Measurement of the proton electromagnetic timelike form-factor with the CMD-3 detector

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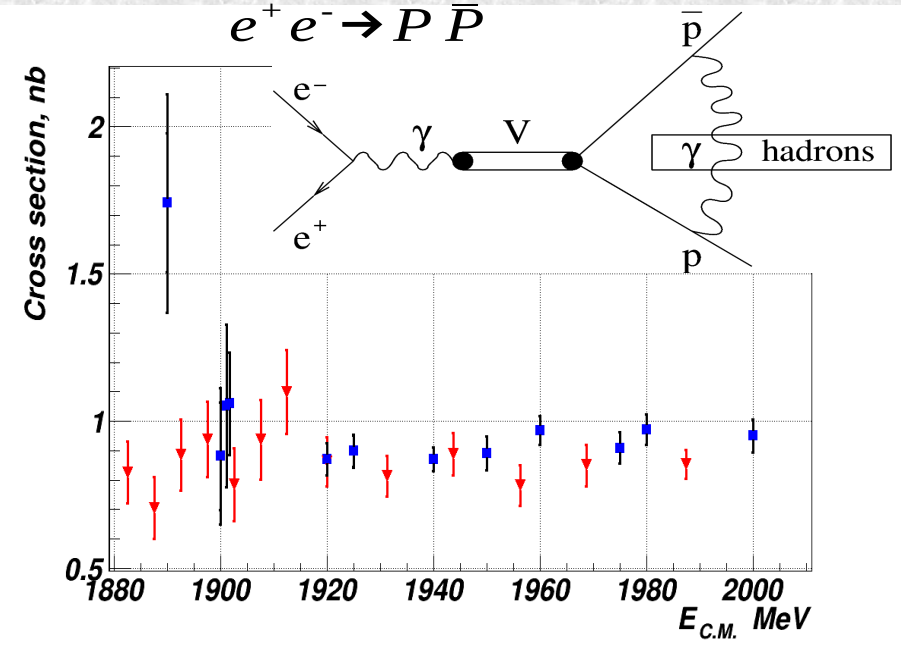
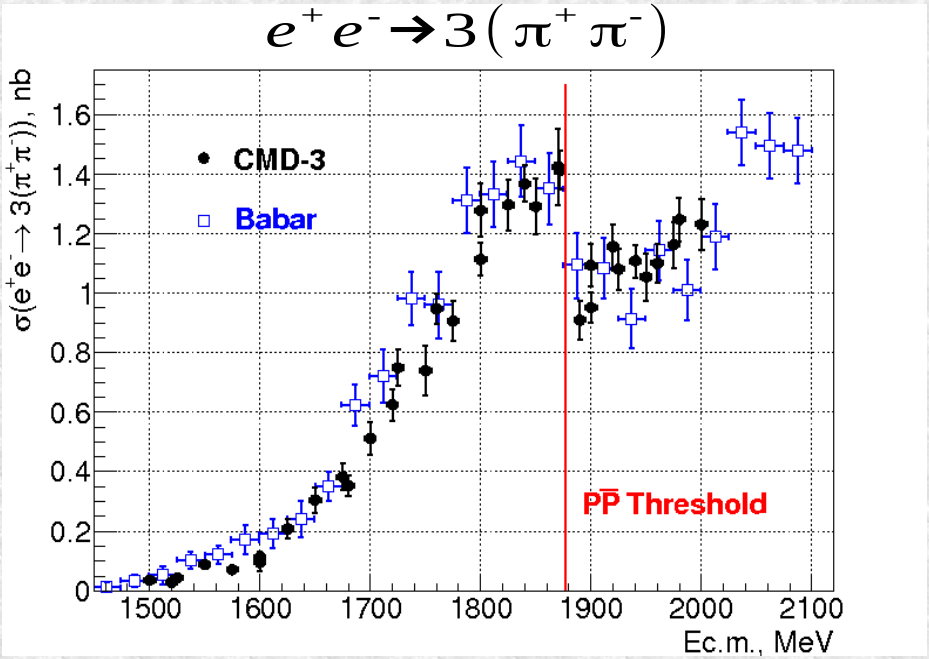
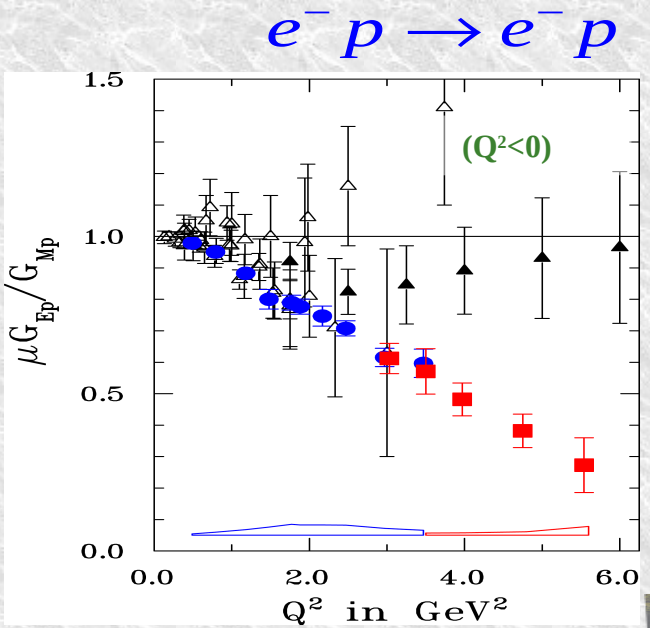
Motivation





Threshold behaviour of P$\bar{P}$ cross section

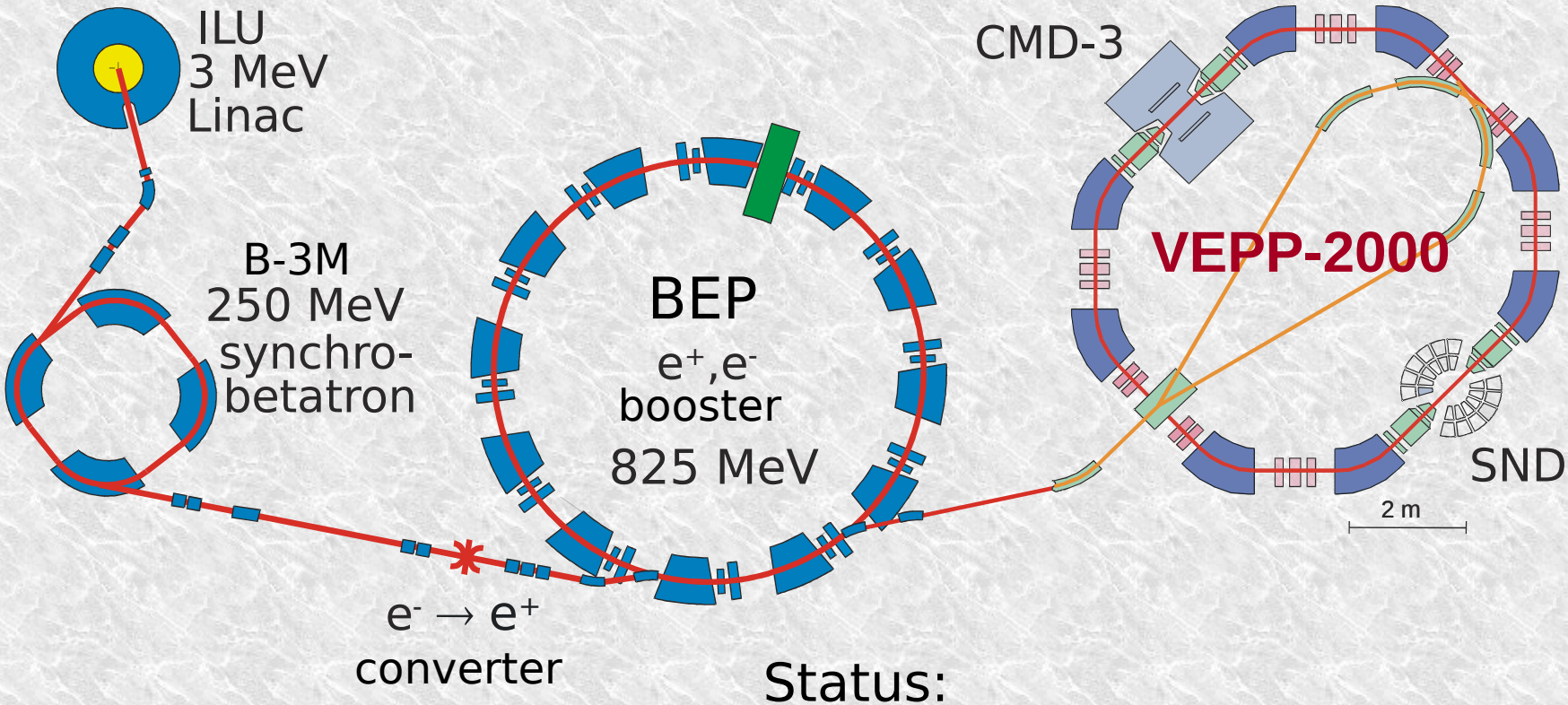
P$\bar{P}$ Threshold behaviour of other process



$$\frac{d\sigma}{do} = \frac{\alpha^2 \beta C}{4s}\left[\left|G_M(s)\right|^2 (1+\cos^2\theta) + \frac{4m_N^2}{s}\left|G_E(s)\right|^2 \sin^2\theta\right]$$

$$C = y/(1-e^{-y}),\quad y = \frac{2\pi\alpha}{\beta}$$

VEPP-2000 collider



- Up to 2 GeV c.m. Energy
- VEPP-2000 uses unique “round beams” optic, which gives record luminosity for 1-bunch machine and will provide:

$L=10^{32}\,cm^{-2}s^{-1}$, $\sqrt{s}=2.0$ GeV

Status:

2010 – start of experiments

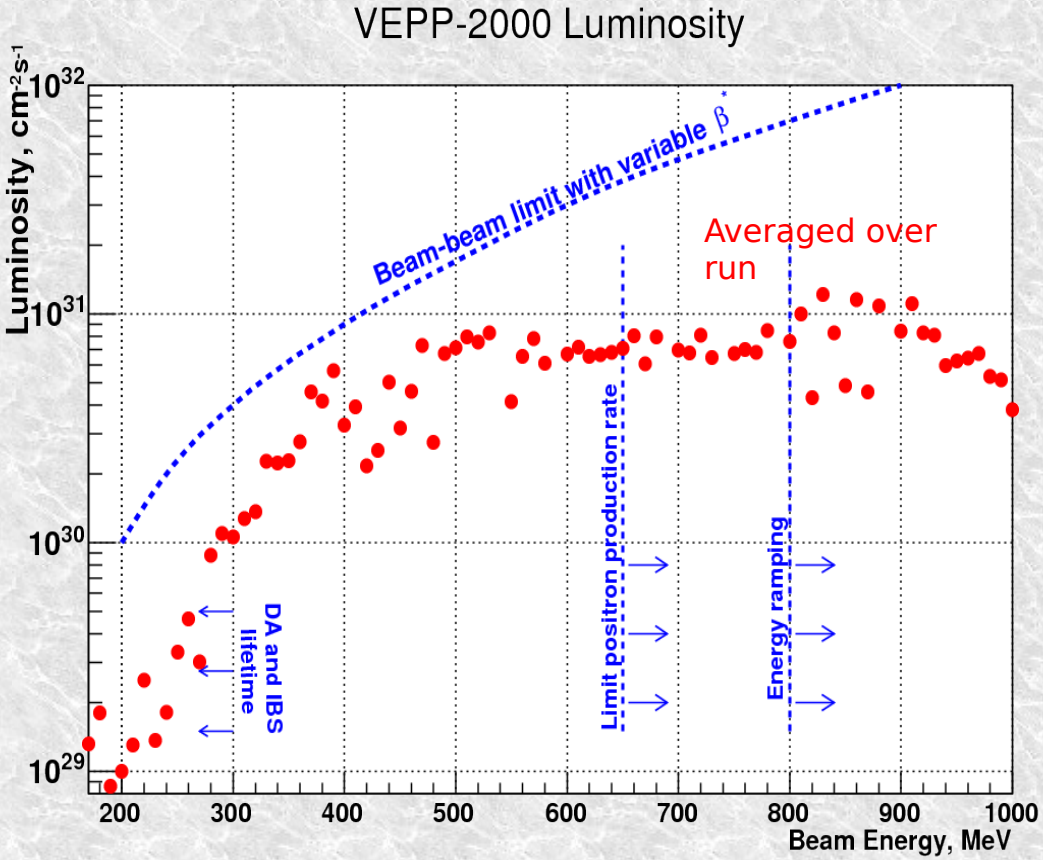
2013-2015 - upgrade of positron injection facility

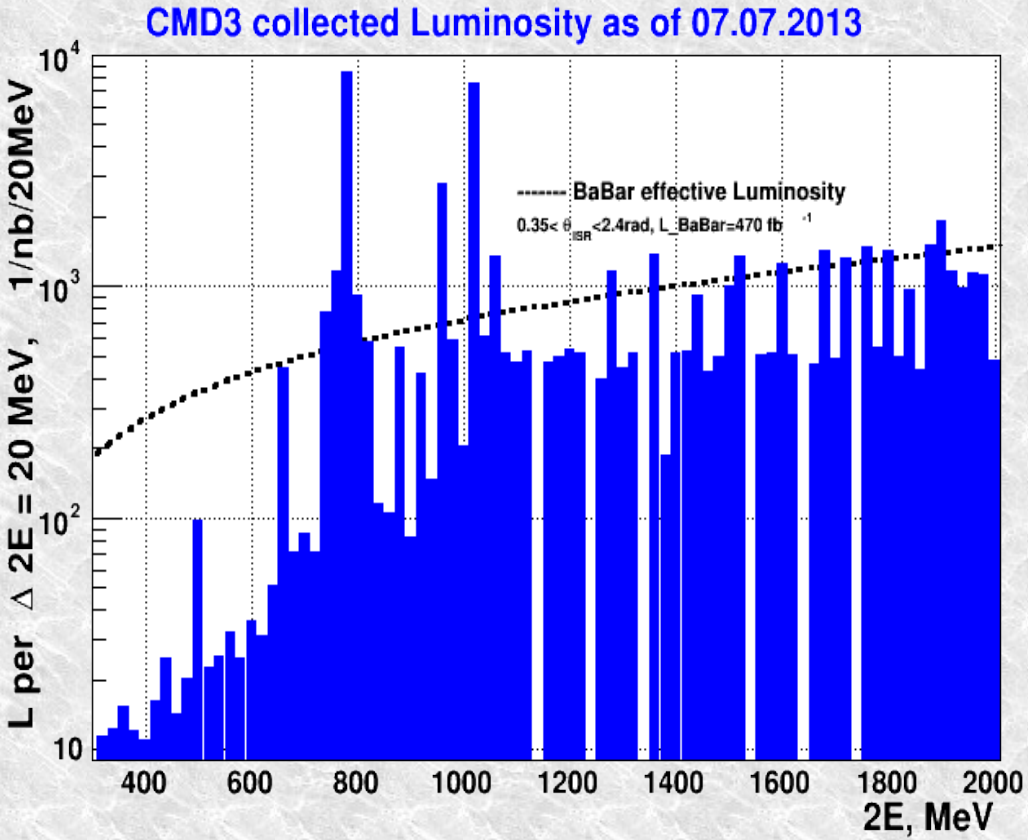
Plans:

≈100 pb^{-1} per detector per year

CMD-3 Collaboration

Collected Luminosity





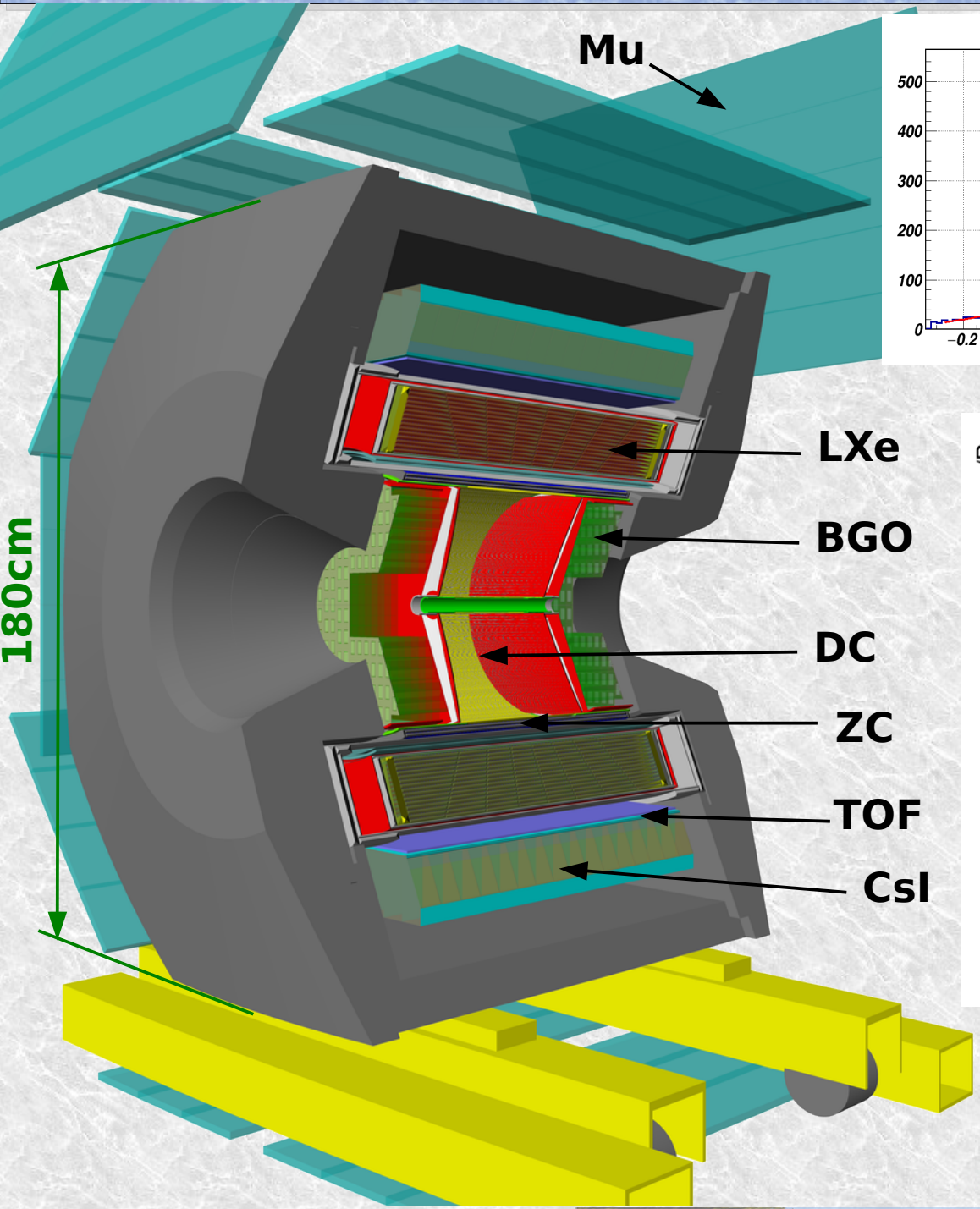
The 10^{31} cm^{-2}s^{-1} luminosity at √s=2.0 GeV was reached

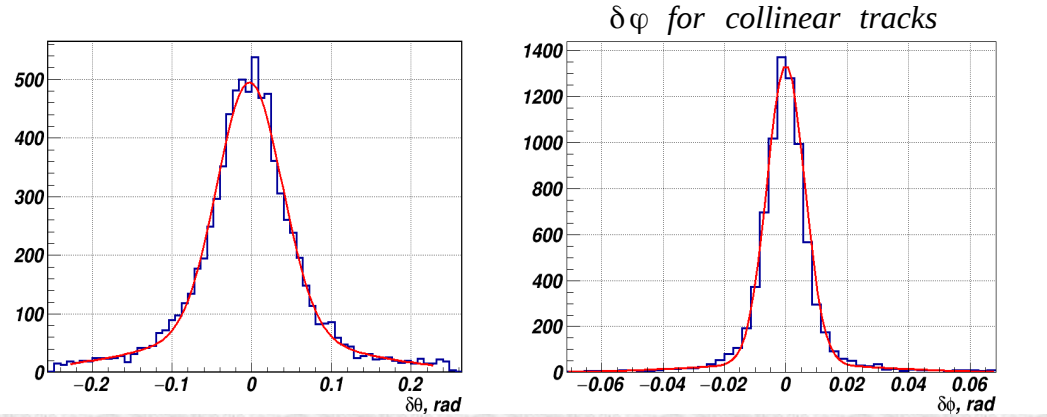
Currently the luminosity at high energy is limited by a deficit of positrons and maximum energy of the booster (now 825 MeV), after upgrade it will gain a factor of 10

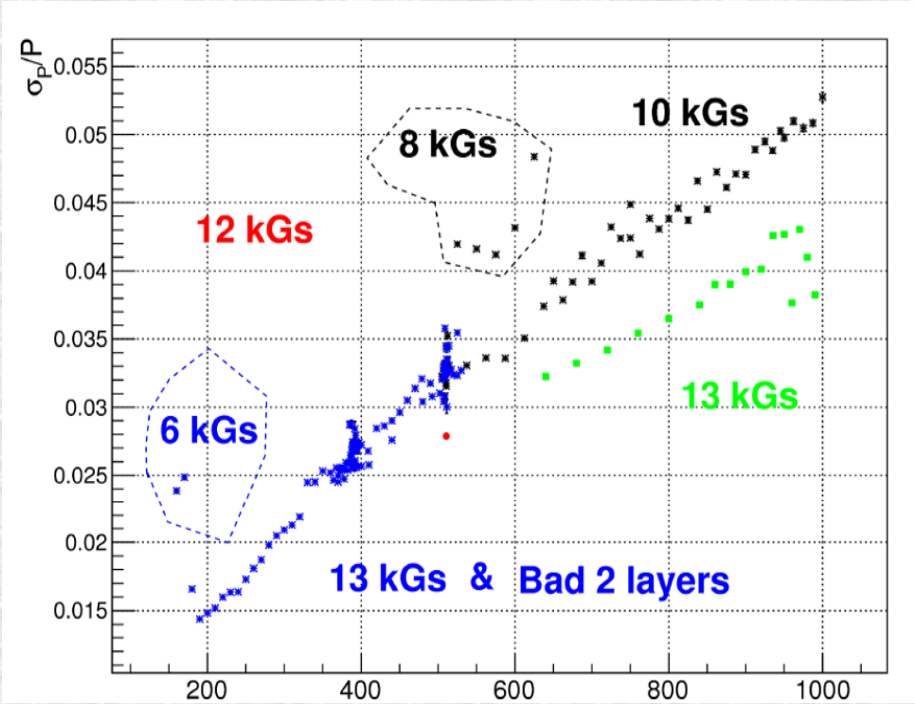
Collected L ~ 60 pb^{-1} per detector

8.3 pb^{-1}	ω - region
9.4 pb^{-1}	< 1 GeV (except ω)
8.4 pb^{-1}	φ - region
34.5 pb^{-1}	> 1.04 GeV

CMD-3 Detector

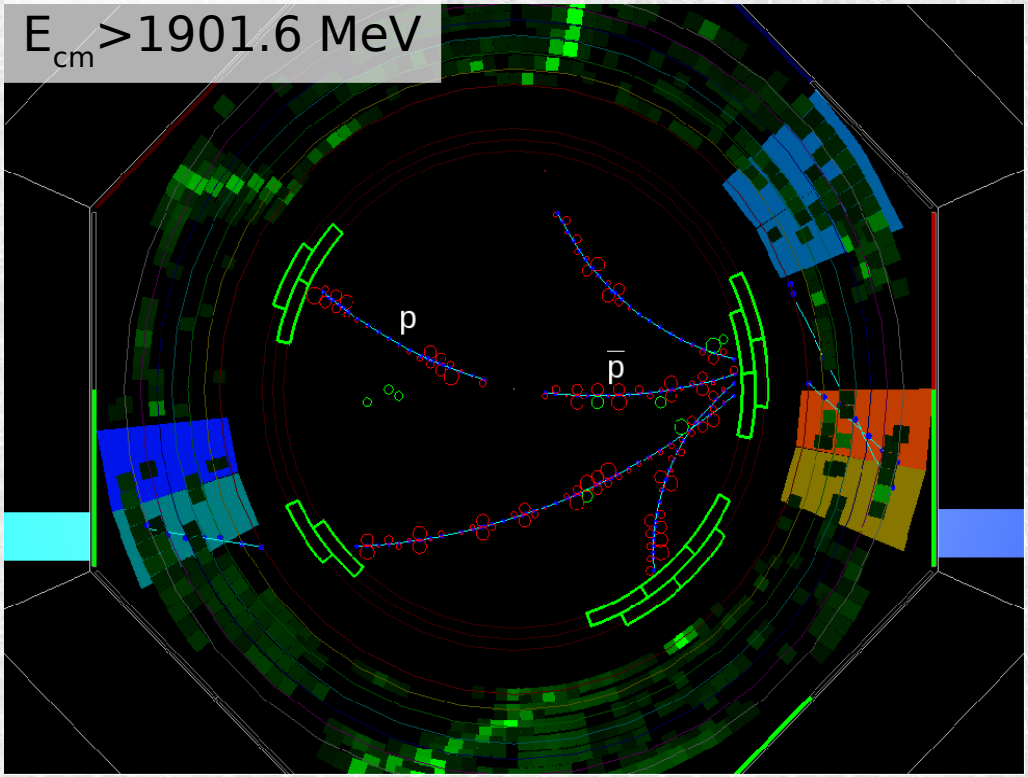


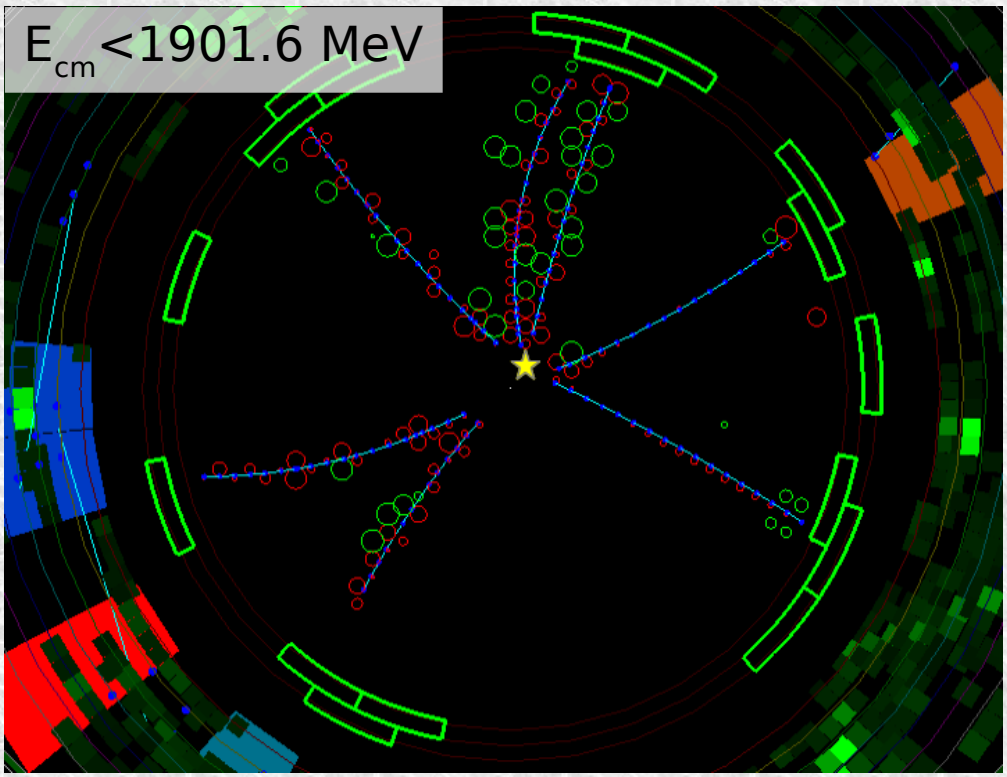




CMD-3 Collaboration

$P\bar{P}$ Events





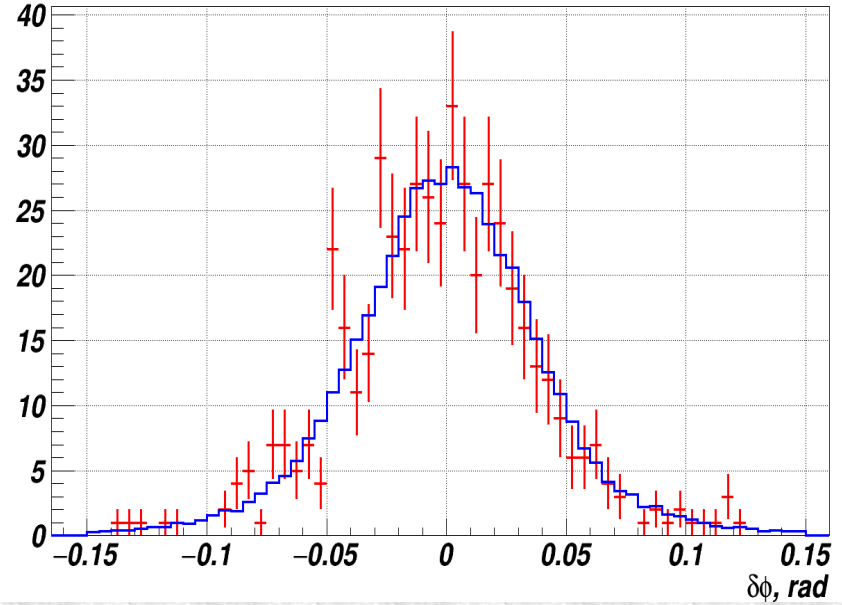
Collinear event:
2 collinear tracks from center, with high dE/dX

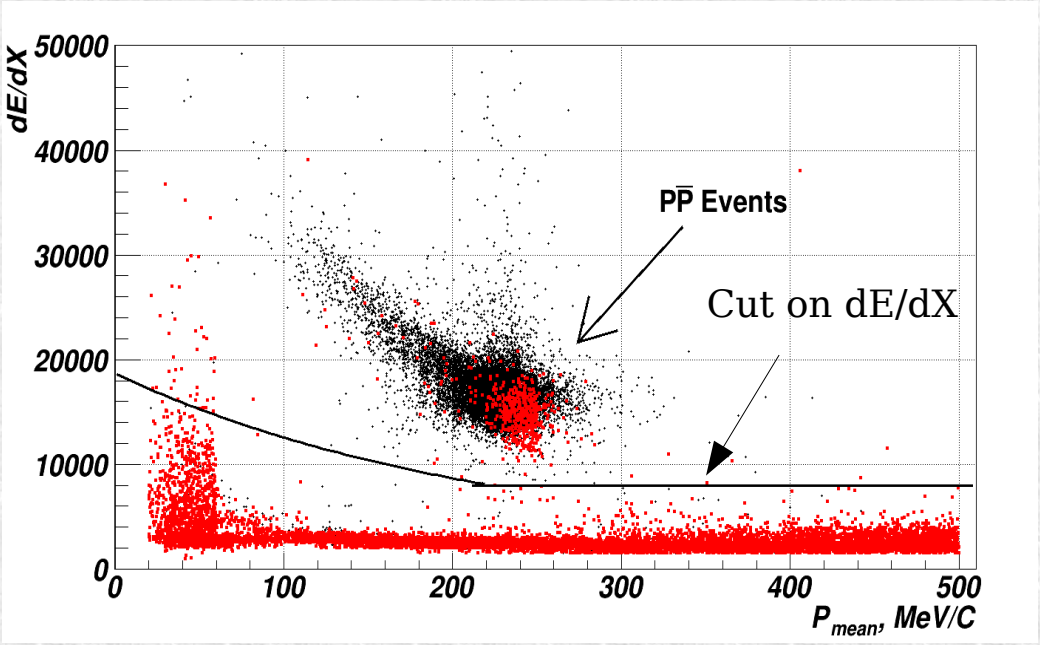
Pipe event:
Many tracks with vertex at vacuum pipe

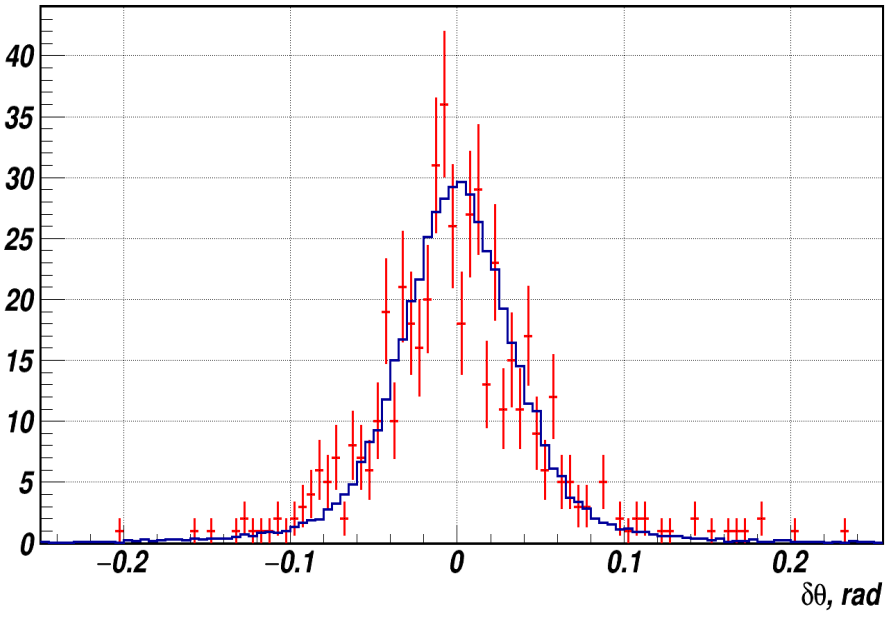
At E_{CM} = 1901.6 MeV we have both type of events

Selection of collinear Events

- $\delta\theta < 0.3$ rad
- $\delta\varphi < 0.15$ rad
- $Q_+ + Q_- = 0$
- $(P_+ - P_-)/(P_+ + P) < 0.15$
- $|z1+z2|/2 < 10$ cm
- $\rho < 0.5$ cm
- $N_{hits} >= 5$
- Cut on dE/dX

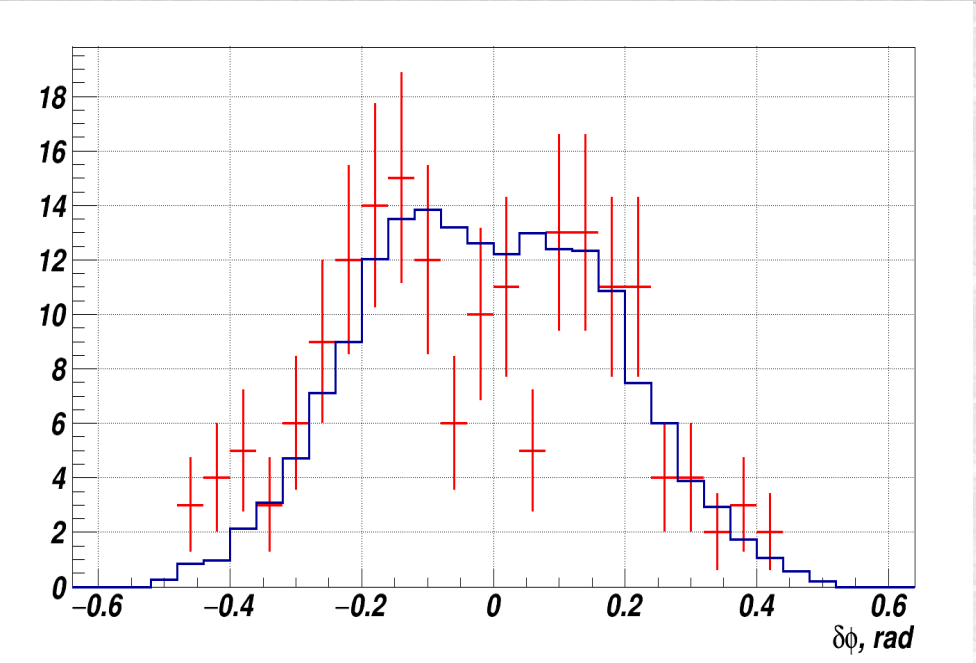


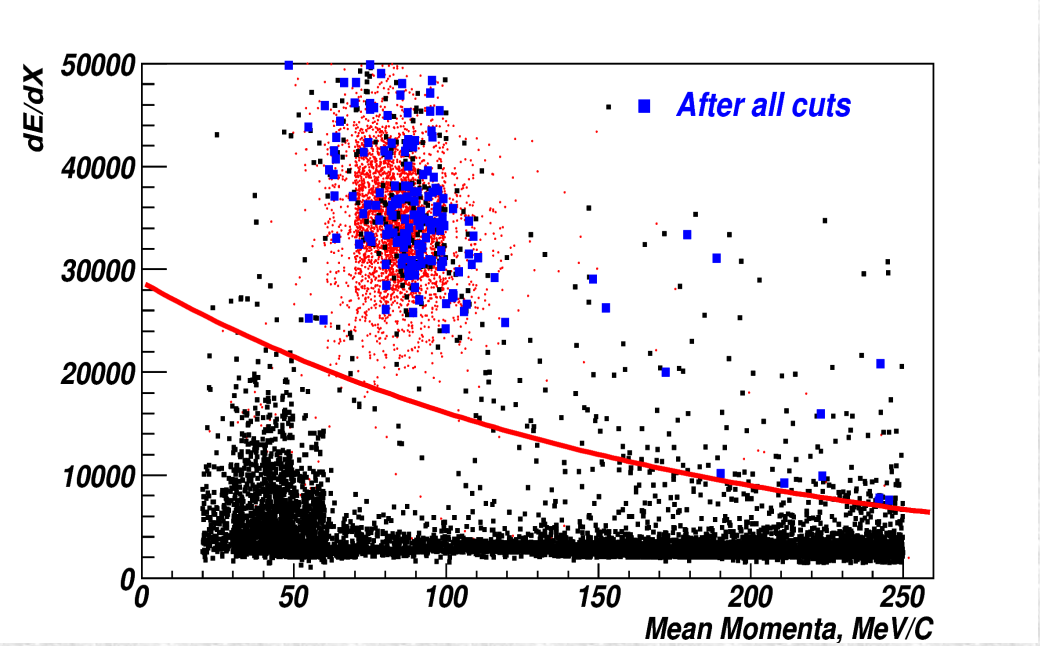


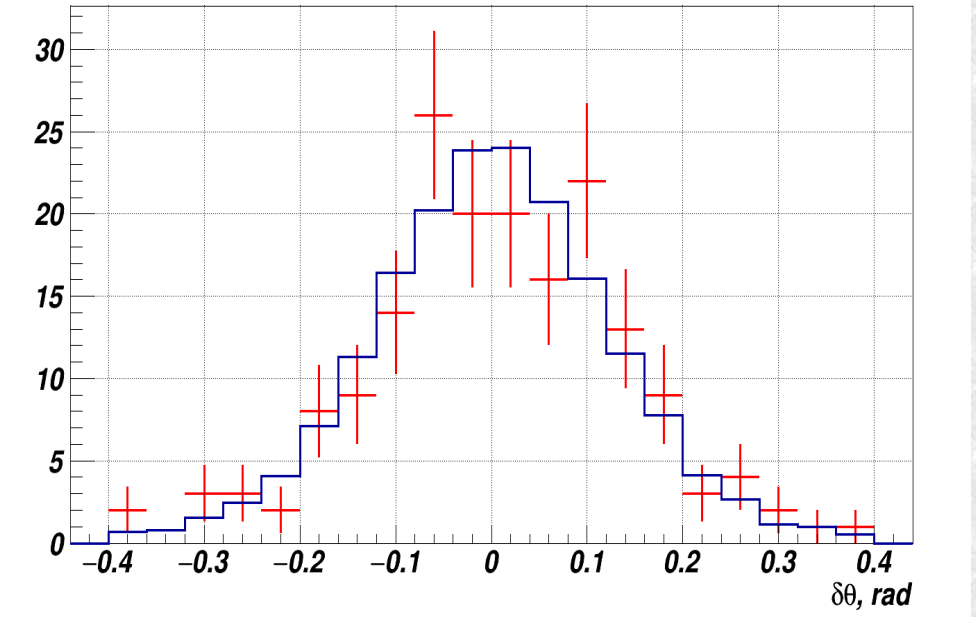


Collinear events for E_{CM}=1901.6 MeV

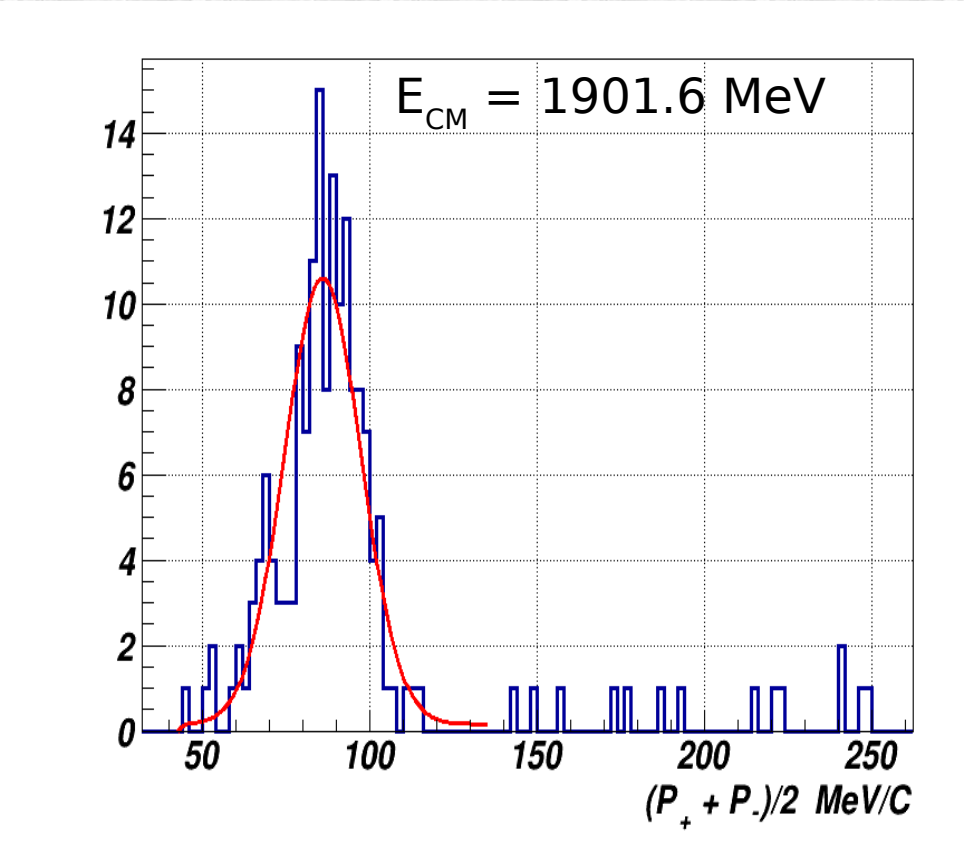
- $\delta\varphi < 0.5$ rad
- $\delta\theta < 0.4$ rad
- $Q_+ + Q_- = 0$
- $(P_+ - P_-)/(P_+ + P) < 1$
- $|z1+z2|/2 < 10$ cm
- $\rho < 1$ cm
- $N_{hits} >= 5$
- Cut on dE/dX

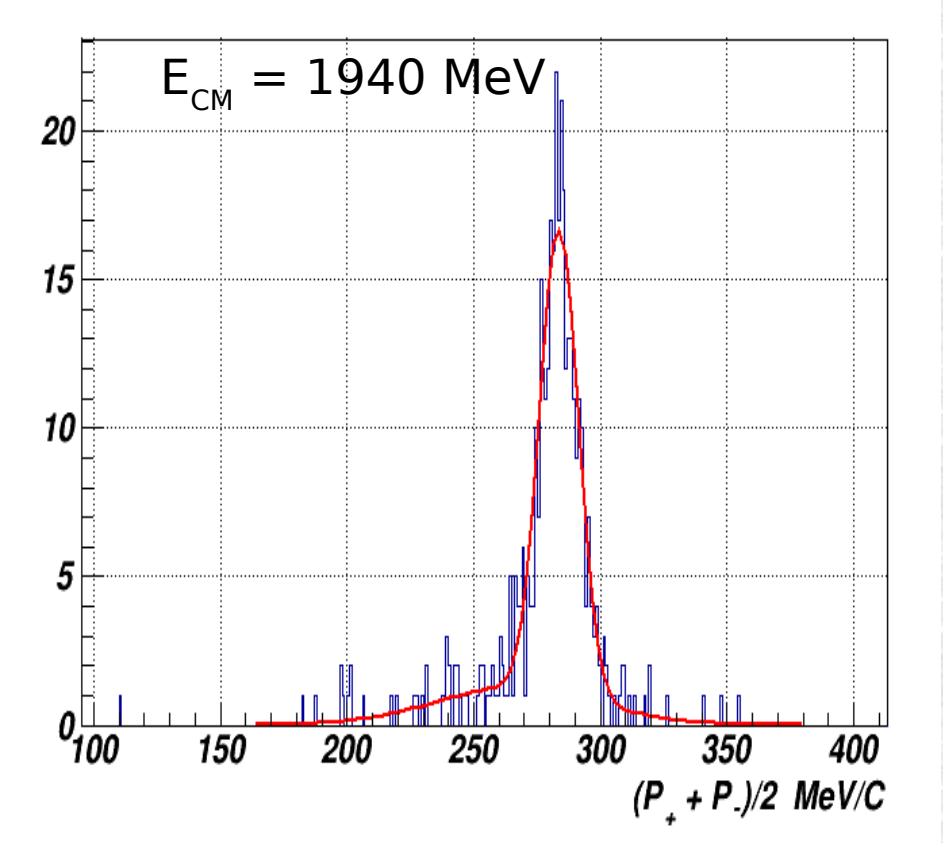






Number of $P\bar{P}$ events





$(P_+ + P_-)/2$ spectra was fitted by shape from simulation with const of background
Part of background is negligible.

Check of track reconstruction efficiency

Test event with $\bar{P}$

- 1 or 2 tracks from beam
- 1 track with negative charge
- |z| < 10 cm
- P < 0.5 cm
- N_{hits} >= 9
- Cut on dE/dX

Define track reconstruction efficiency

$\varepsilon = N_{P\bar{P}} / N_{\bar{P}}$ where:

$N_{\bar{P}}$ – number of events in test set

$N_{P\bar{P}}$ -number of $P\bar{P}$ events in test set

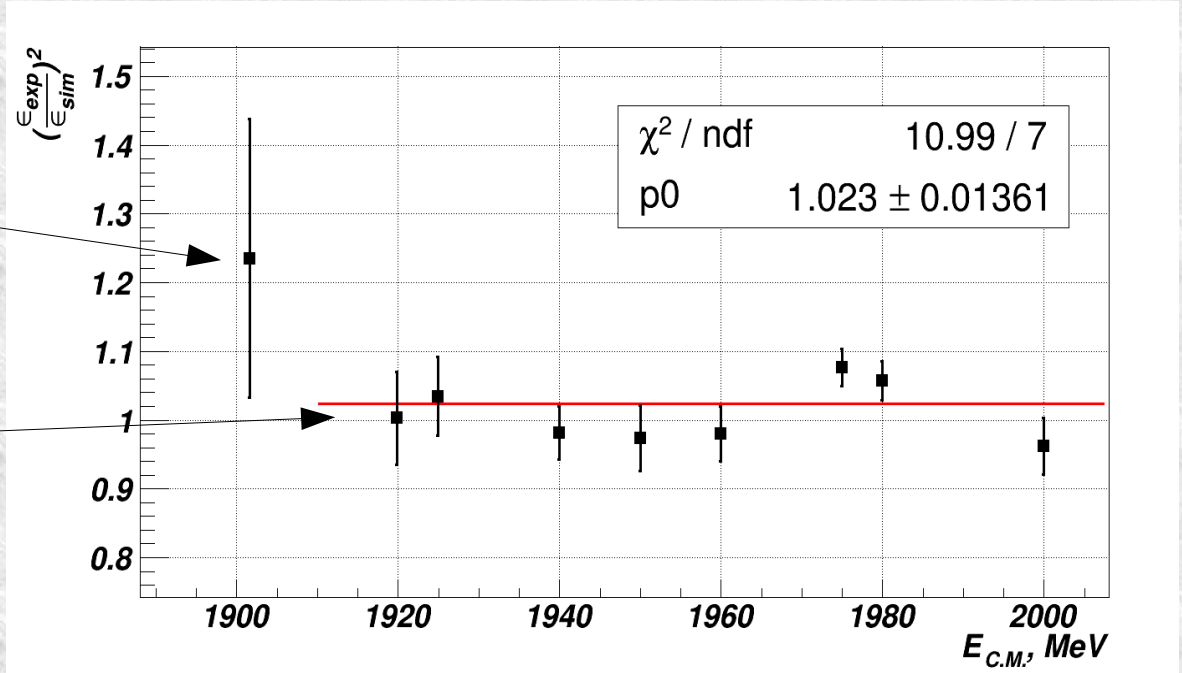
The track efficiency correction is $\varepsilon_{exp} / \varepsilon_{sim}$

The correction of event registration efficiency is $(\varepsilon_{exp} / \varepsilon_{sim})^2$

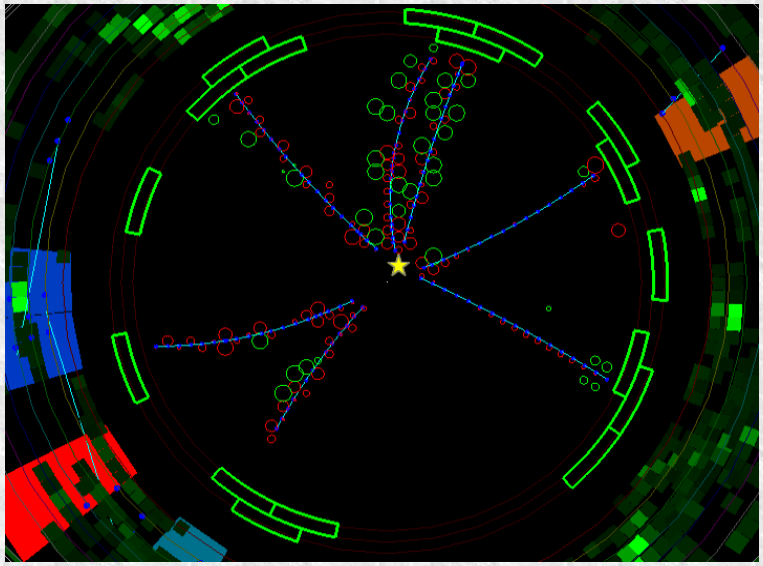
Due to uncertainty in E_{CM} & thickness of vacuum pipe wall Have to take into account.

Relative small effect, included in systematic error

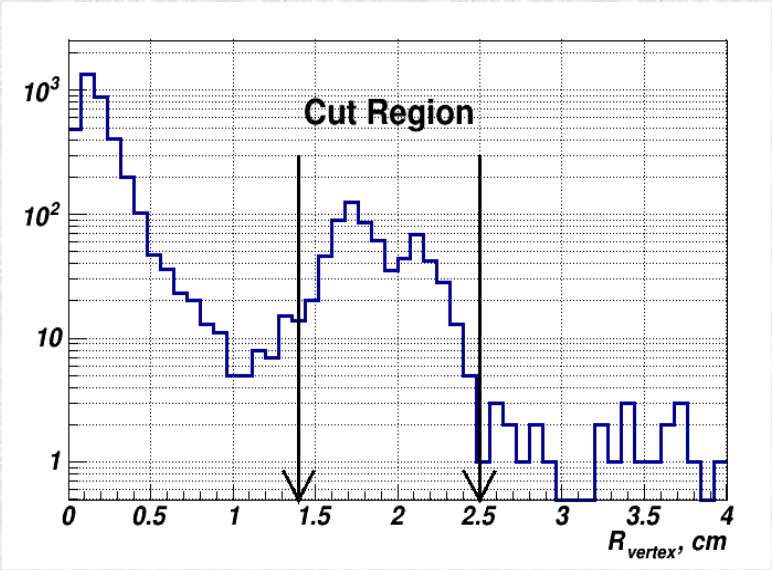
$$\sigma_{born} = \frac{N_{event}}{L*(1-\delta)*\epsilon}\left(\frac{\epsilon_{simul}}{\epsilon_{exp}}\right)^2$$

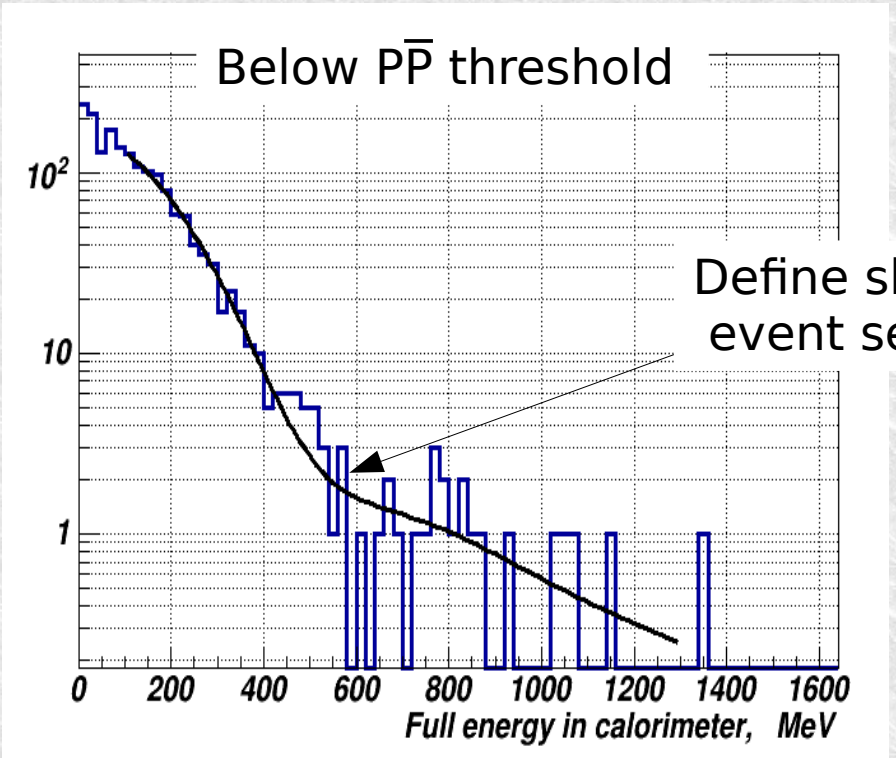


Pipe events

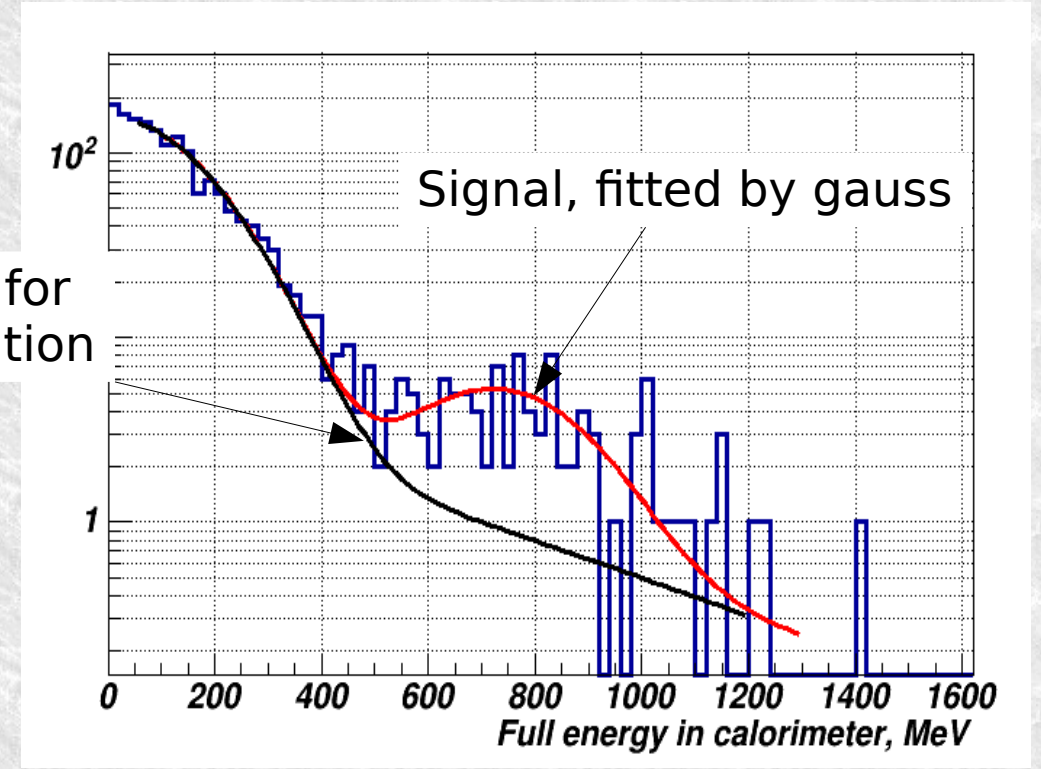


- At least one vertex
- $N_{track}>3$
- $1.4<R_{vertex}<2.5$ cm
- $|Z_{vertex}|<10$ cm

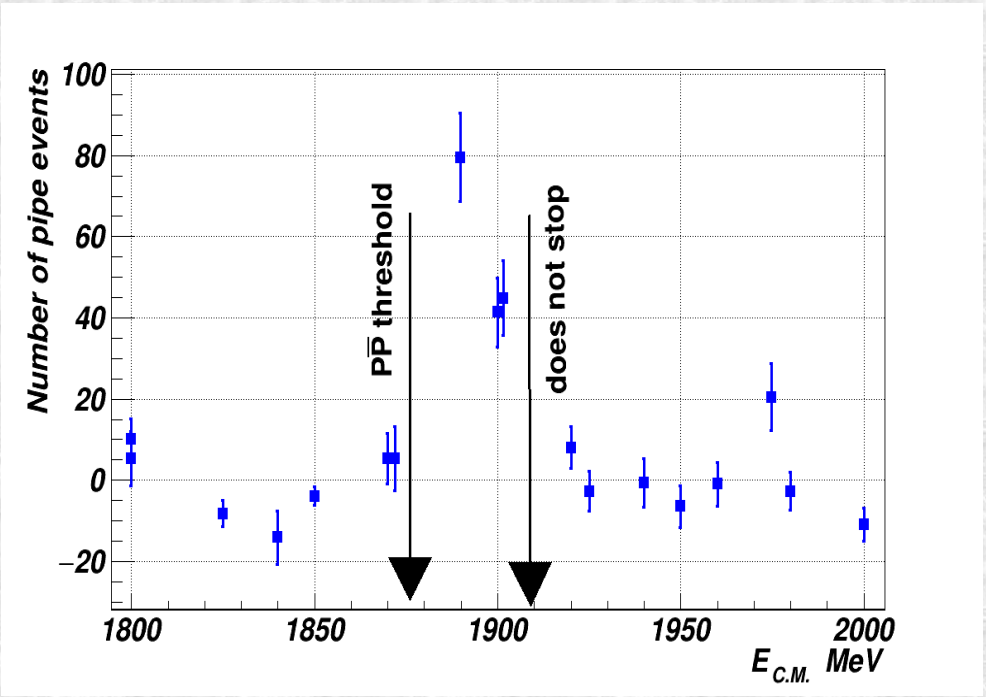


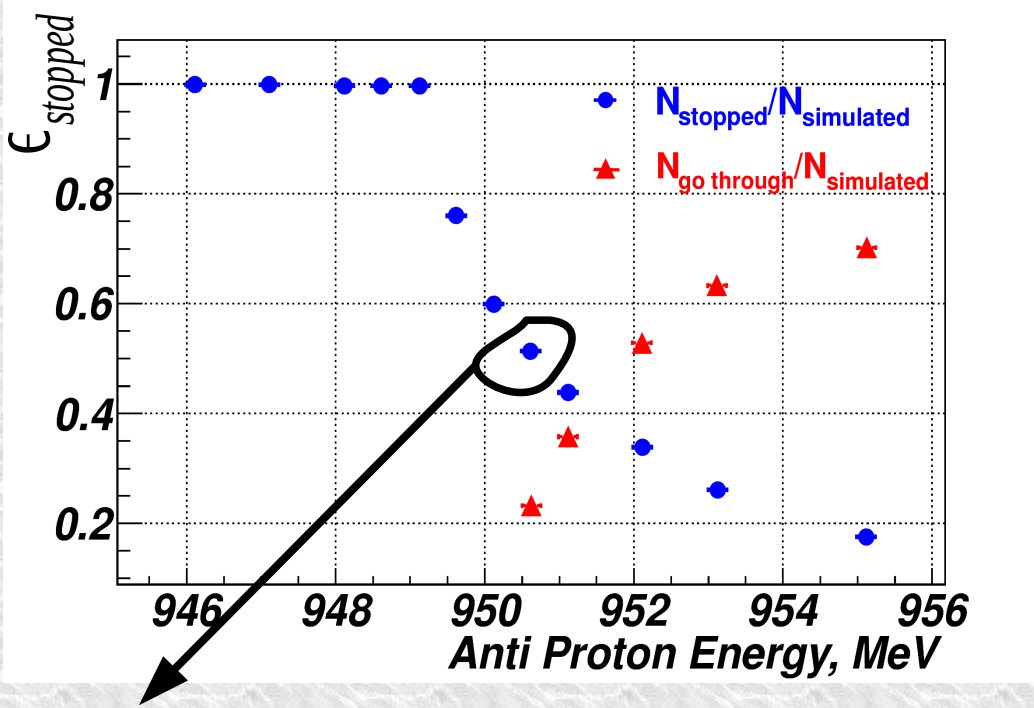


Define shape for event separation



Number of pipe events





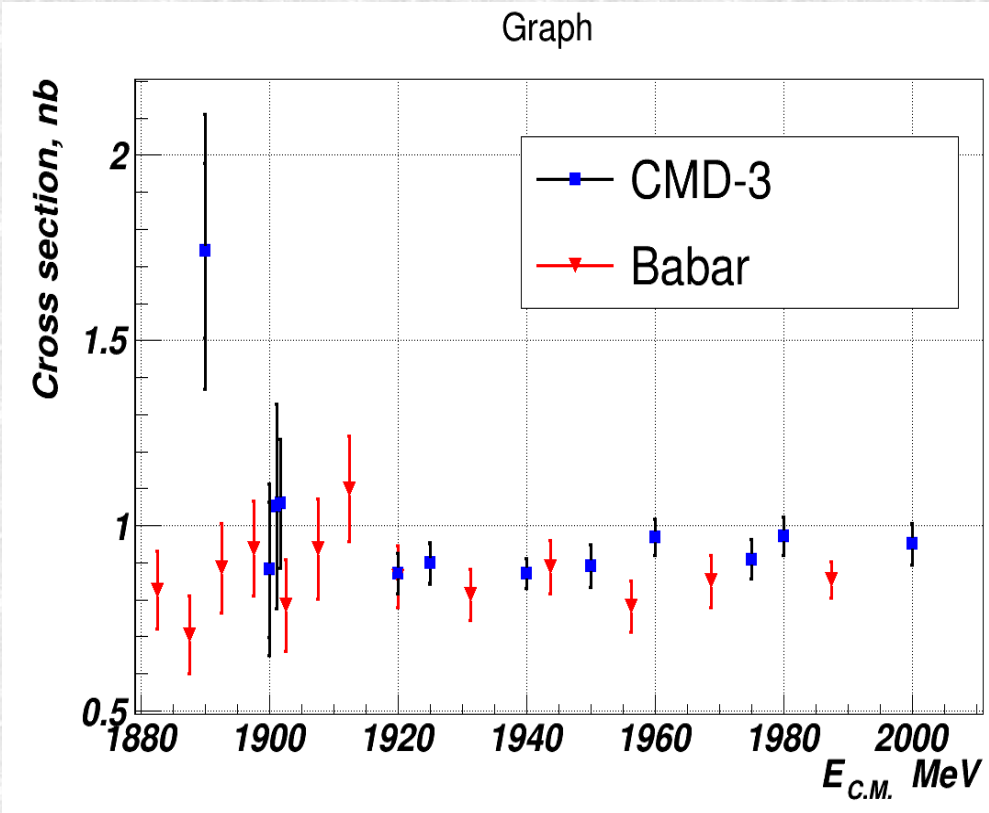
Reconstruction Efficiency ($\boldsymbol{\varepsilon_{ann}}$) of pipe events is E_{cm} independent and can be taken from E_{cm}=1901.6 MeV where we have both type of event

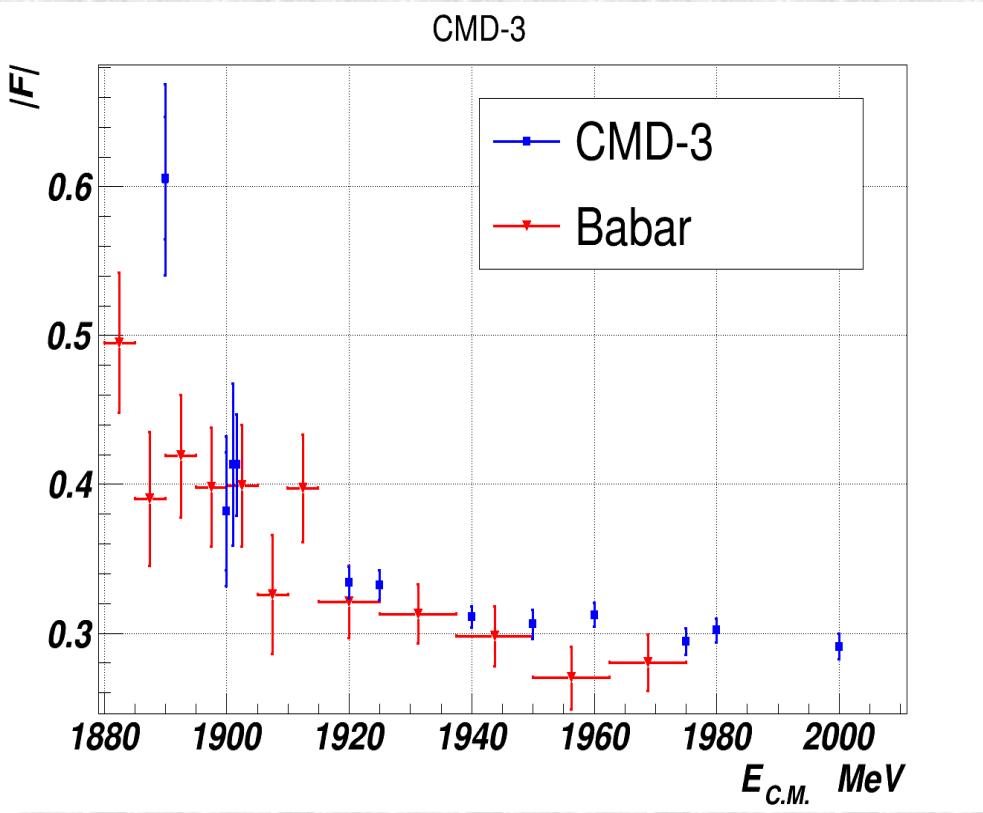
$$\epsilon_{ann}\epsilon_{stopped}=\frac{N_{pipe}(1-\delta)}{L\sigma_{born}}=\frac{N_{pipe}\epsilon_{coll}L(1-\delta)}{N_{coll}L(1-\delta)}=\frac{N_{pipe}\epsilon_{coll}}{N_{coll}}\Rightarrow$$

$$\Rightarrow\epsilon_{ann}=\frac{N_{pipe}\epsilon_{coll}}{N_{coll}\epsilon_{stopped}}=0.13\pm0.02$$

$$\sigma_{born}=\frac{N_{pipe}}{L\epsilon_{ann}\epsilon_{stopped}(1-\delta)}$$

Cross section & Form-factor





Systematic error

for E_{CM} >960 MeV:

5% - accuracy of simulation & Ge/Gm

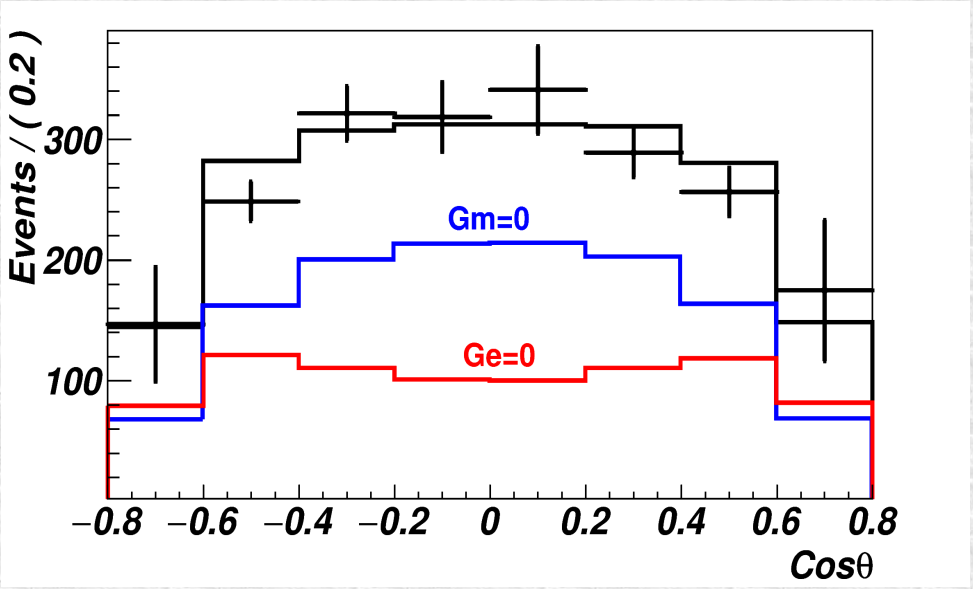
for E_{CM}<960 MeV:

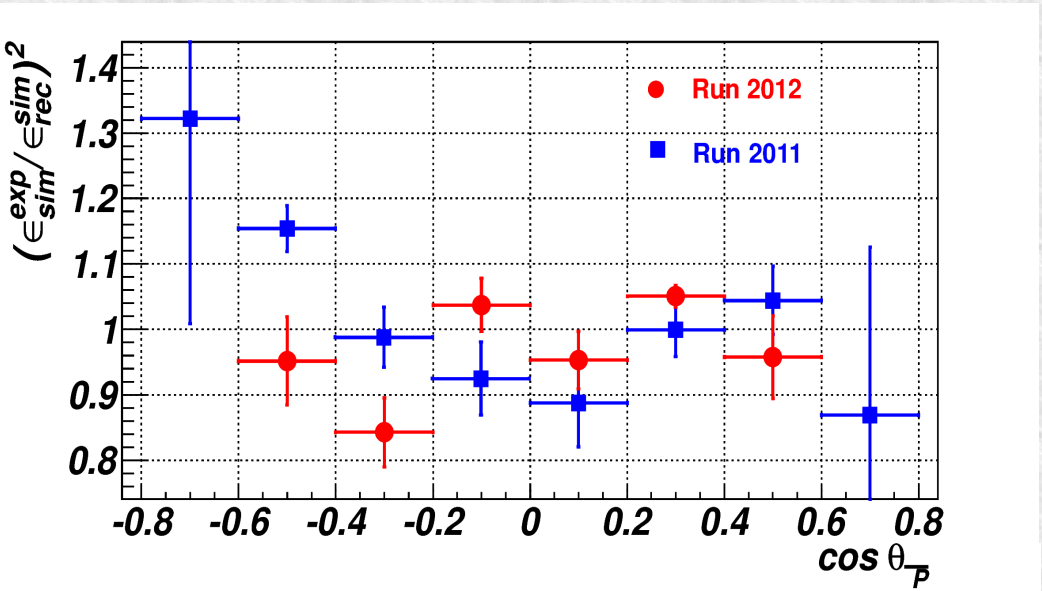
15% - uncertainty in beam energy

20% - Pipe wall thickness and material uncertainty

Ge/Gm

$$\frac{d\sigma}{do} = \frac{\alpha^2 \beta C}{4s}\left[\left|G_M(s)\right|^2 (1+\cos^2\theta) + \frac{4m_N^2}{s}\left|G_E(s)\right|^2 \sin^2\theta\right]$$

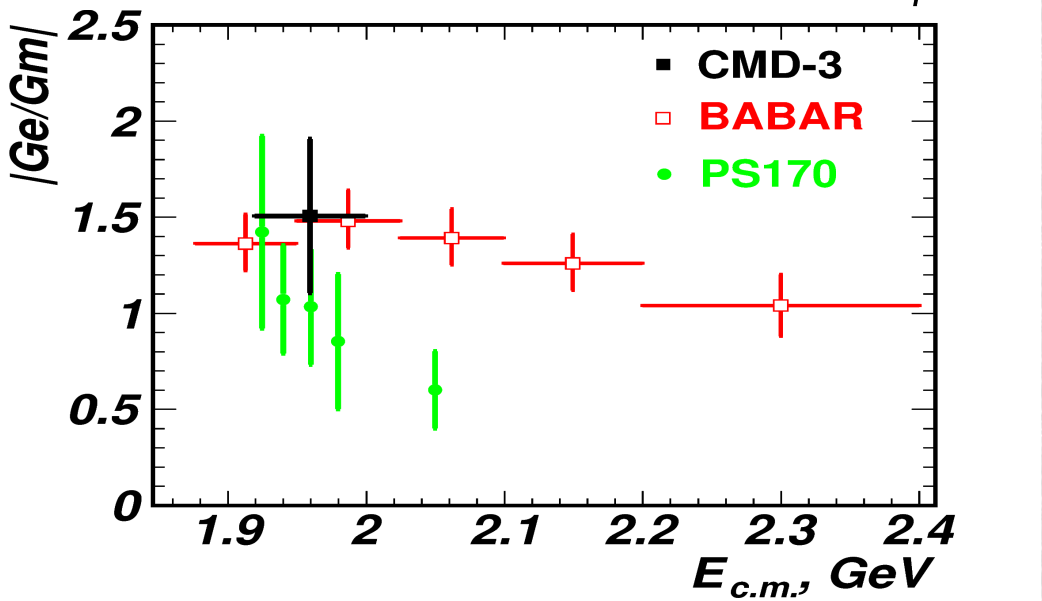




Statistic from all energy points

$$\frac{Ge}{Gm} = 1.49 \pm 0.24 \pm 0.3$$

20% Systematic error define by small angle area



Plans

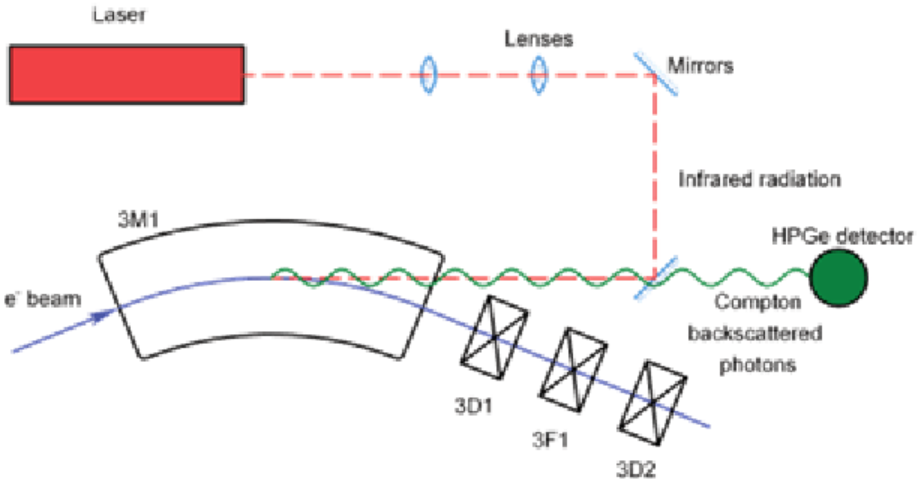
•After upgrade VEPP-2000 collected 50-100 pb^{-1} at the energy range with small step.

•We can measured threshold behaviour of cross section.

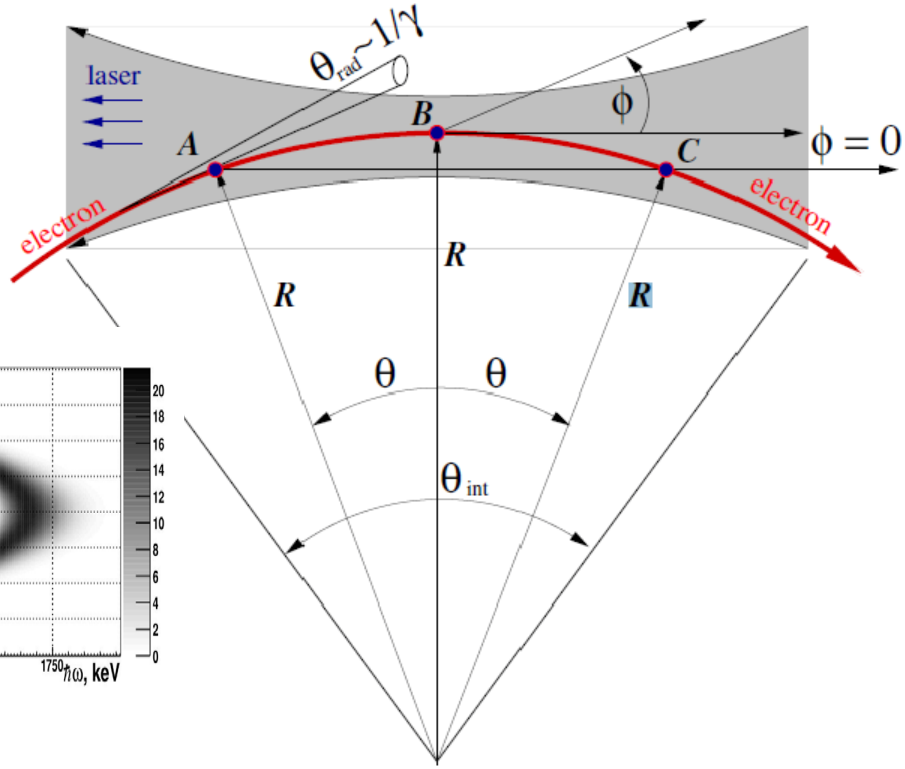
•Higher than 1950 MeV measured energy dependence Ge/Gm

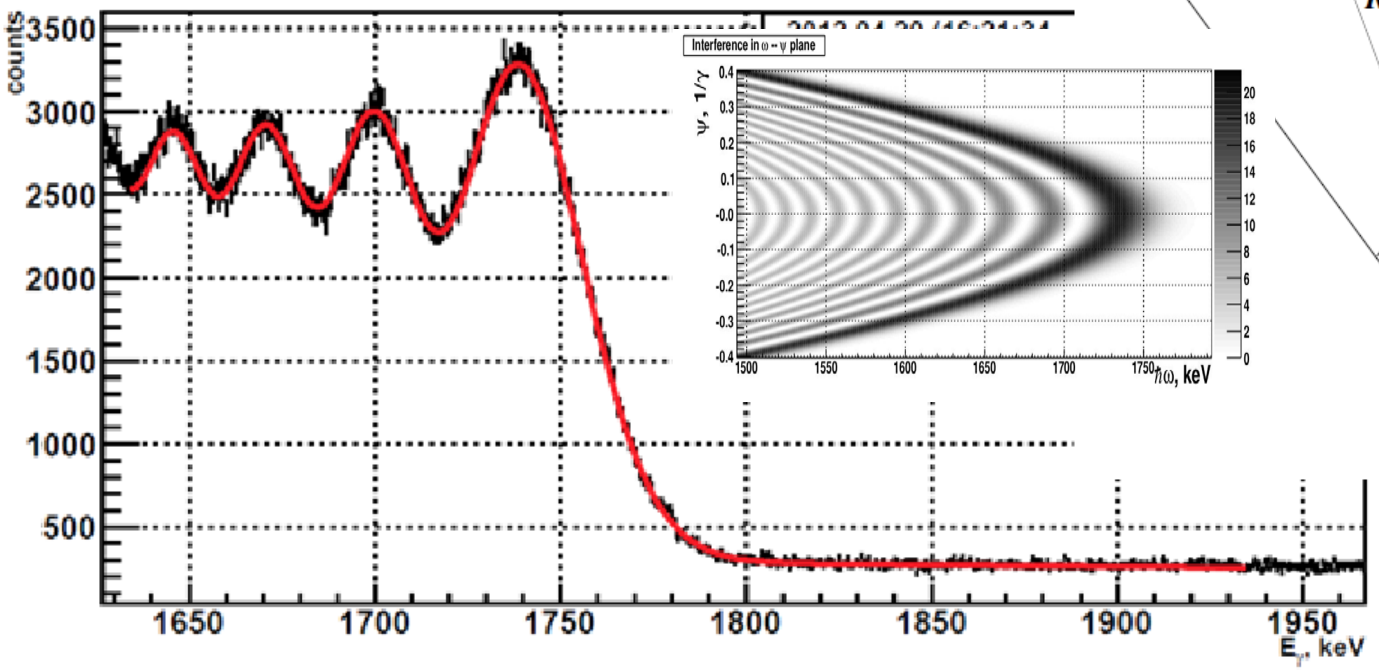
Energy measurement by Compton back scattering

Starting from 2012, energy is monitored continuously using compton backscattering



Излучение из точек A и C под углом φ = 0 интерферирует





E = 993.662 ± 0.016 МэВ

M.N. Achasov et al. arXiv:1211.0103v1 [physics.acc-ph] 1 Nov 2012