BEAM ENERGY MEASUREMENT (BEM)

M-Q. Ruan, G-Y. Tang, J-Y. Zhang

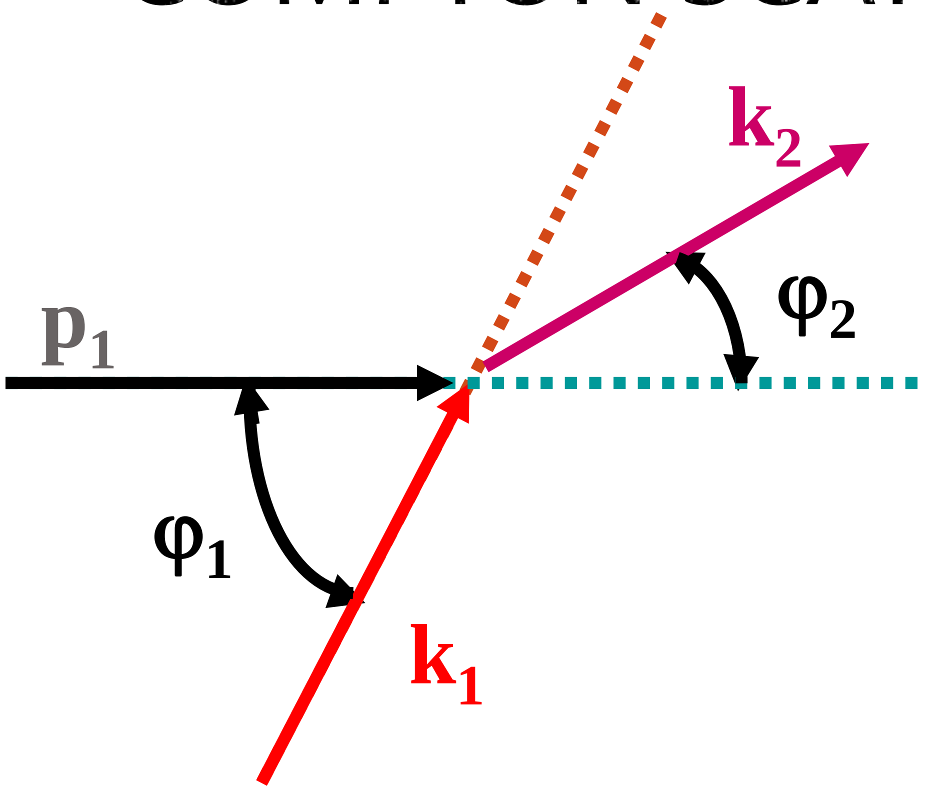
The 3rd CEPC P&S Meeting

OUTLINE

Focus on Compton scattering method.

- ~~Motivation~~
- BEM@BEPC-II
- Pre…pre CDR of BEM@CEPC

COMPTON SCATTERING



In terms of relativistic invariant

$$s = -(p_1 + k_1)^2 = -(p_2 + k_2)^2$$
$$t = -(p_1 - p_2)^2 = -(k_1 - k_2)^2$$
$$u = -(p_1 - k_2)^2 = -(p_1 - k_1)^2$$

In laboratory system

$$s = m^2 + 2\gamma m\, \omega_1 (1 - \beta \cos \varphi_1)$$
$$t = -2\, \omega_1\, \omega_2 (1 - \cos[\varphi_1 - \varphi_2])$$
$$u = m^2 - 2\gamma m\, \omega_2 (1 - \beta \cos \varphi_2)$$

$$\omega_2 = \frac{\omega_1 (1 - \beta \cos \varphi_1)}{1 - \beta \cos \varphi_2 + \frac{\omega_1}{\gamma m}(1 - \cos[\varphi_1 - \varphi_2])}$$

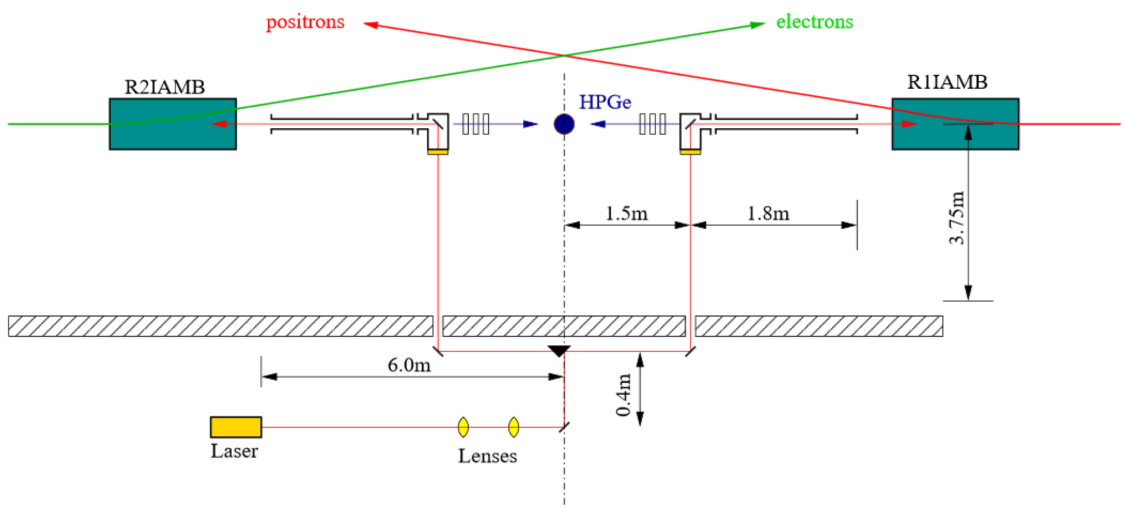
$$\beta = p_1 / E_1$$
$$\gamma = E_1 / m_e$$

Novel Radiation Sources Using Relativistic Electrons *(by P.Rullhusen, X.Artru, P.Dhez)*

BEM@BEPC-II

Nuclear Inst. and Methods in Physics Research, A 659 (2011)

- Compton Back-scattering: (head-to-head collision)
  - $E_{beam} = \frac{\omega_{max}}{2}\sqrt{1 + \frac{m_e^2}{\omega_0\omega_{max}}}$
- Hardware: locate at north IP of BEPC-II
  - Laser and optical system.
  - High purity germanium detector: 16384 channels.
  - Pulse generator and isotopes.
  - Data acquisition system.



BEM@BEPC-II

Nuclear Inst. and Methods in Physics Research, A 659 (2011)

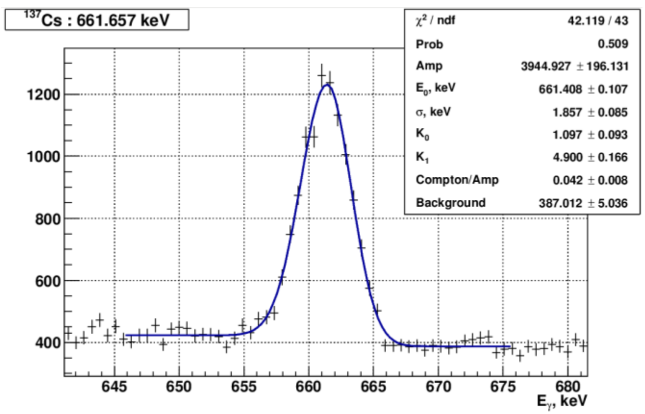
- Online procedure:

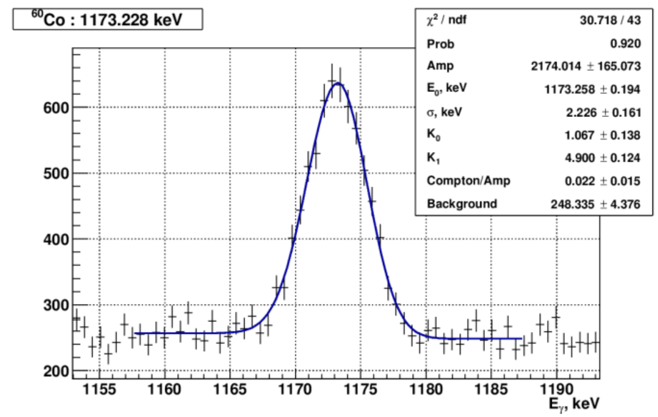
1. Obtain photon spectrum in tens of minutes. Sum sequential photon spectrums (or not).
2. Find and identify peak one by one
3. Fit calibration lines by a response function.
4. Determine the energy dependencies of response function parameters, including the dector resolution.
5. Fit the edge position.
6. Evaluate beam energy and spread.

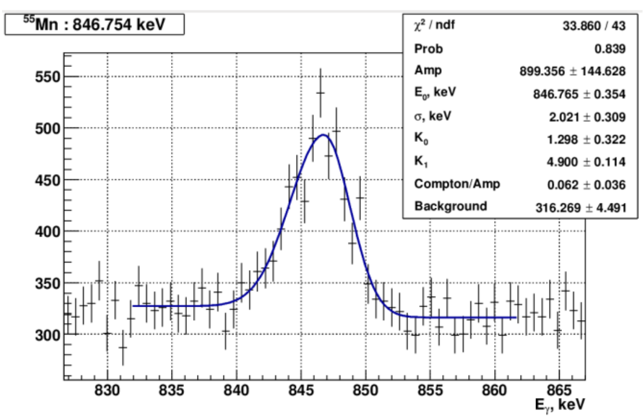
BEM@BEPC-II

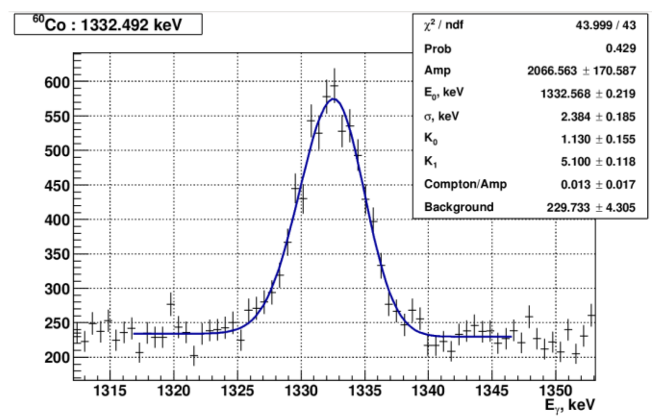
$$f(x) = A \cdot \begin{cases} exp[-\frac{(x-x_0)^2}{2\sigma^2}], & 0 < x - x_0 < +\infty, \\ C + (1-C)exp[-\frac{(x-x_0)^2}{2(K_0\sigma)^2}], & -K_0K_1\sigma < x - x_0 \le 0, \\ C + (1-C)exp[K_1(\frac{(x-x_0)}{(K_0\sigma)} + \frac{K_1}{2})], & -\infty < x - x_0 \le -K_0K_1\sigma, \end{cases}$$

- Isotopes:
  - Cs137: 661.657keV; Co60: 1173.228keV and 1332.492keV; Mn55: 846.754keV.









BEM@BEPC-II

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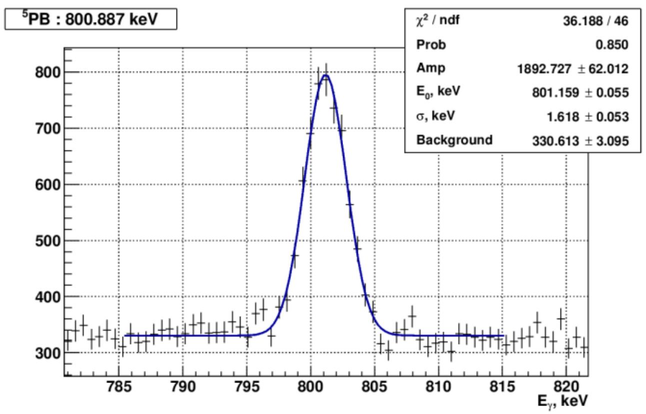
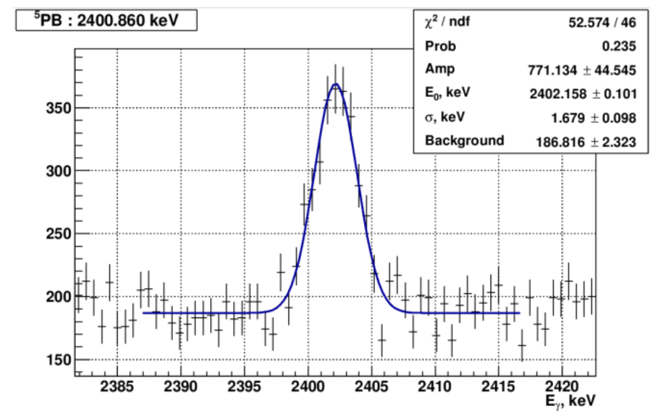
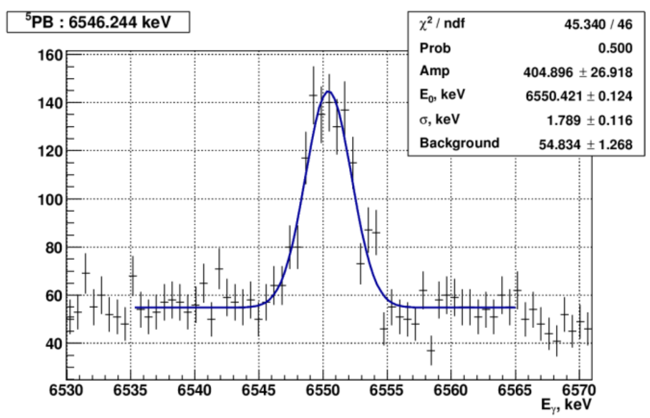
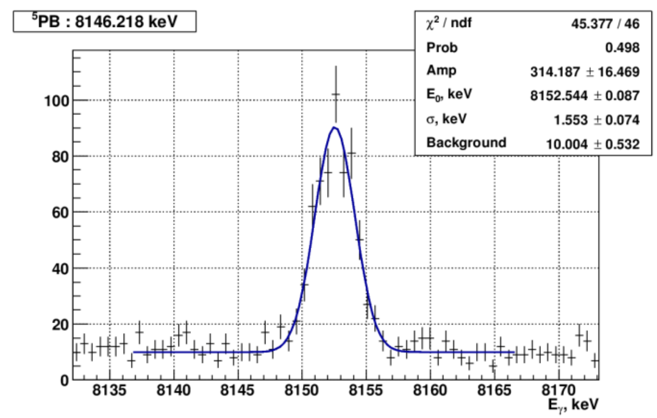
- Pulsers:
  - linear response: $peak\ position = zero\ point + gain \times voltage$



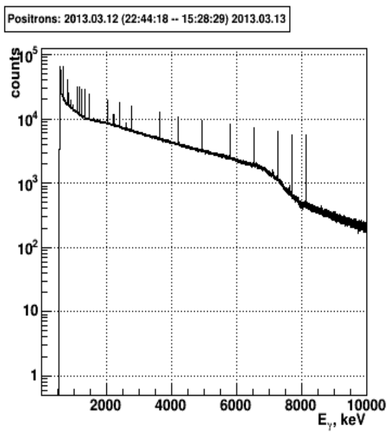


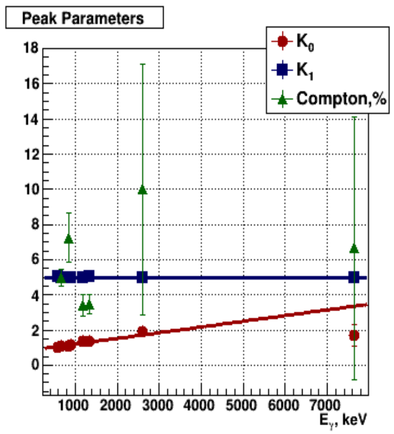


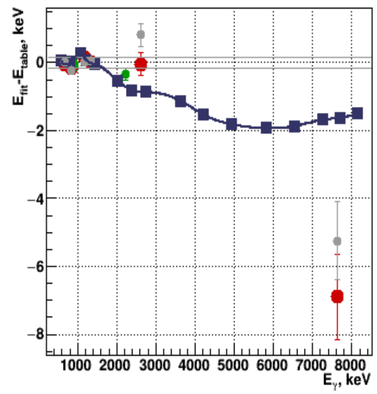


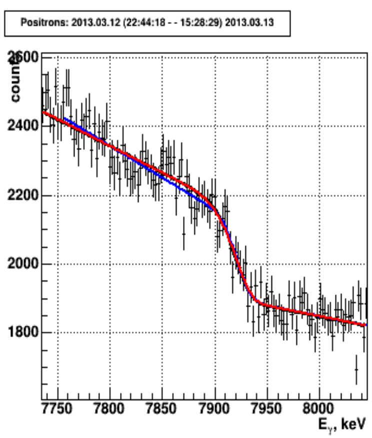
BEM@BEPC-II

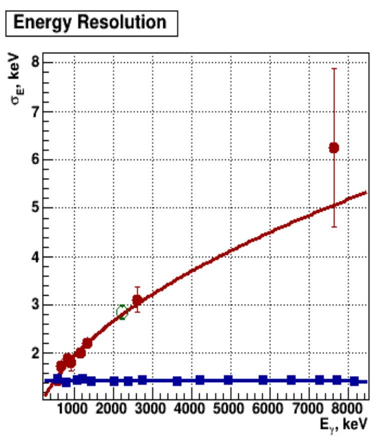
- Online procedure:
  - Nucl.Instrum.Meth. A659 (2011) 21-29











Zero = 1.44316 keV

Gain = 0.61183 keV/Ch

"Fano" = 1.117 ± 0.079

"Noise" = 0.670 ± 0.007 keV

W_{max} = 7928.358 ± 1.969 keV

$\sigma_{W_{max}}$ = 7.35 ± 2.49 keV

E_{beam} = 2130.821 ± 0.265 MeV

$\sigma_{E_{beam}}$ = 987.3 ± 334.0 keV

time from: 22:44:18 / 2013.03.12

time upto: 15:28:29 / 2013.03.13

HPGe dector
- Photon spectrum during scores of minutes

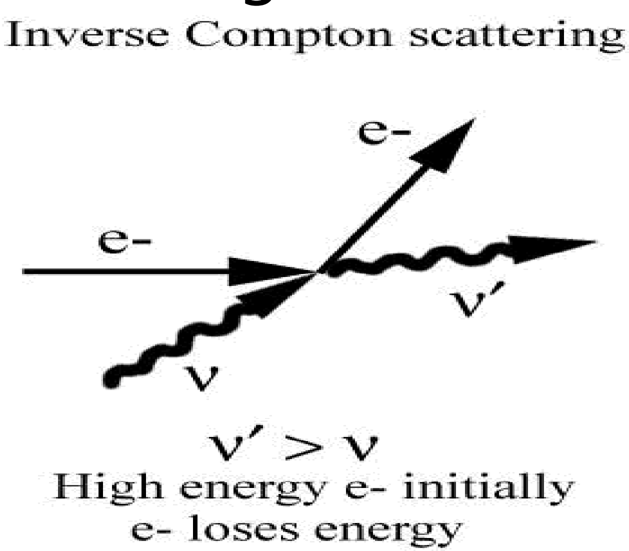
Peak searching
- Co60, Cs137, Mn55….
- Pulse generator

Peak fitting
- calibration and resolution of the System

Edge fitting

PRE…PRE CDR OF BEM@CEPC

- If we do the same thing as @BEPC-II
  - 120GeV(beam) + 0.11eV(CO2 laser)→20GeV (scattering photon). Too large to be measured precisely.
- Measure lepton position after scattering;
  - Head to head collision.
- Measure photon energy after scattering;
  - Change Xangle.



MEASURE LEPTON

- Simple simulation is ongoing.
  - Beam energy spread: 0.16%.
  - Bunch size: x~70μm,
    y~0.16μm.
  - Distance: 100m.
- Suitable fitting function should be determined from simulation.
- New simulation based on MadX will be done if necessary.
  - Uncertainty of B field.

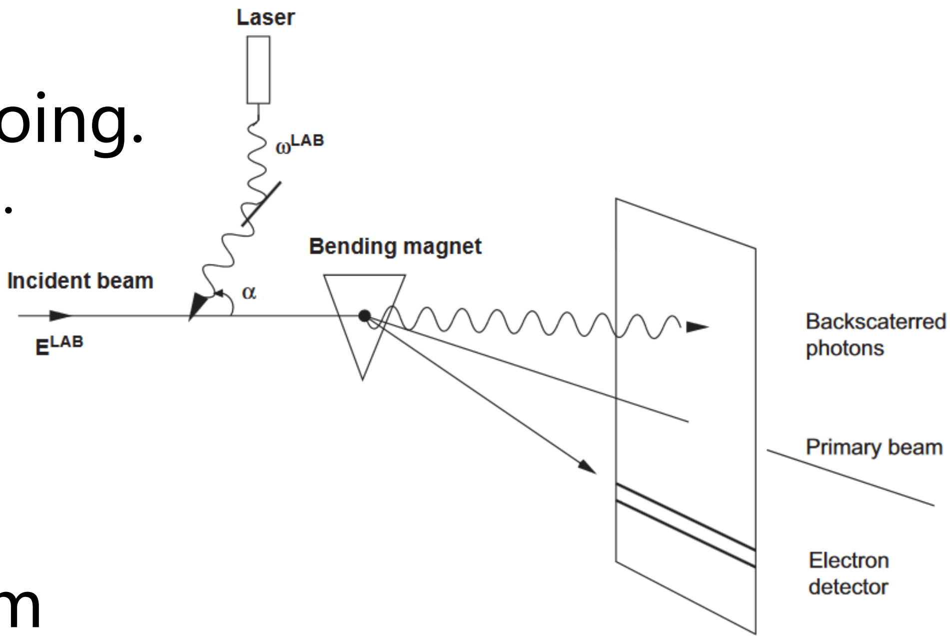


Fig. 8. Scheme of the proposed energy spectrometer based on Compton backscattering.

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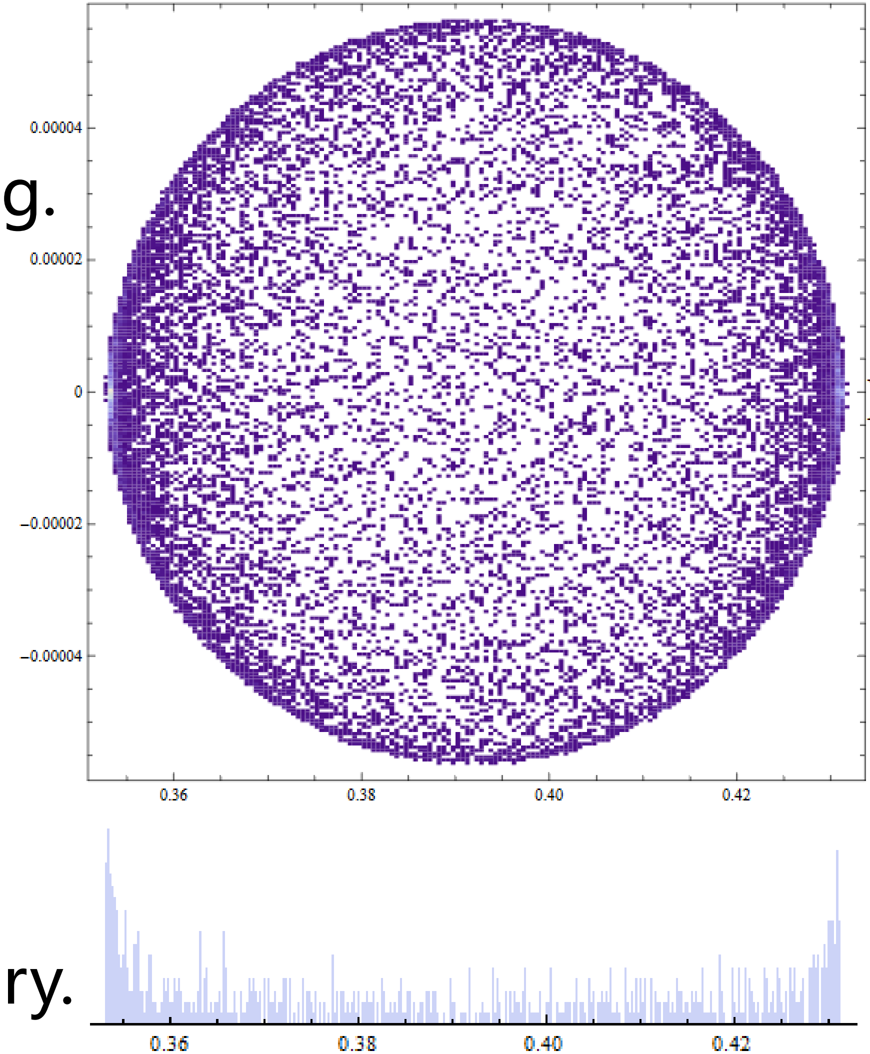

Unit: m

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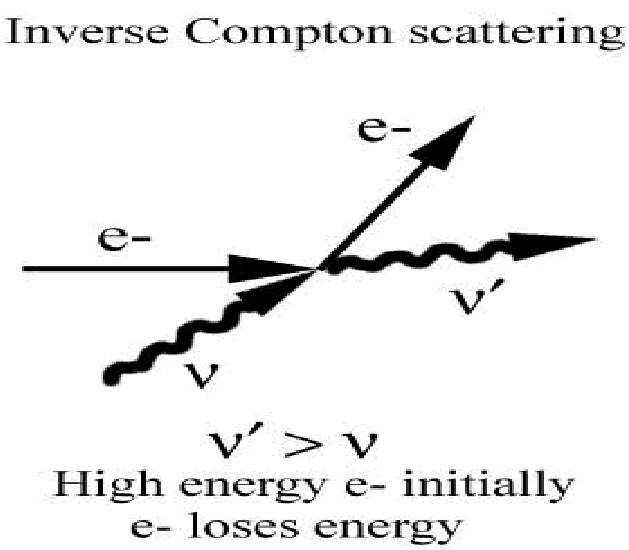
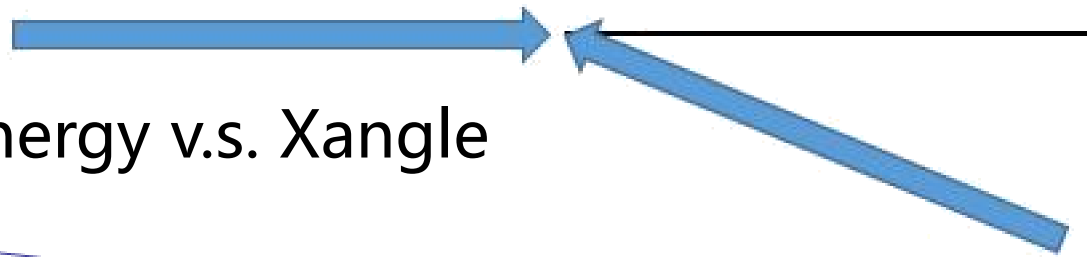
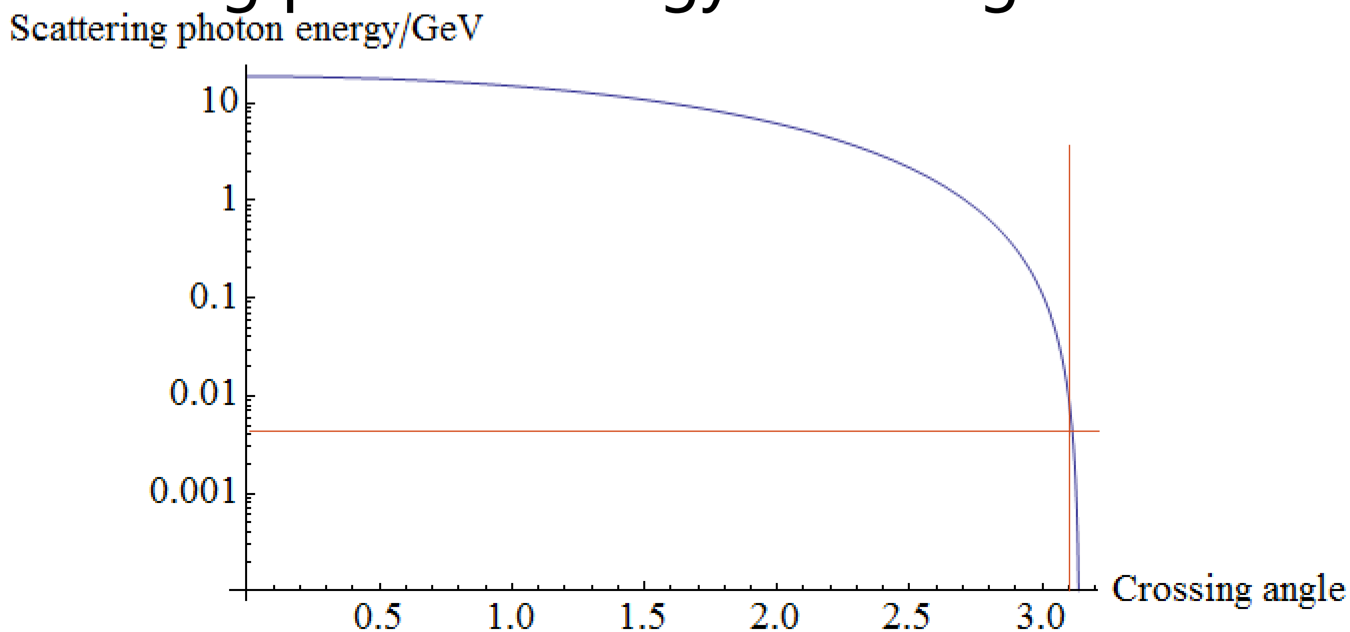


CHANGE CROSSING ANGLE

- Crossing angle $[0, \pi]$



- Scattering photon energy v.s. Xangle



  - When Xangle is 3.12 rad, maximum scattering photon energy is 2.815 MeV.
  - Tl208: 2.614MeV.

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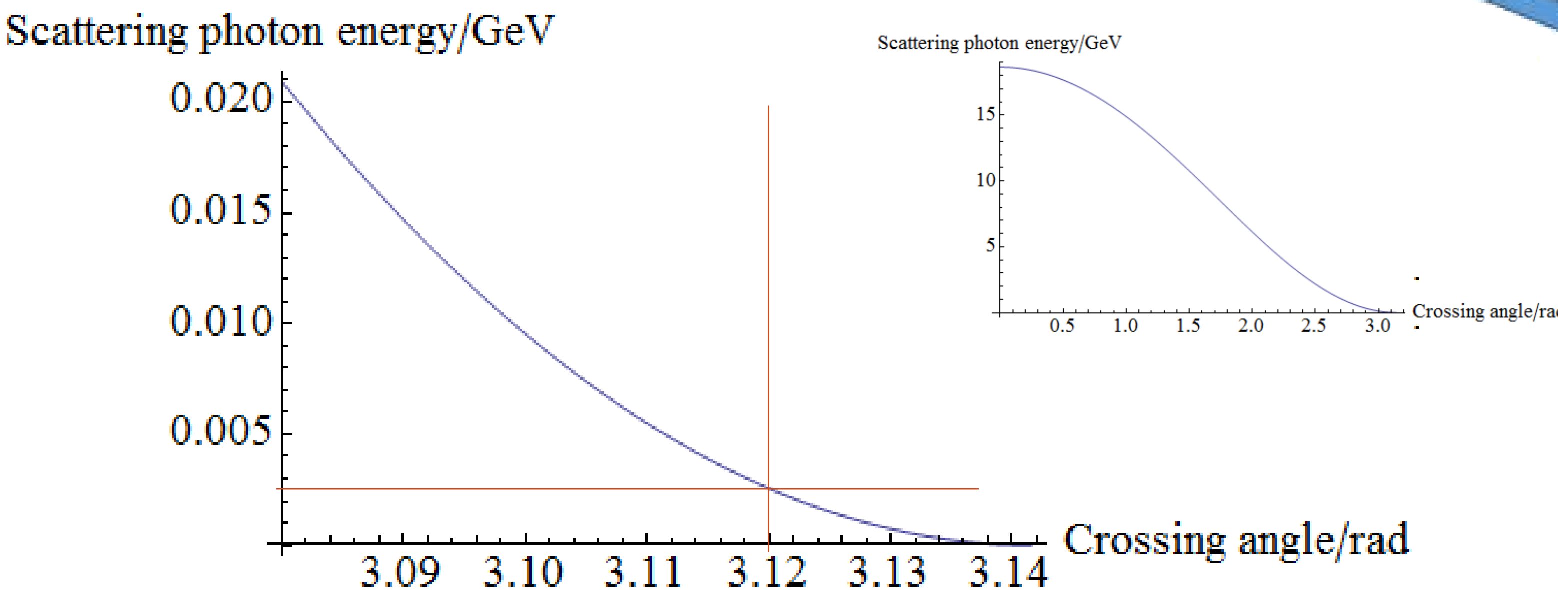

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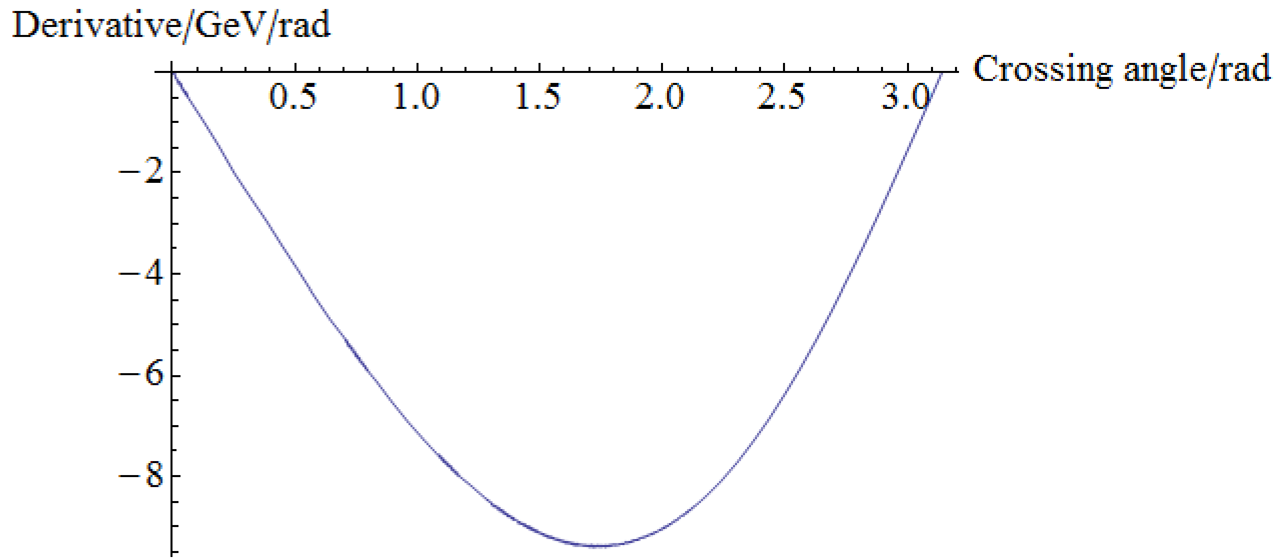
CHANGE CROSSING ANGLE

- Uncertainty estimation:
  - Derivative v.s. Xangle



- If 10^{-5} relative uncertainty of beam energy is required, the uncertainty of Xangle should be $10^{-4} \sim 10^{-5}$ radian.

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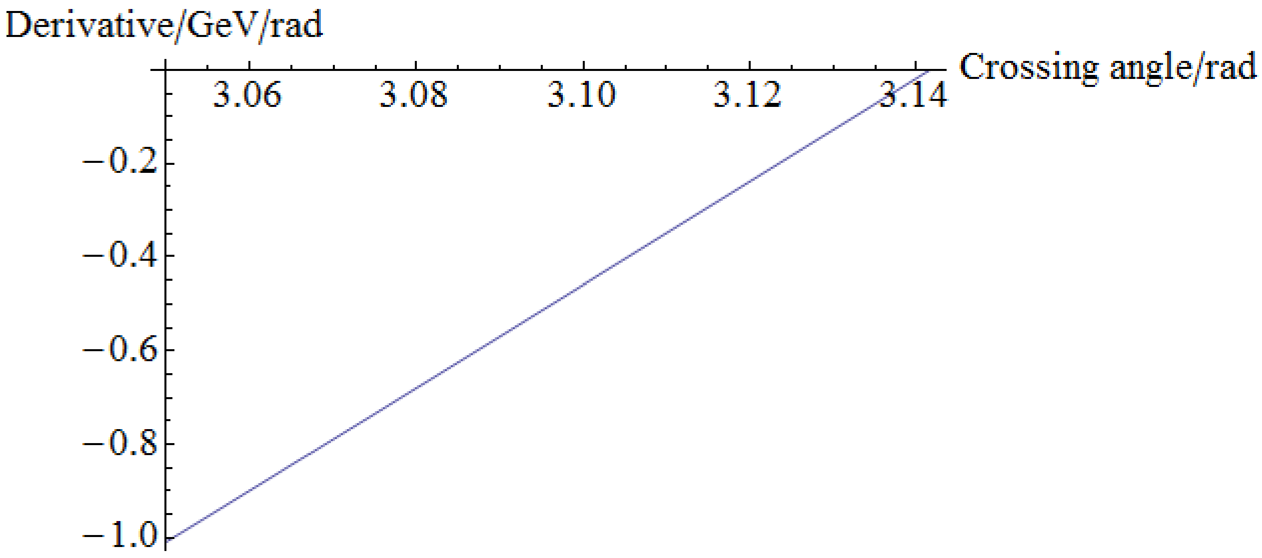

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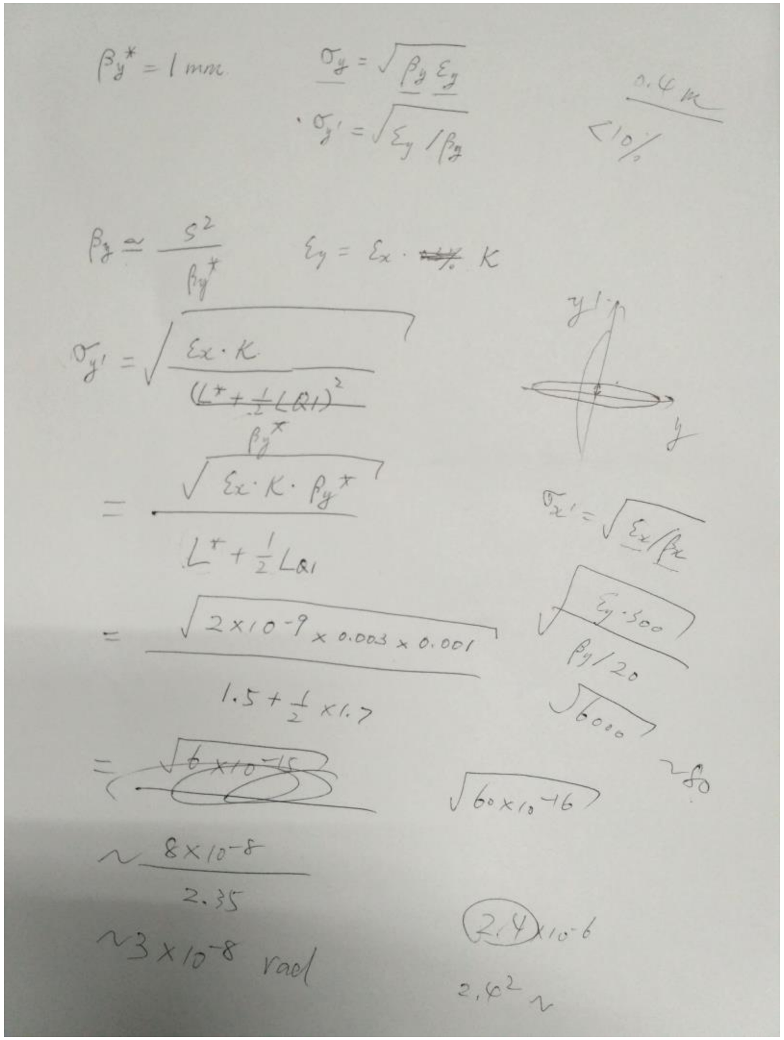
CHANGE CROSSING ANGLE

- Minimum: $\sigma_{py} \sim 3 \times 10^{-8}$rad,

  $\sigma_{px} \sim 2.4 \times 10^{-6}$rad.

σ_{py}, σ_{px} mean the py, px momentum emittance.

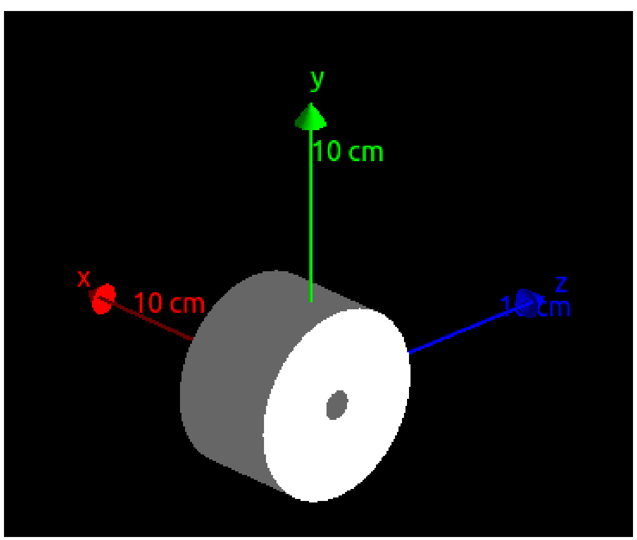
- Meet the requirement (10^{-5} rad).
- More details (including MC simulation) will be given after discussing with accelerator people.

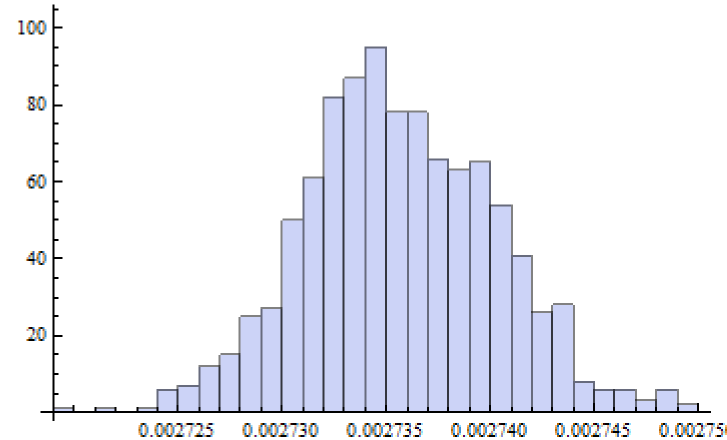


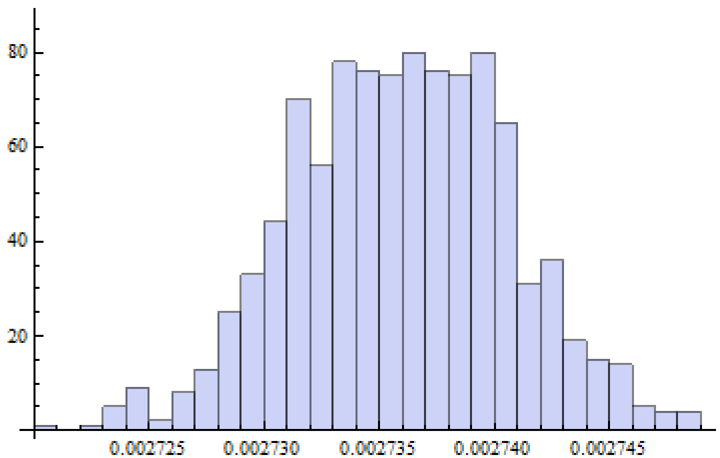
Thanks to Jianwei's discussion.

CHANGE CROSSING ANGLE

- Toy MC is done. (1000 events with different acceptance)
- Momentum emittance, energy spread and acceptance of HPGe detector are considered.
- Geant4 Model of Ge.

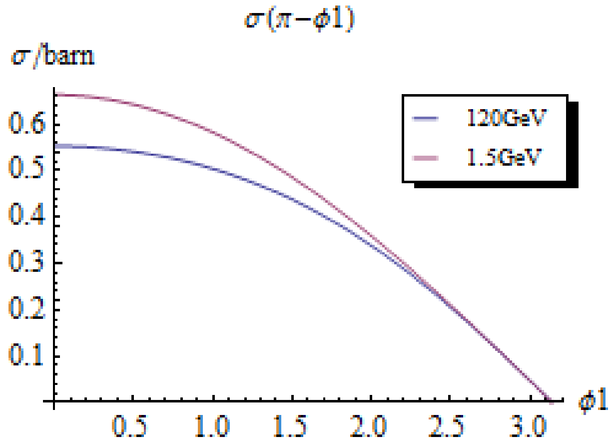


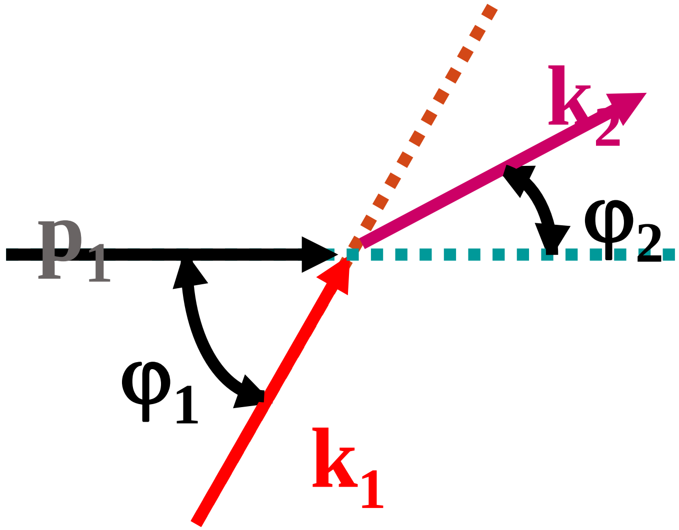


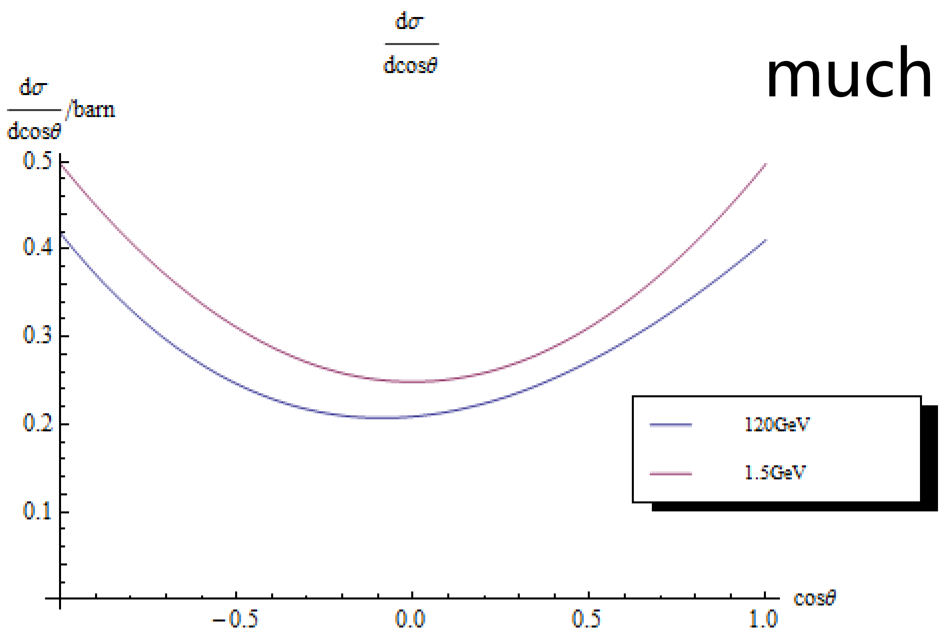


ESTIMATION OF EVENT RATE

- Head-to-head collision:



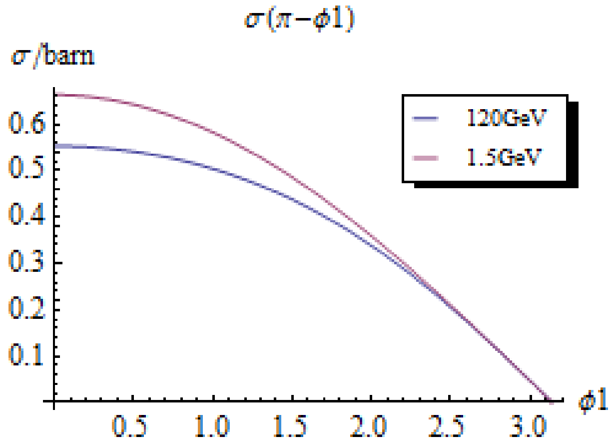


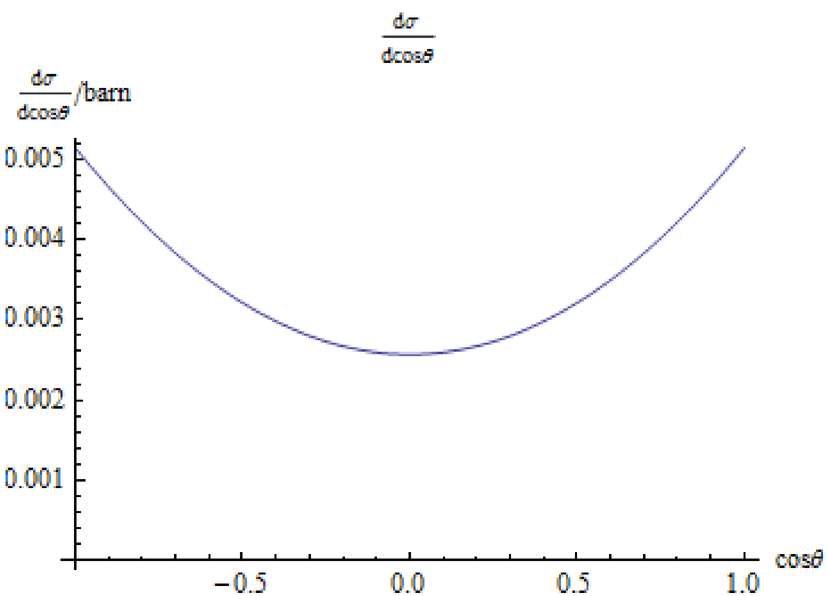


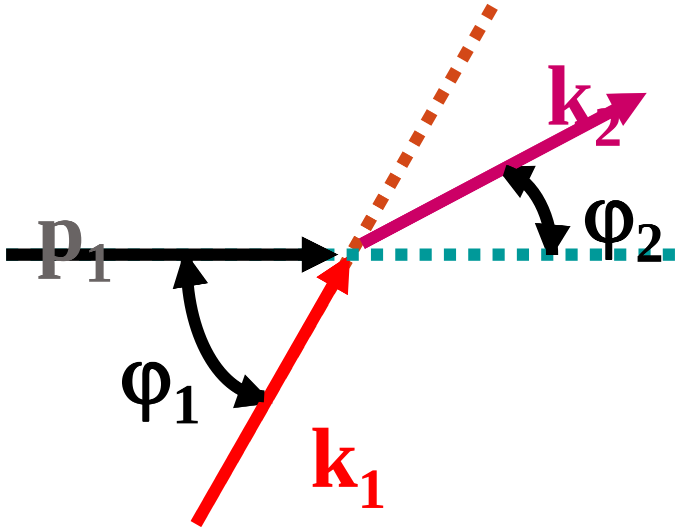
Event rate should be as much as @BEPC-II.

ESTIMATION OF EVENT RATE

- Xangle~3.12 collision:



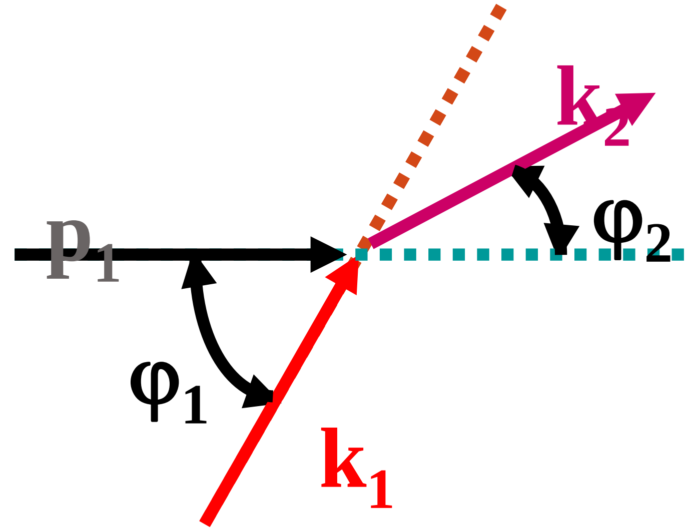




$$\frac{\frac{d\sigma}{dcos\theta}|_{120GeV}}{\frac{d\sigma}{dcos\theta}|_{1.5GeV}} \sim \frac{1}{100}$$

120GeV

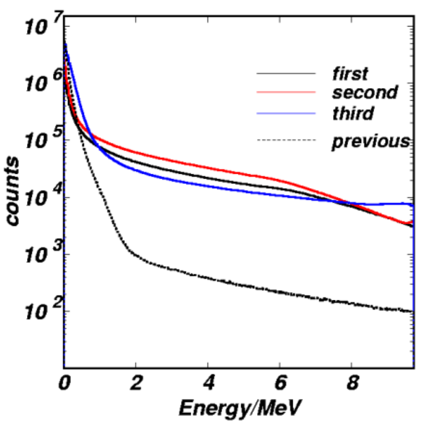
ESTIMATION OF EVENT RATE



- Xangle~3.12 collision:
  - Event number:
    $$N = \sigma_T \cdot \iiint \rho_i \cdot \rho_e \, dxdydz$$
  - BEPC-II~5× 10^{32}; CEPC~ 200× 10^{32}
  - $\frac{\rho_{e_{cepc}}}{\rho_{e\_bepcII}} \sim 6$
  - $\frac{Event\ rate\ @CEPC}{Event\ rate\ @BEPC-II} = \frac{1}{17}$. (How to Increase laser power?)

SUMMARY: BEM @ CEPC

- Measure lepton position after scattering;
  - New Simulation with MadX to take B field fluctuation into account.
- Measure photon energy after scattering.
  - Check all calculation.
  - MC simulation.
  - Background (synchrotron radiation, etc.)? Signal-to-noise ratio?



Thank you!