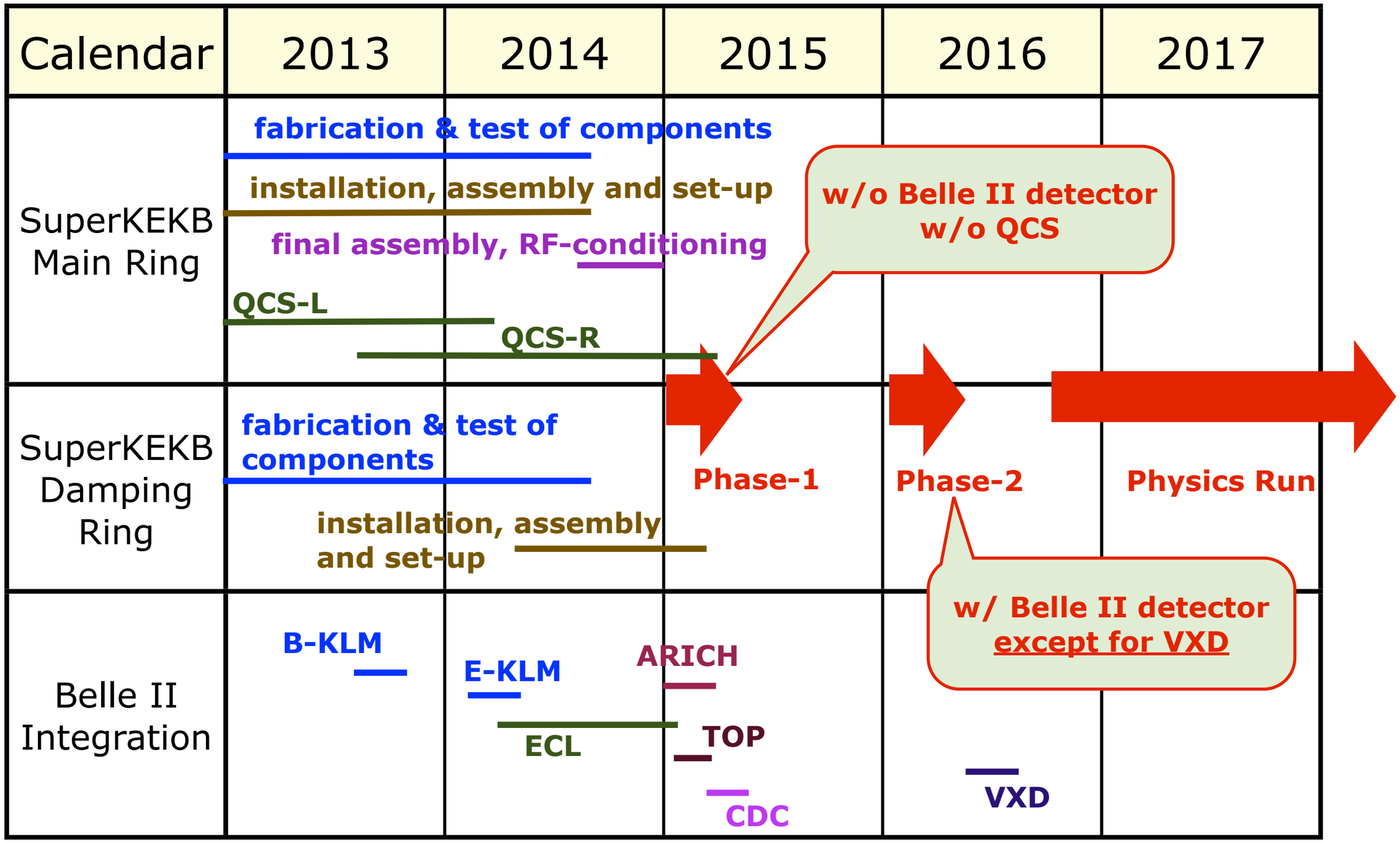



| | Belle | Belle II |
|---|---|---|
| Trigger rate | 500Hz | 30kHz |
| Event size | 40kB | 300kB(max) |

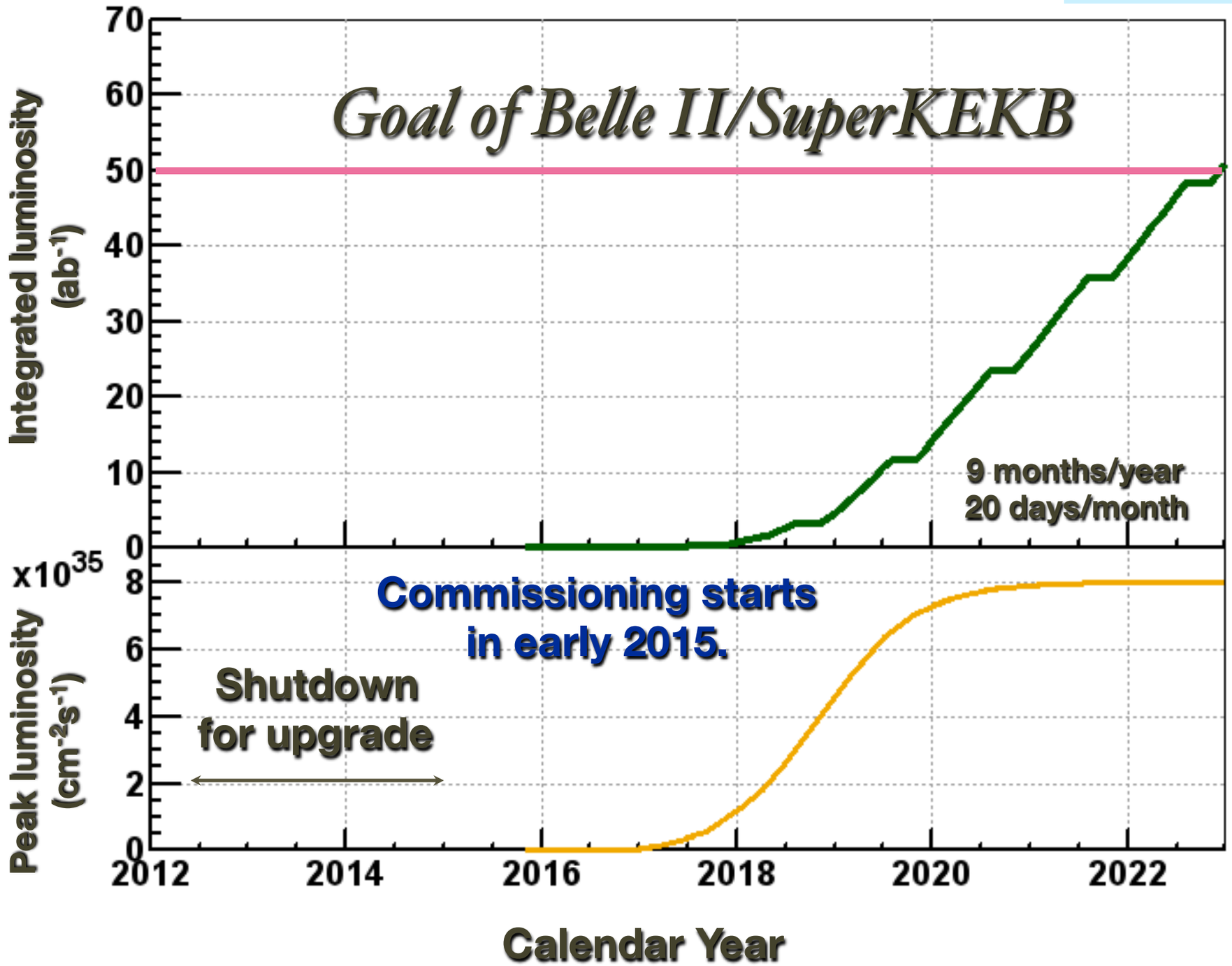
Those systems have been examined at DESY test beam(PXD+SVD) and at Spring-8 (CDC)

# Construction & Commissioning Schedule



# Luminosity Projection

50/ab around 2024



# Conclusions

- Constructions of SuperKEKB accelerator & Belle II detector are in progress.
- We will further gear up to complete in coming year.
- The 1st beam is scheduled in early 2015, and physics run with full Belle II detector will start from late 2016.

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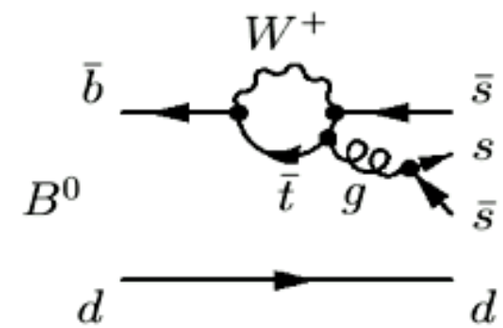
**Большое спасибо**

# Spare Slides

# Physics at Precision Frontier

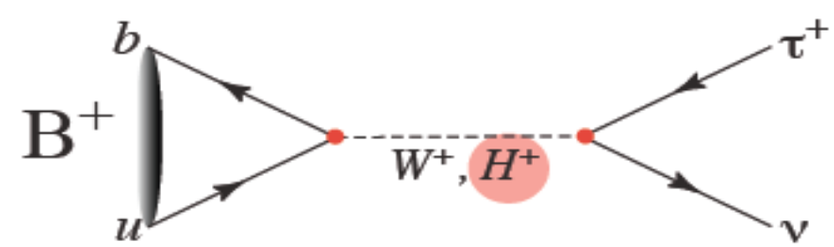
- Excellent laboratory to search for:




  - CP violation from New Physics
    - difference in b→sqq (via penguim) and b→ccs ?
  - Lepton flavor violation in tau decays

$$\mathcal{B}(\tau \to \mu\gamma) \simeq 3.0 \times 10^{-7} \left(\frac{\tan\beta}{60}\right)^2 \left(\frac{1\ \mathrm{TeV}/c^2}{m_{SUSY}}\right)^4$$

  - Unique way to look at charged Higgs couplings of $b$-$H^{\pm}$-$u$/$b$-$H^{\pm}$-$c$ via $B \to \tau\nu / B \to D\tau\nu$

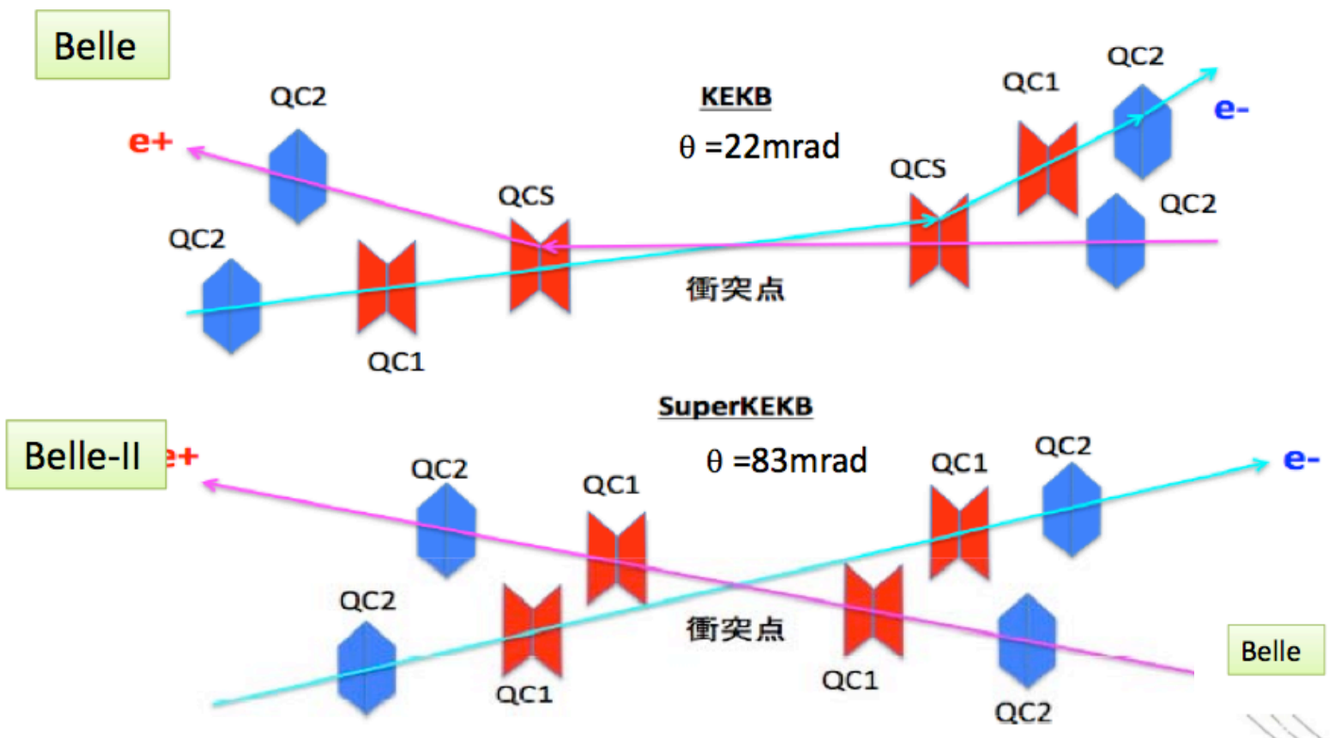



- Independent of LHC:
  - If LHC finds New Physics, flavor structure has to be investigated at super B-factory
  - If no New Physics, super B-factory is only place to search for new phenomena at higher energy scale.

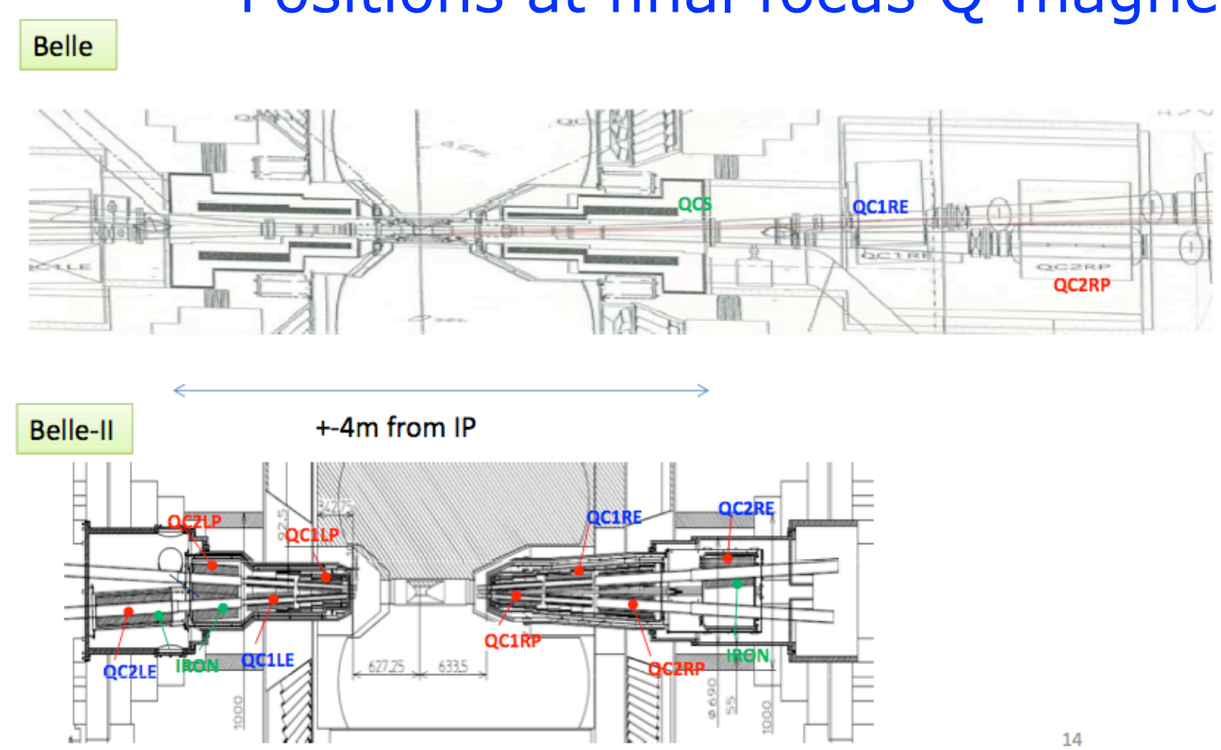
# Interaction Region

**Squeeze beam at more closer at IP**

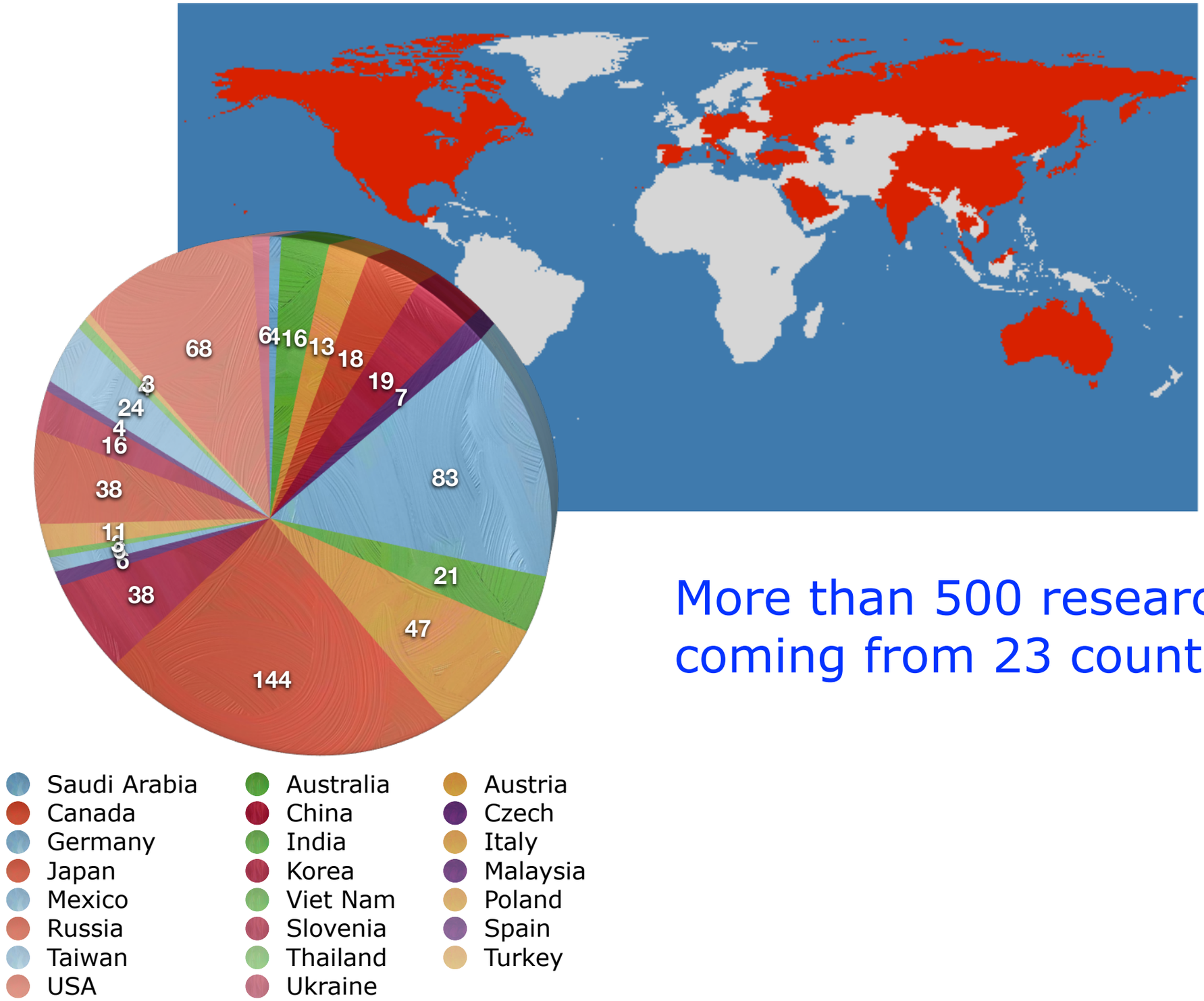
**→ larger crossing angle**




Positions at final focus Q-magnets



# Belle II Collaboration




More than 500 researchers coming from 23 countries/region