Comparison Phokara and Connexc for TL proton FF measurement

(based on BESIII e+e- scan data at 2.0~3.08 GeV)

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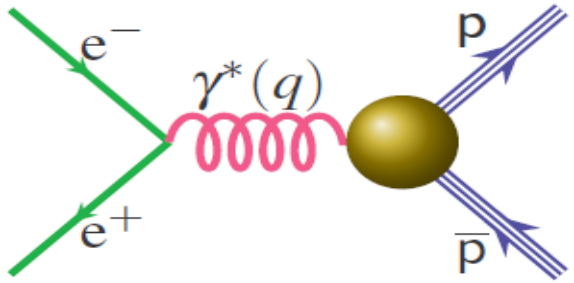
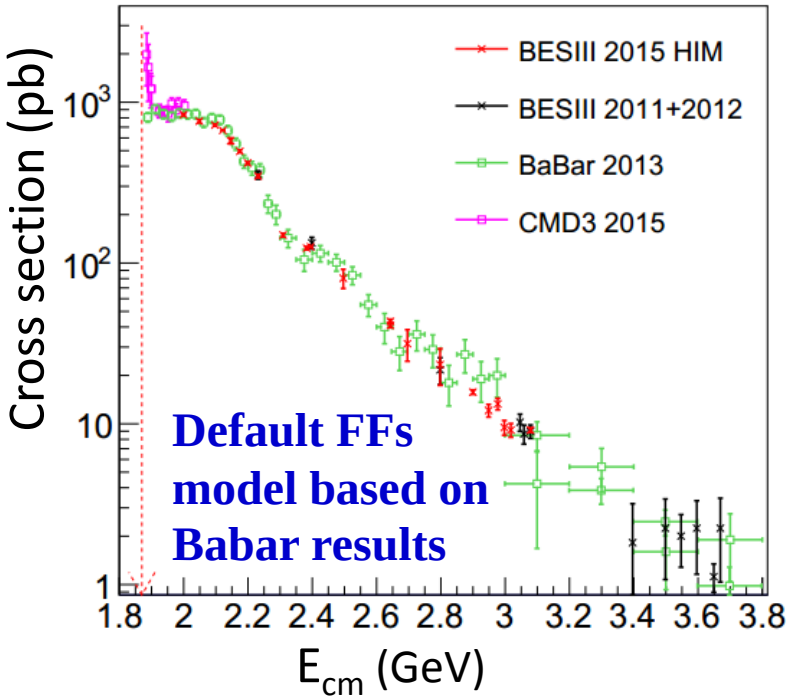
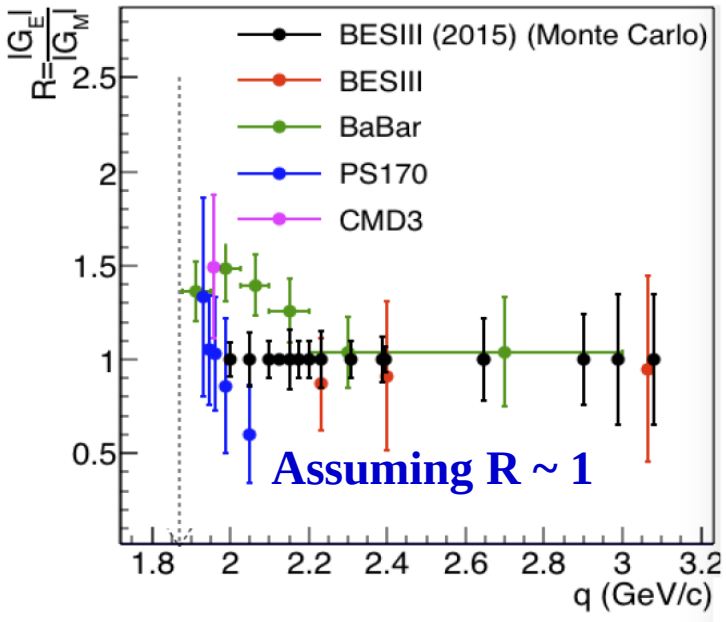
Introduction

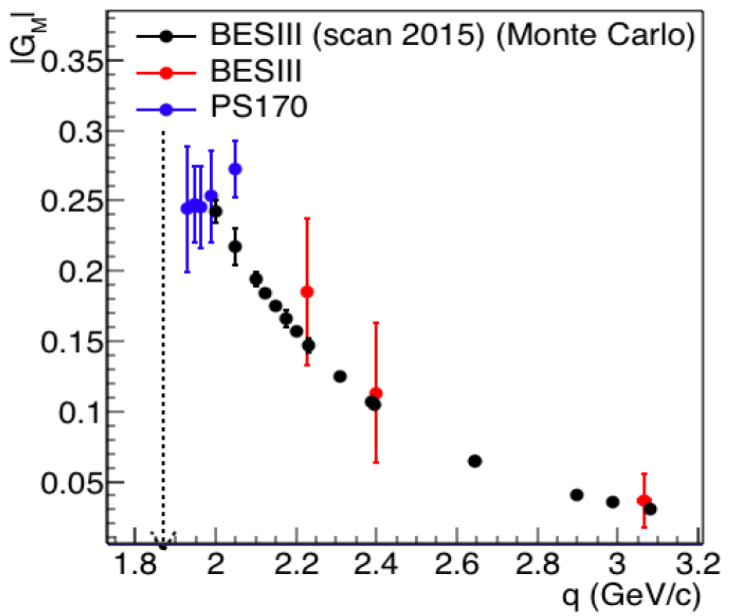
Born process



current experimental result and prediction







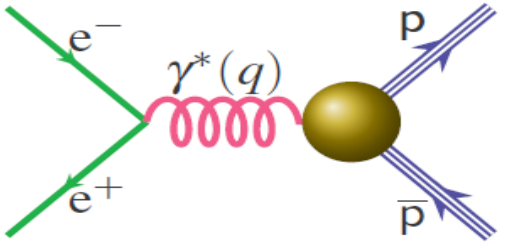
'2015 HIM' based on simulation with Phokhara v9.1 [arXiv: 1407.7995v2].

1. **for σ, unprecedented accuracies above 2.0 GeV: 0.5% @ 2.125 GeV; 26% @ 2.8 GeV**
2. **for R ~ 9% - 35%, comparable as space-like region**
3. **for G_M ~ 1% ~ 9%, for G_E 3% ~ 35% (unprecedent!)**
4. possible extraction of the forward-backward asymmetry (2γ– contribution,…), periodic structure of TL FFs?

We need a good generator with high precision!

Brief introduction of PHOKHARA (v9.1) and ConExc (BesEvtGen-00-03-69)

- Both ConExc and PHOKHARA can satisfy our requirement of proton FFs measurement in $e^+e^- \to p\bar{p}$.
- common:
  - event generators for exclusive processes
  - NLO for $e^+e^- \to p\bar{p}$
  - Vacuum polarization
  - Both precision are high ~1% ?



- differences between:

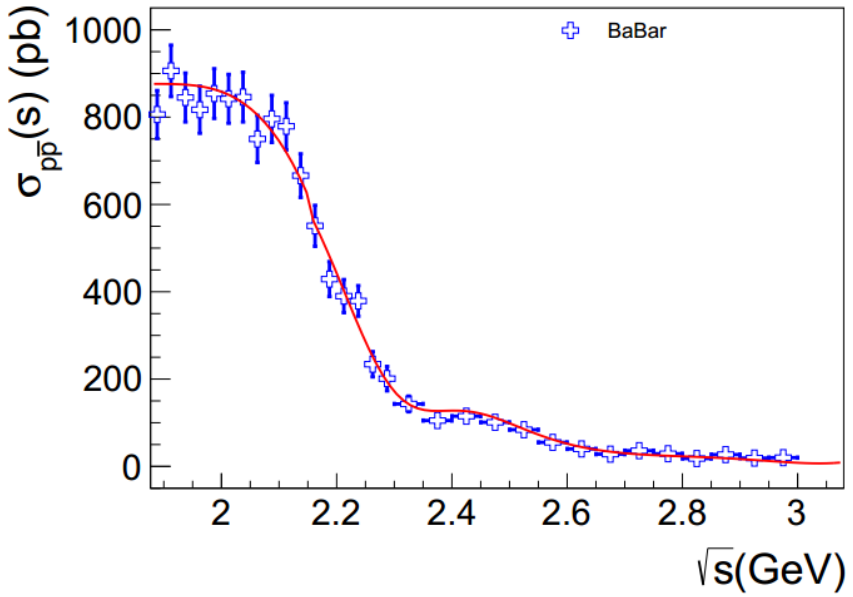
	ConExc	PHOKHARA
Modes	68	10
Coulomb effect	By inputting σ*C	Implemented in the model
Initial state radiation	NLO with one method	NLO with another method
Vacuum plorization	Fred Jegerlehner	Fred Jegerlehner or Thomas Teubner
Final state radiation	By PHOTOS package	no
$\sigma_{Born+NLO}$	Calculated directly by formula	Calculated with generated events
Photons generated	Only one	One or two

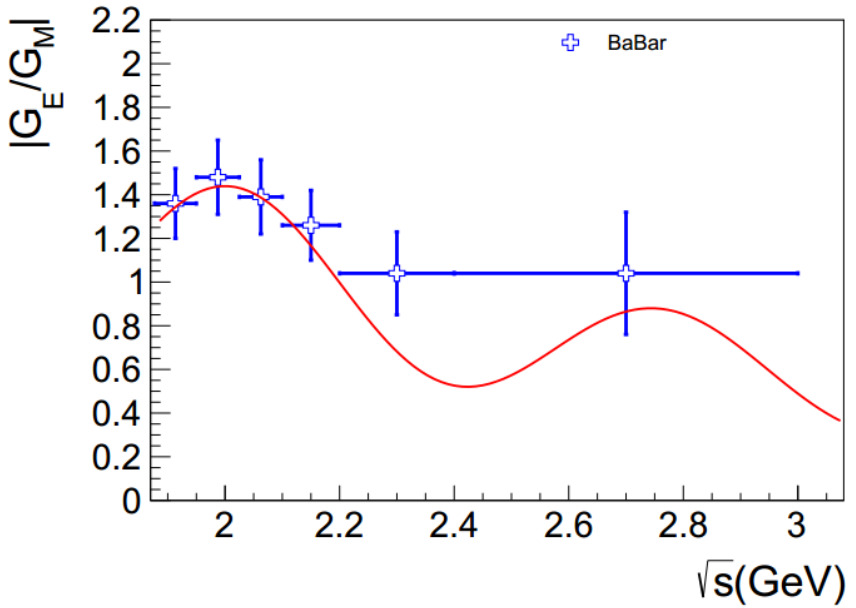
The same input Born σ and $R = |G_E|/|G_M|$

input model

$$\sigma_{p\bar{p}}(s) = \begin{cases} \dfrac{a_0\pi^2\alpha^3}{s(1-e^{-\frac{-\pi\alpha_s(s)}{\beta(s)}})(1+(\frac{\sqrt{s}-2m_p}{a_1})^{a_2})} + a_3, \sqrt{s} \le 2.15\,GeV \\ \sum_{i=4}^{10} a_i(\sqrt{s})^{i-4} + \dfrac{a_{11}}{\sqrt{2\pi}a_{12}} e^{-\frac{(\sqrt{s}-a_{13})^2}{2a_{12}^2}}, \sqrt{s} > 2.15\,GeV \end{cases}$$

$$|(G_E/G_M)(s)| = \frac{1}{b_8} e^{b_0+b_1\sqrt{s}}(b_2 + b_3\cos(b_4 + b_5\sqrt{s}))(1+\frac{s}{b_6})(1+\frac{s}{b_7})^2$$

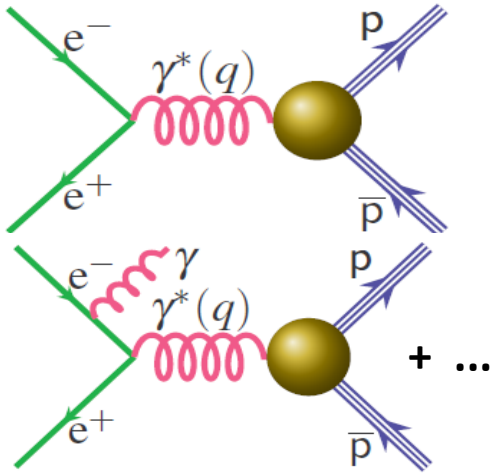




Why input Born σ & $R = \frac{|G_E|}{|G_M|}$ or $|G_E|$ & $|G_M|$?

Born:

NLO: + ...



1. Born cross section

$$\sigma_{B\bar{B}}^{Born}(q^2) = \frac{4\pi\alpha^2\beta C}{3q^2}\left[|G_M(q^2)|^2 + \frac{1}{2\tau}|G_E(q^2)|\right]$$

2. Separation of $|G_E|$ and $|G_M|$ (or $R = \frac{|G_E|}{|G_M|}$) through angular analysis:

$$\frac{d\sigma_{B\bar{B}}^{Born}}{d\Omega_{CM}} = \frac{\alpha^2\beta C}{4q^2}\left[(1+\cos^2\theta_B^{CM})|G_M|^2 + \frac{1}{\tau}|G_E|^2\sin^2\theta_B^{CM}\right] \qquad \tau = \frac{q^2}{4M_B^2}, \beta = \sqrt{1-1/\tau},$$

In experiment:

1. $\sigma_{Born}^{exp} = \frac{N_{obs}}{L\cdot\varepsilon\cdot(1+\delta)}$ and $\frac{dN}{\epsilon(1+\delta)\times d\cos\theta_p} = \frac{L\hbar c\pi\alpha^2\beta C}{2s}|G_M|^2\left[(1+\cos^2\theta_p) + \frac{1}{\tau}\frac{|G_E|^2}{|G_M|^2}\sin^2\theta\right]$

2. $(1+\delta) = \frac{\sigma_{Born+NLO}^{theory}}{\sigma_{Born}^{theory}}$ is the radiative correction factor; ε is the selection efficiency; ε(1+δ) should be similar at different energy points.

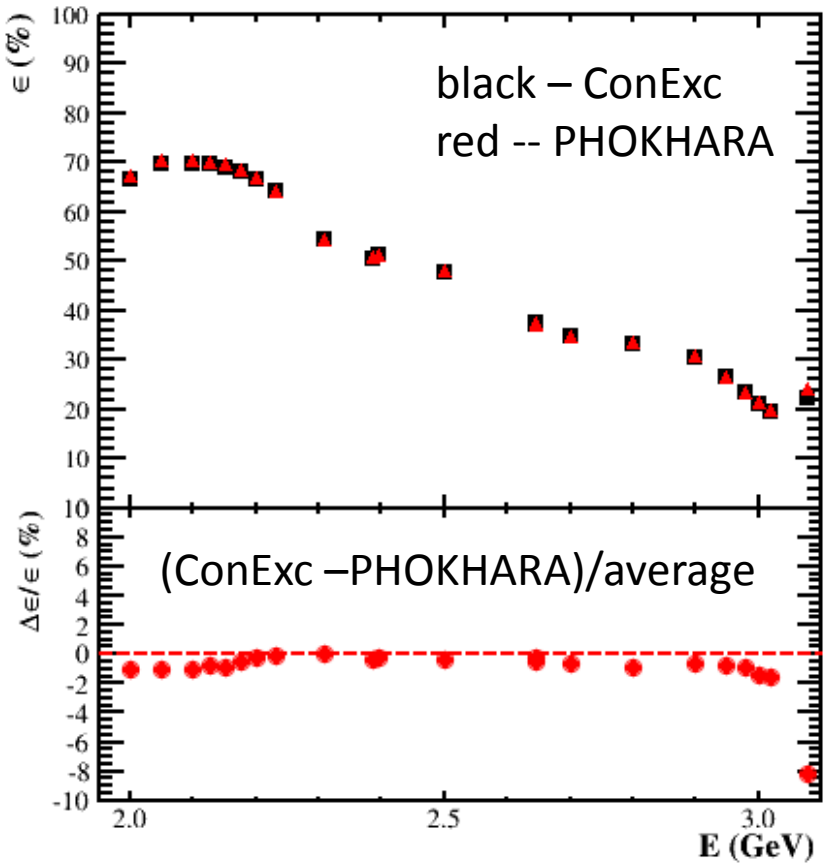
Output from ConExc (BesEvtGen-00-00-69) and PHOKHARA (v9.1) (Born+NLO)

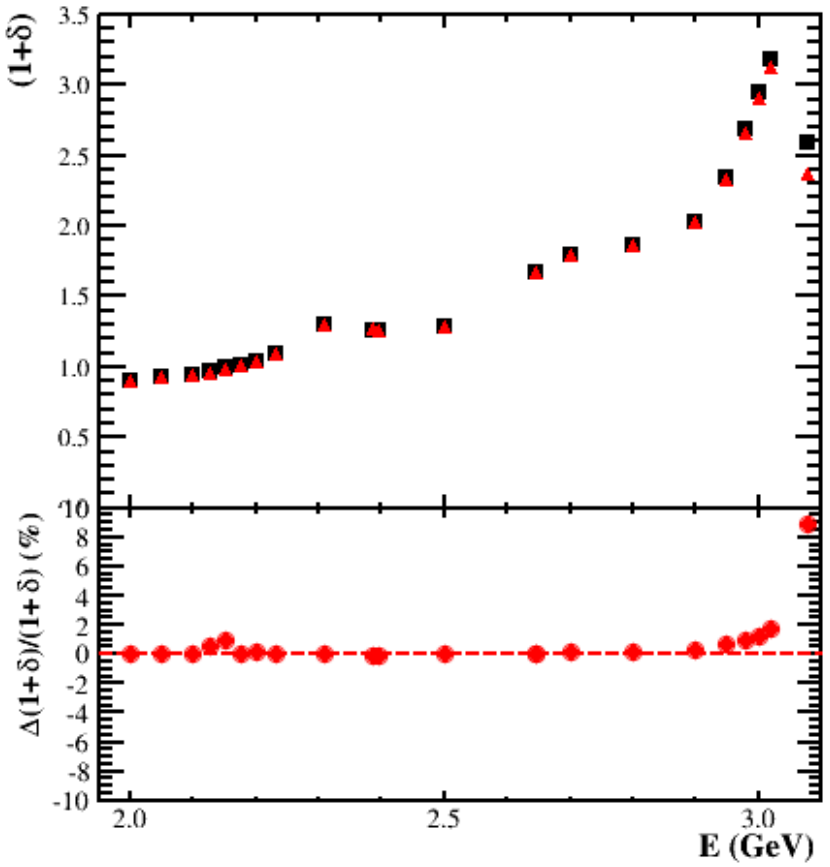
Similar results obtained except at high energies, ie. 3.08 GeV.

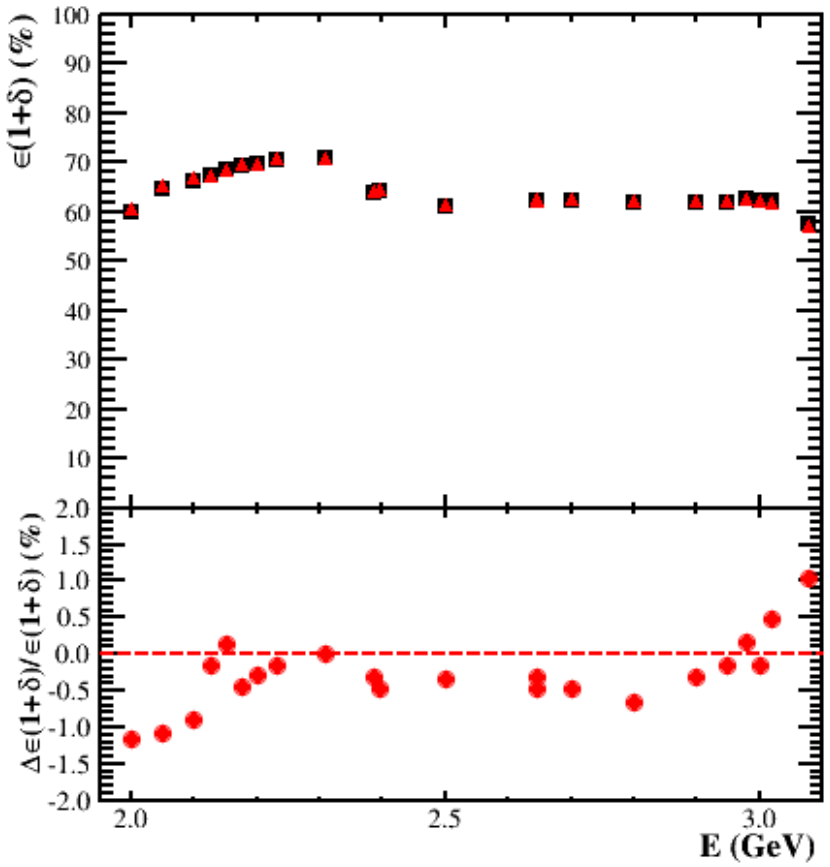
- ✓ ε -- BESIII selection efficiency
- ✓ (1+δ) -- $\frac{\sigma_{Born+NLO}}{\sigma_{Born}}$ radiation correction factor
- ✓ ε(1+δ) – should be consistent at different energy points

E (GeV)	ε (%) ConExc	ε (%) PHOKHARA	(1+δ) ConExc	(1+δ) PHOKHARA	ε(1+δ) ConExc	ε(1+δ) PHOKHARA
2	66.6	67.3	0.903	0.903	60.1	60.8
2.05	69.9	70.6	0.926	0.926	64.7	65.4
2.1	69.7	70.4	0.949	0.949	66.2	66.8
2.12655	69.8	70.3	0.965	0.96	67.4	67.5
2.15	69.1	69.7	0.993	0.984	68.6	68.5
2.175	68.2	68.5	1.016	1.016	69.3	69.6
2.2	66.6	66.8	1.045	1.044	69.6	69.8
2.2324	64.2	64.3	1.1	1.099	70.6	70.7
2.3094	54.6	54.6	1.299	1.299	70.9	70.9
2.3864	50.5	50.7	1.266	1.267	64.0	64.2
2.396	51.3	51.4	1.253	1.254	64.2	64.5
2.5	47.8	48	1.28	1.28	61.2	61.4
2.6444	37.4	37.5	1.671	1.67	62.4	62.7
2.6464	37.1	37.3	1.676	1.675	62.2	62.4
2.7	34.7	34.9	1.797	1.795	62.4	62.7
2.8	33.2	33.5	1.86	1.858	61.8	62.2
2.9	30.5	30.7	2.029	2.022	61.9	62.1
2.95	26.4	26.6	2.346	2.33	62.0	62.1
2.981	23.3	23.5	2.69	2.664	62.6	62.5
3	21.1	21.4	2.947	2.91	62.3	62.4
3.02	19.5	19.8	3.18	3.125	62.2	61.9
3.08	22.3	24.2	2.585	2.366	57.7	57.1

Output from ConExc (BesEvtGen-00-03-69) and PHOKHARA (v9.1) (Born+NLO)







At most low energy points:

- **ε: ConExc is ~1% lower than PHOKHARA;**
- **(1+δ): ConExc is similar to PHOKHARA;**
- **ε(1+δ): ConExc is ~1% lower than PHOKHARA.**

At high energy points, line 3.08 GeV:

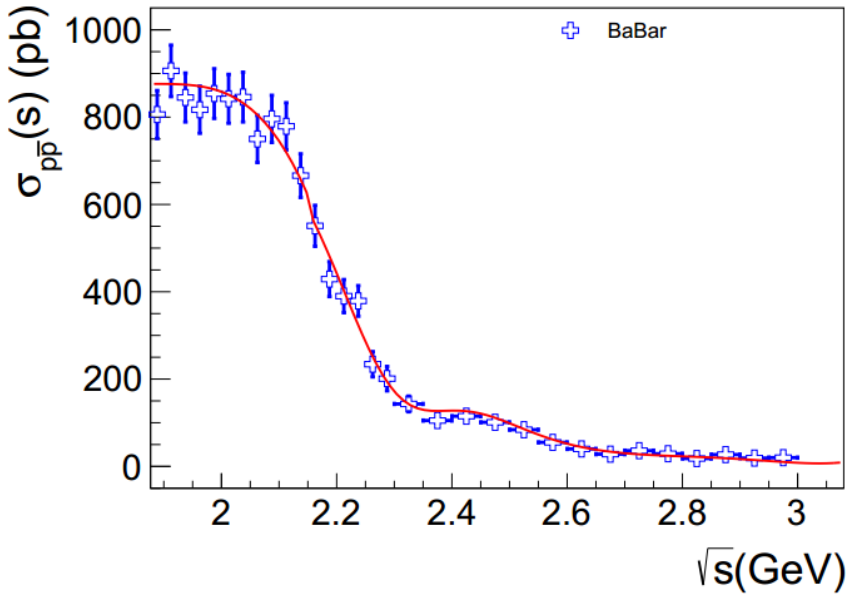
- **large differences in ε, (1+δ), and ε(1+δ).**
- **do not know the reason yet. input ?**

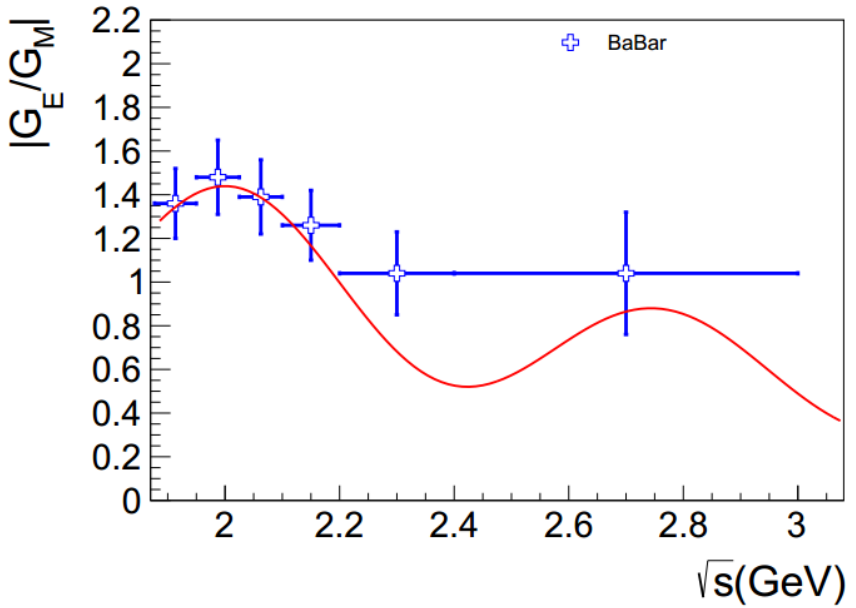
The same input Born σ and $R = |G_E|/|G_M|$

input model

$$\sigma_{p\bar{p}}(s) = \begin{cases} \dfrac{a_0\pi^2\alpha^3}{s(1-e^{-\frac{-\pi\alpha_s(s)}{\beta(s)}})(1+(\frac{\sqrt{s}-2m_p}{a_1})^{a_2})} + a_3, \sqrt{s} \le 2.15\,GeV \\ \sum_{i=4}^{10} a_i(\sqrt{s})^{i-4} + \dfrac{a_{11}}{\sqrt{2\pi}a_{12}} e^{-\frac{(\sqrt{s}-a_{13})^2}{2a_{12}^2}}, \sqrt{s} > 2.15\,GeV \end{cases}$$

$$|(G_E/G_M)(s)| = \frac{1}{b_8} e^{b_0+b_1\sqrt{s}}(b_2 + b_3\cos(b_4 + b_5\sqrt{s}))(1+\frac{s}{b_6})(1+\frac{s}{b_7})^2$$



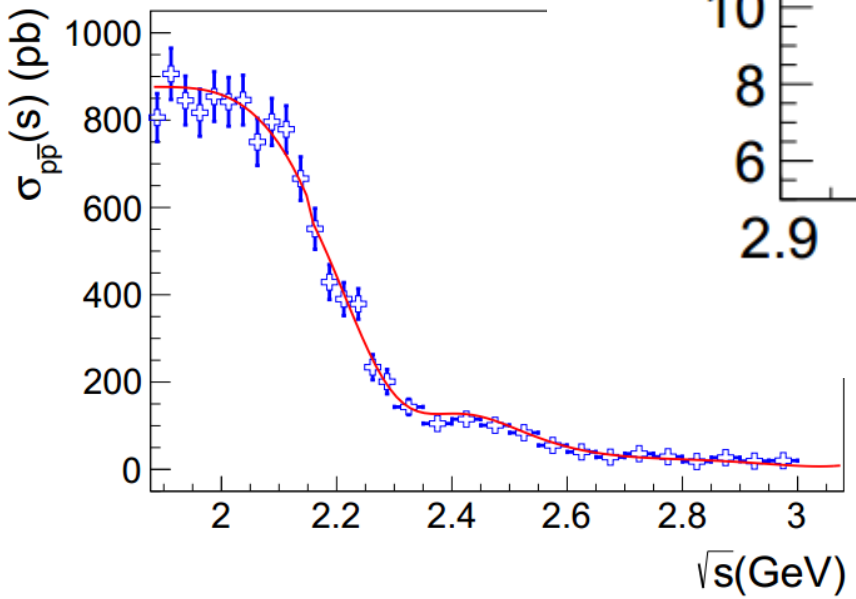


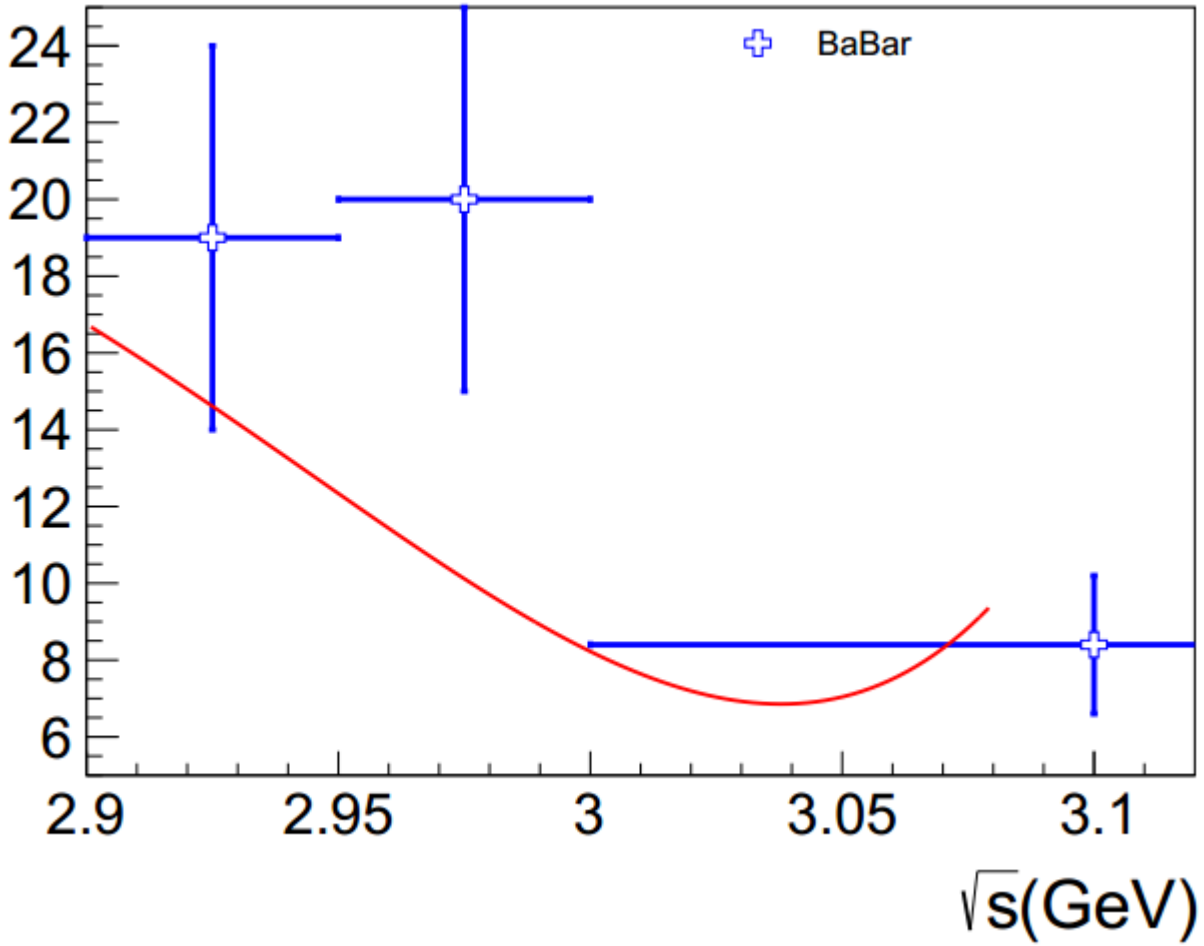
The same input Born σ and $R = |G_E|/|G_M|$

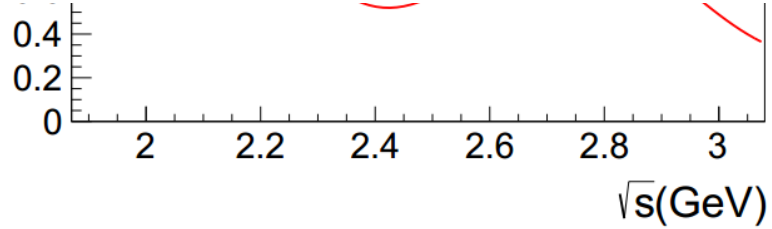
input model

$$\sigma_{p\bar{p}}(s) = \begin{cases} \dfrac{\qquad}{s(1-} \\ \displaystyle\sum_{i=4}^{10} \end{cases}$$

$$|(G_E/G_M)(s)| = \frac{1}{b_8} e^{}$$

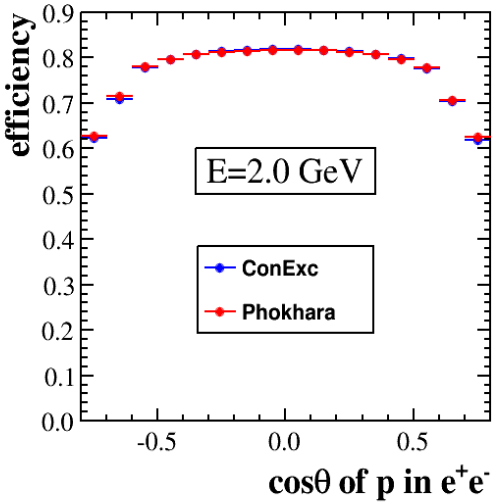


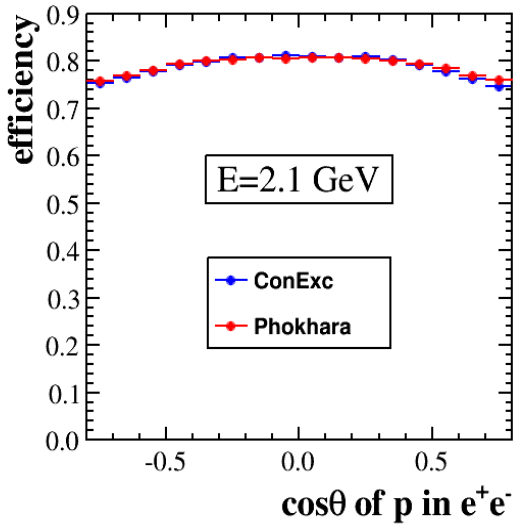


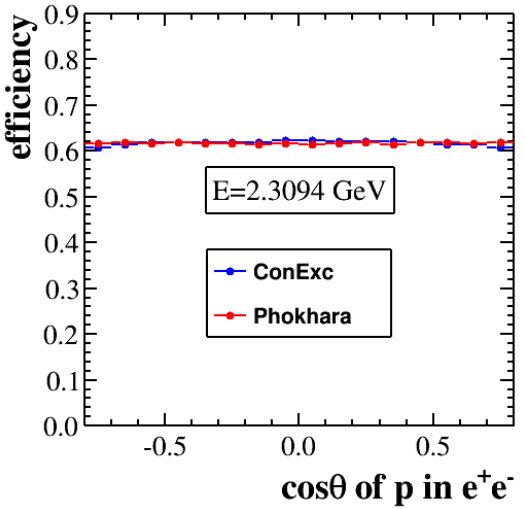


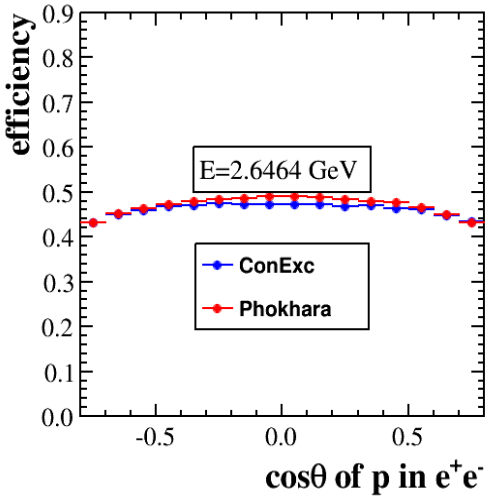
Output from ConExc (BesEvtGen-00-03-69) and PHOKHARA (v9.1) (Born+NLO)

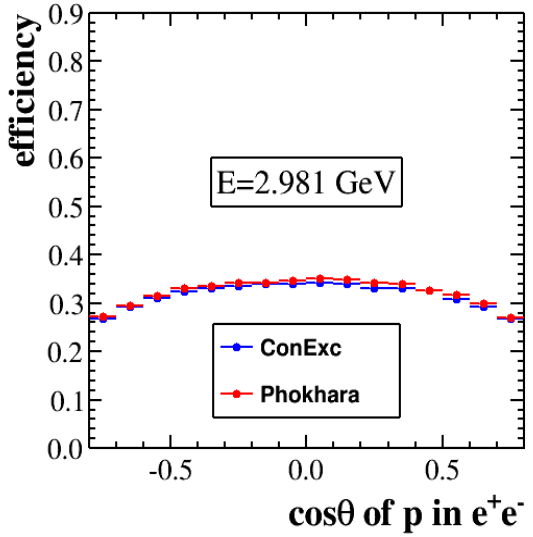
- curves of BESIII selection efficiency ε, looks similar but different at high energy

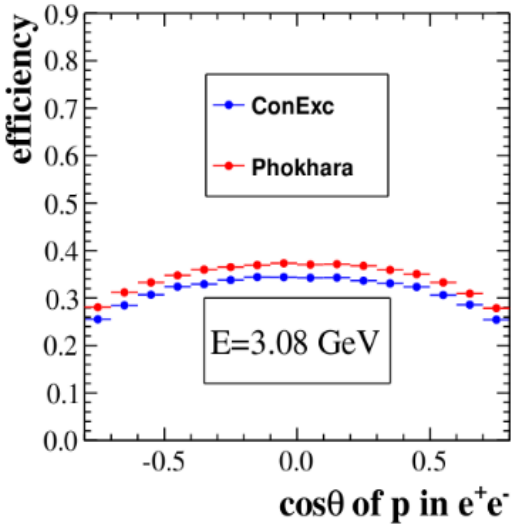








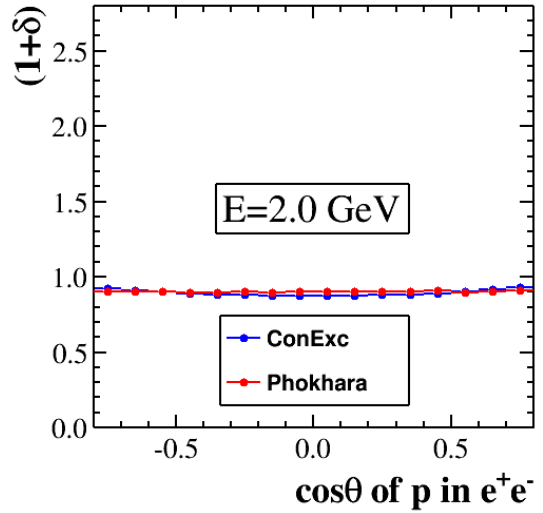


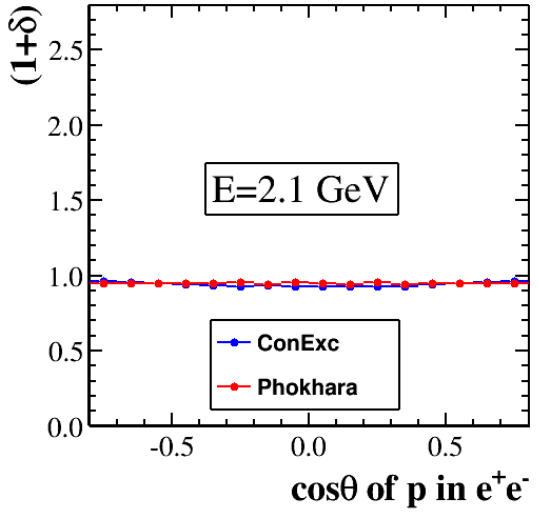


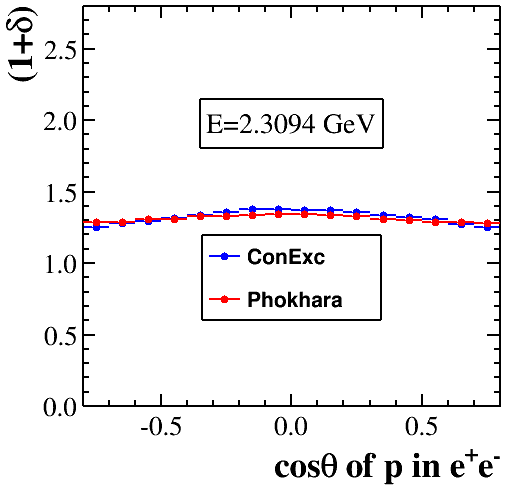
The difference at high energy caused by ?

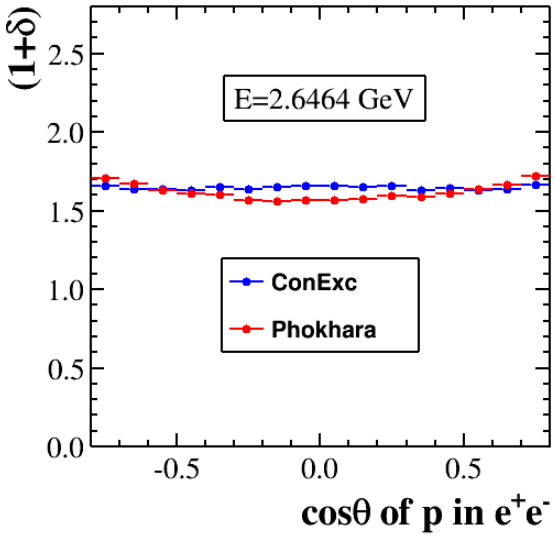
Output from ConExc (BesEvtGen-00-03-69) and PHOKHARA (v9.1) (Born+NLO)

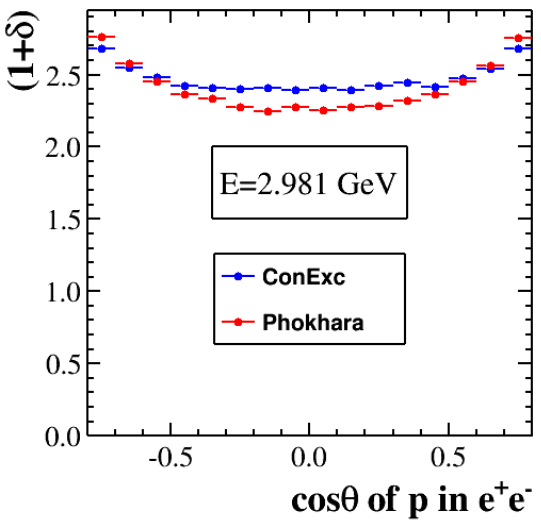
- curves of (1+δ), looks similar at low energy, but different at high energy

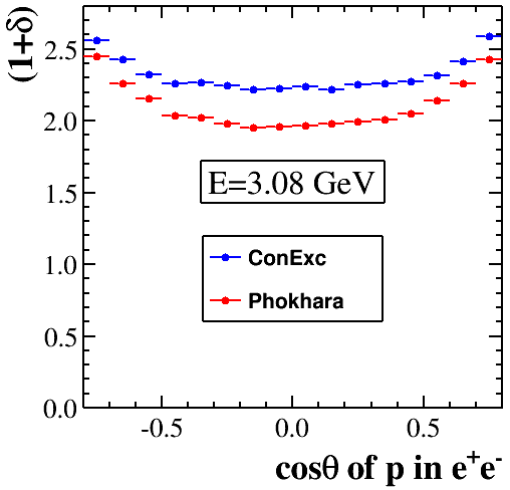








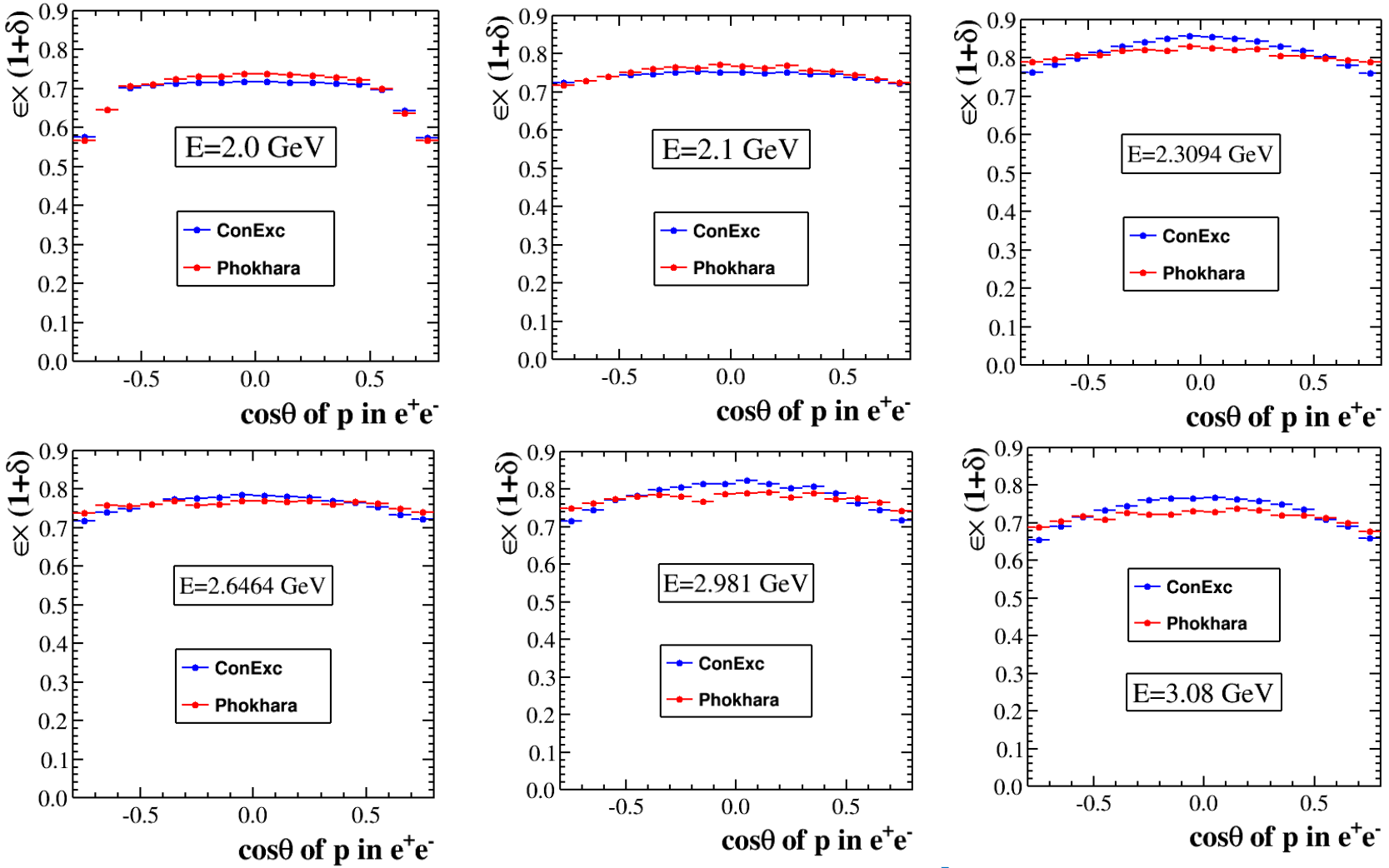




The difference at high energy caused by ?

Output from ConExc (BesEvtGen-00-03-69) and PHOKHARA (v9.1) (Born+NLO)

- curves of $\varepsilon(1+\delta)$, little difference at all energy points



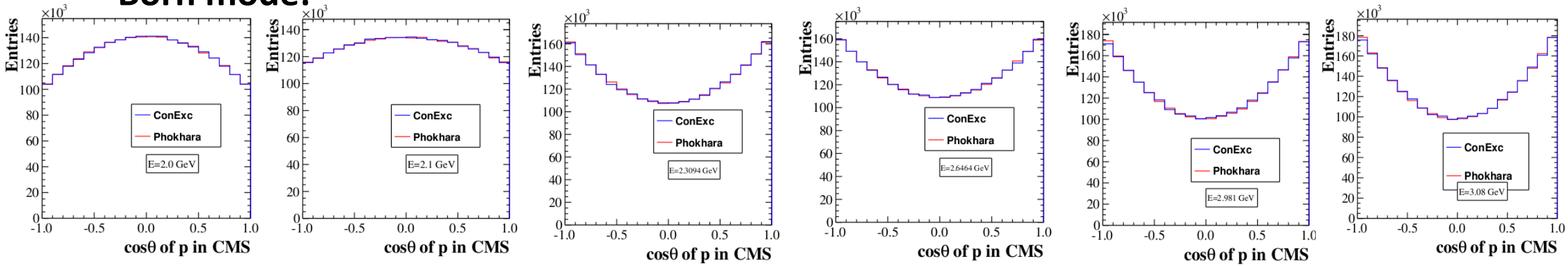
The difference at high energy caused by ?

→ little difference in the corrected data distribution → little difference in R and G_M.

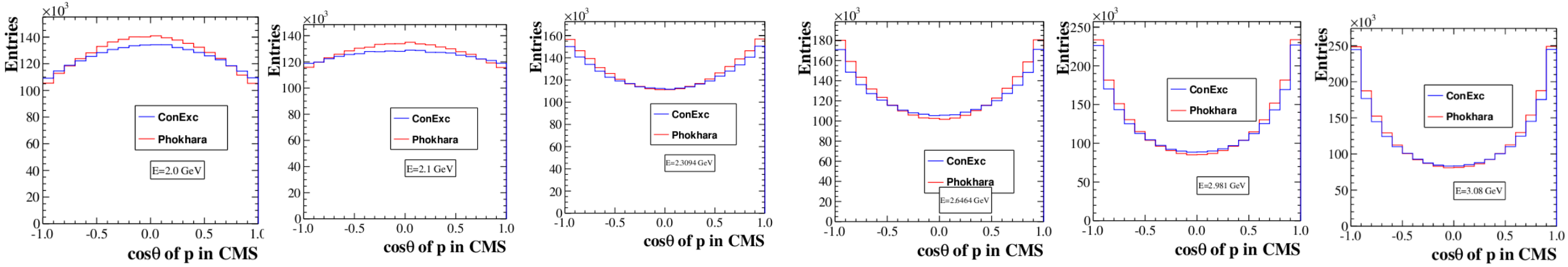
Output from ConExc (BesEvtGen-00-03-69) and PHOKHARA (v9.1) (Born+NLO)

cosθ distribution of proton in Born and Born+NLO modes

Born mode:



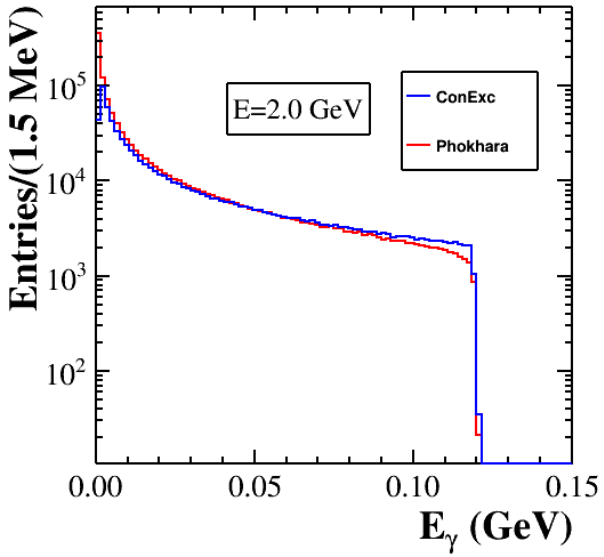
Born+NLO mode:

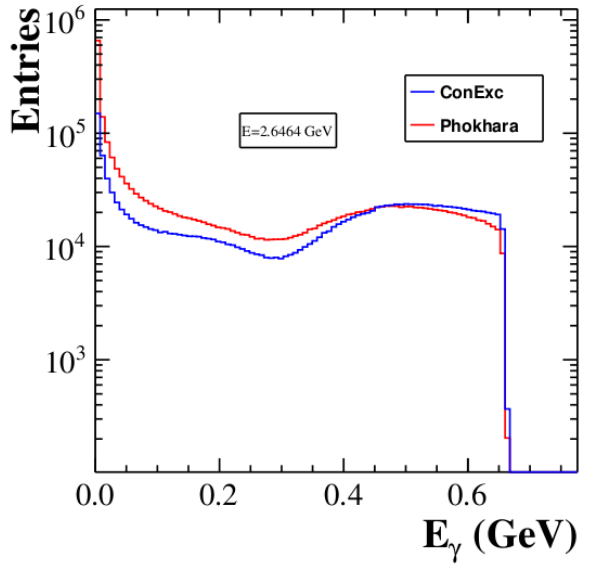


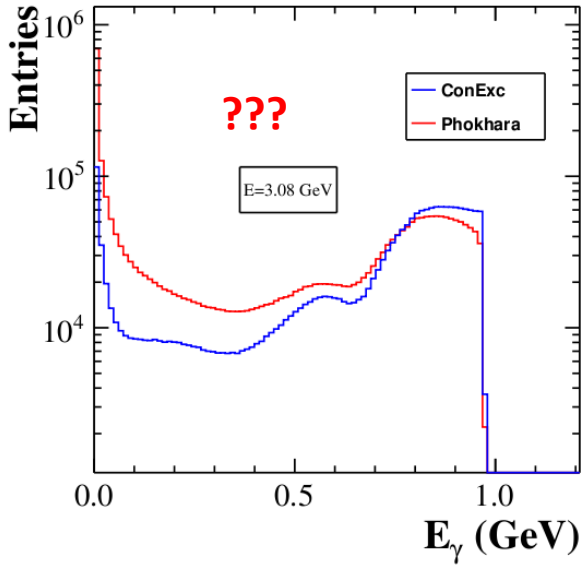
The samples of Born mode are very similar. But the samples of Born+NLO mode have difference → difference in (1+δ)

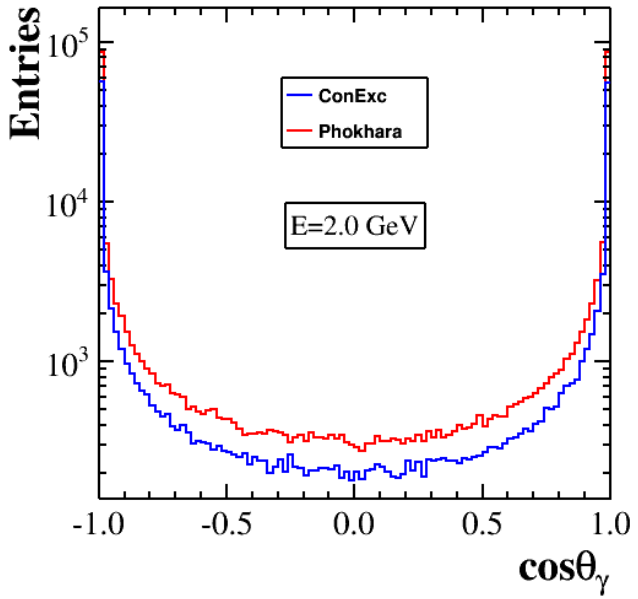
Output from ConExc (BesEvtGen-00-03-69) and PHOKHARA (v9.1) (Born+NLO)

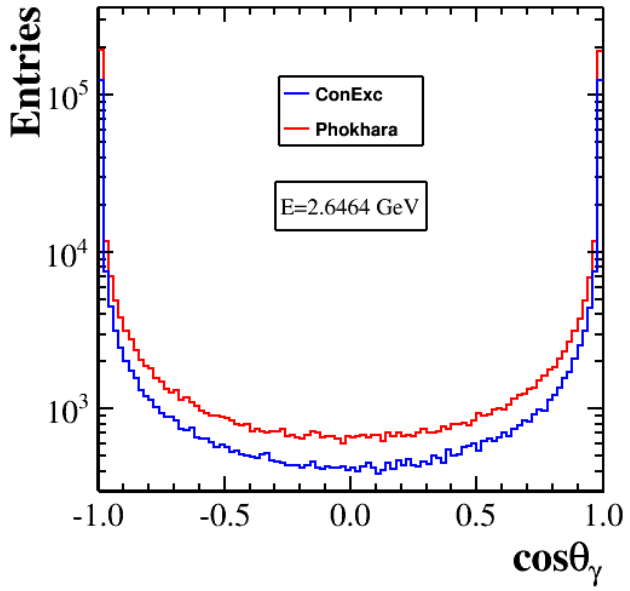
MCTruth of radiated photon

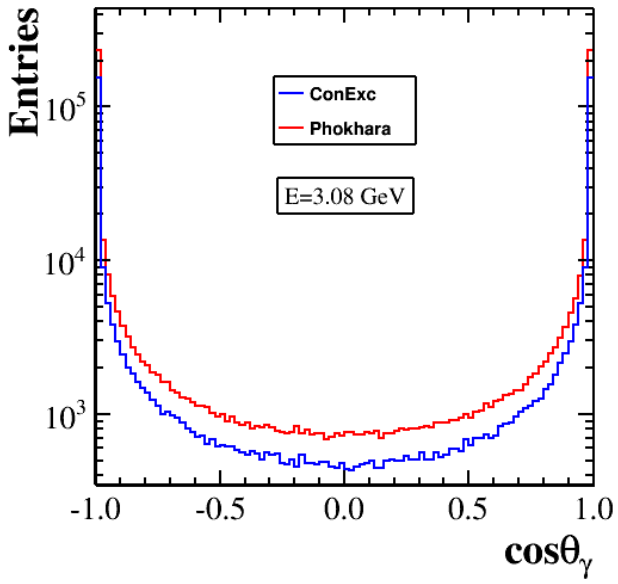










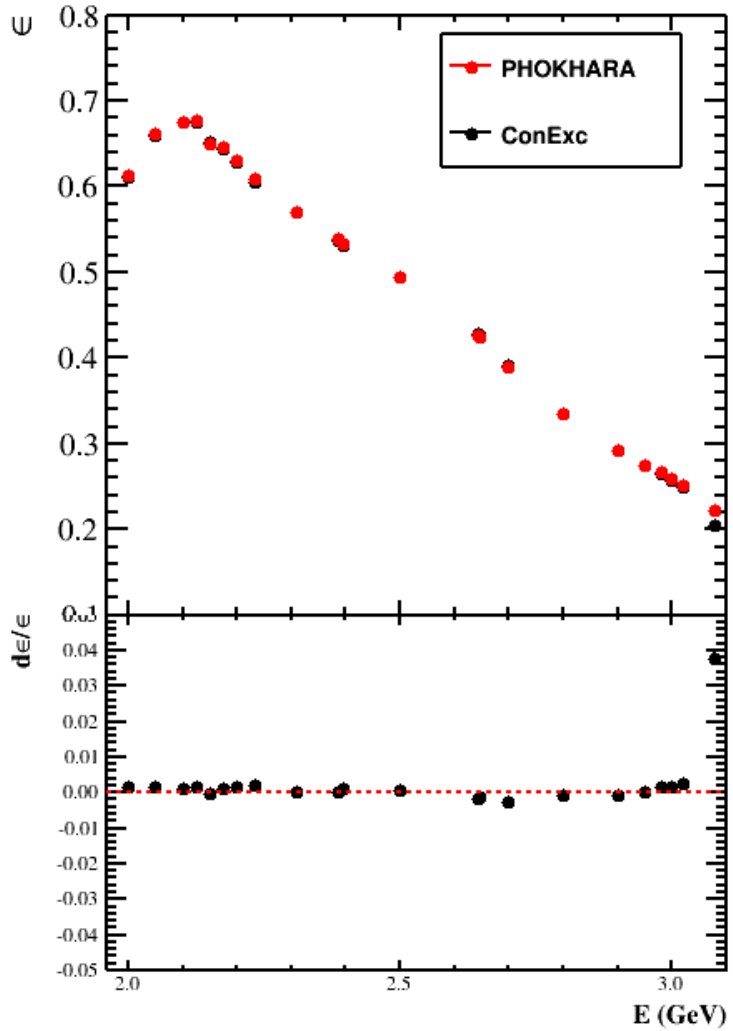


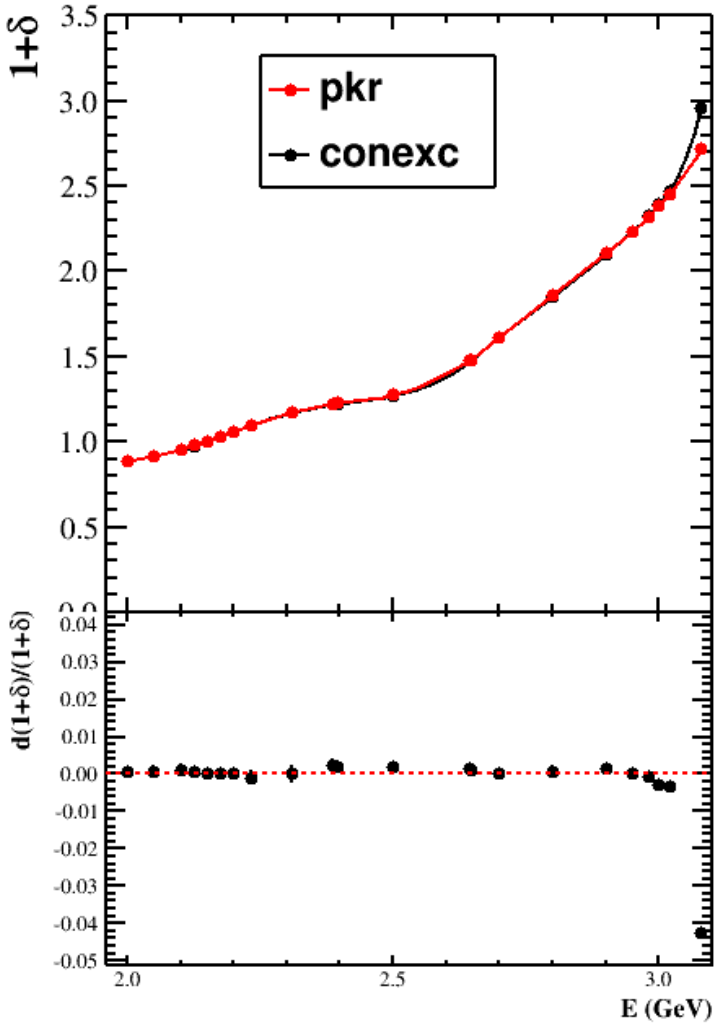
Better result from ConExc (BesEvtGen-00-03-18) and PHOKHARA (v9.1) (Born+NLO)

Comparing ConExc (BesEvtGen-00-03-69) and ConExc(BesEvtGen-00-03-18), the way of the initial radiation changed, and a better VP is used.

But more in detail needs to be understood.

Energy (GeV)	eff_phokhra	eff_conexc	fisr_Phokhara	fisr_conexc
2	0.6131 +- 0.0006	0.6112 +- 0.0007	0.886 +- 0.002	0.885 +- 0.001
2.05	0.6608 +- 0.0005	0.6591 +- 0.0007	0.918 +- 0.003	0.917 +- 0.001
2.1	0.6755 +- 0.0004	0.6740 +- 0.0007	0.955 +- 0.003	0.953 +- 0.001
2.125	0.6765 +- 0.0005	0.6745 +- 0.0007	0.978 +- 0.003	0.977 +- 0.001
2.15	0.6501 +- 0.0006	0.6505 +- 0.0007	1.001 +- 0.003	1.001 +- 0.001
2.175	0.6452 +- 0.0005	0.6437 +- 0.0007	1.029 +- 0.003	1.029 +- 0.001
2.2	0.6295 +- 0.0004	0.6276 +- 0.0007	1.058 +- 0.003	1.058 +- 0.001
2.2324	0.6077 +- 0.0006	0.6054 +- 0.0007	1.096 +- 0.004	1.098 +- 0.002
2.3094	0.5696 +- 0.0004	0.5697 +- 0.0007	1.172 +- 0.005	1.172 +- 0.002
2.3864	0.5378 +- 0.0006	0.5376 +- 0.0007	1.224 +- 0.003	1.218 +- 0.002
2.396	0.5326 +- 0.0006	0.5316 +- 0.0007	1.228 +- 0.003	1.223 +- 0.002
2.5	0.4944 +- 0.0006	0.4938 +- 0.0007	1.274 +- 0.003	1.269 +- 0.002
2.6444	0.4263 +- 0.0006	0.4277 +- 0.0007	1.479 +- 0.003	1.475 +- 0.003
2.6464	0.4242 +- 0.0006	0.4254 +- 0.0007	1.483 +- 0.003	1.480 +- 0.003
2.7	0.3888 +- 0.0006	0.3909 +- 0.0007	1.609 +- 0.003	1.608 +- 0.003
2.8	0.3343 +- 0.0006	0.3350 +- 0.0007	1.858 +- 0.005	1.855 +- 0.004
2.9	0.2912 +- 0.0005	0.2917 +- 0.0006	2.105 +- 0.001	2.098 +- 0.002
2.95	0.2747 +- 0.0005	0.2747 +- 0.0006	2.234 +- 0.002	2.234 +- 0.002
2.981	0.2657 +- 0.0004	0.2648 +- 0.0006	2.323 +- 0.002	2.327 +- 0.002
3.0	0.2581 +- 0.0004	0.2573 +- 0.0006	2.384 +- 0.003	2.397 +- 0.002
3.02	0.2510 +- 0.0004	0.2498 +- 0.0006	2.455 +- 0.003	2.472 +- 0.002
3.08	0.2213 +- 0.0004	0.2052 +- 0.0006	2.717 +- 0.003	2.959 +- 0.002

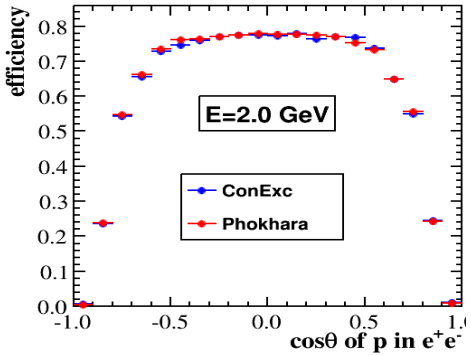


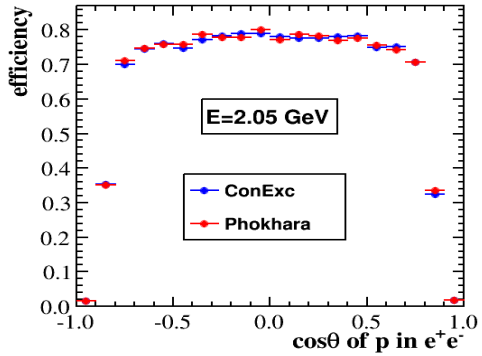


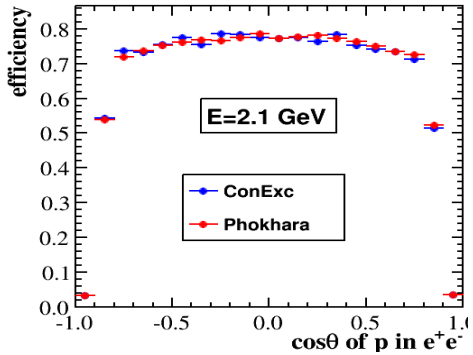
Better result with BesEvtGen-00-03-18 compared with PHOKHARA

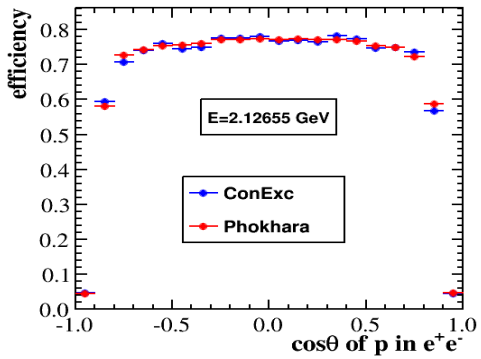
The difference < 1% unless at 3.08 GeV (~4%). Why 3.08 GeV?

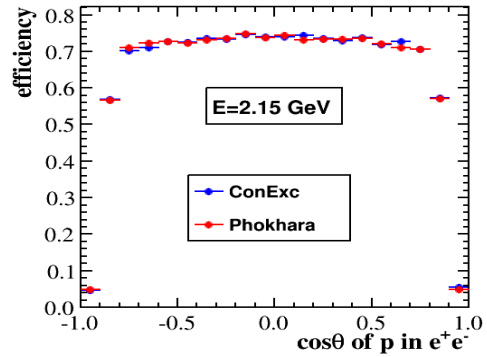
Comparison between ConExc (BesEvtGen-00-03-18) and Phokhara (v9.1) (Born+NLO)

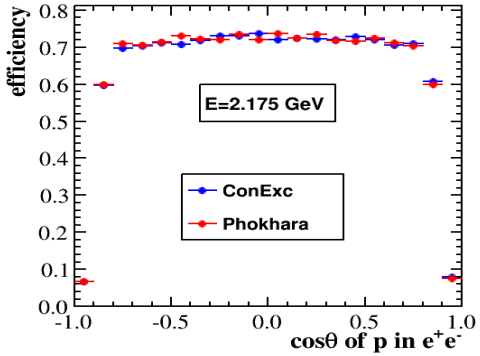


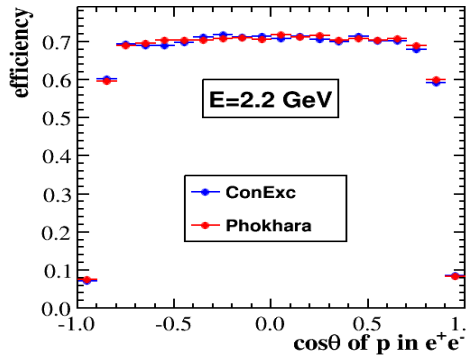


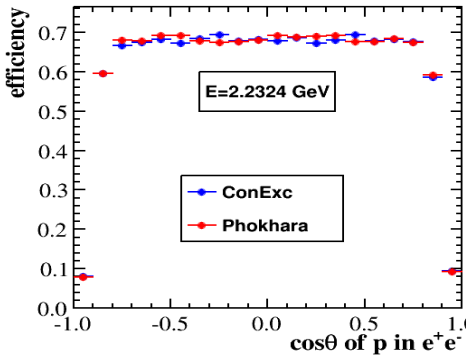


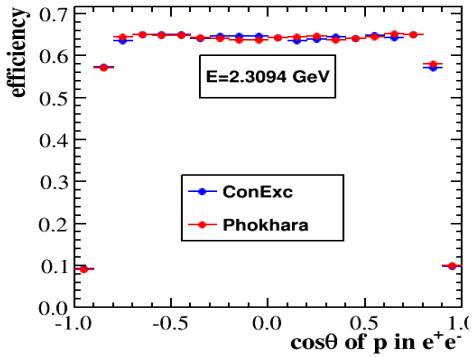


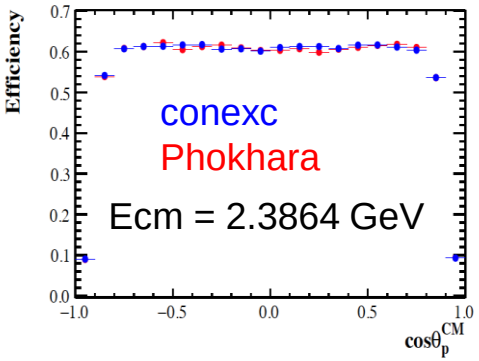


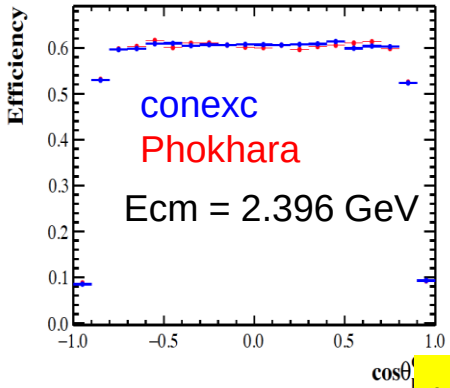


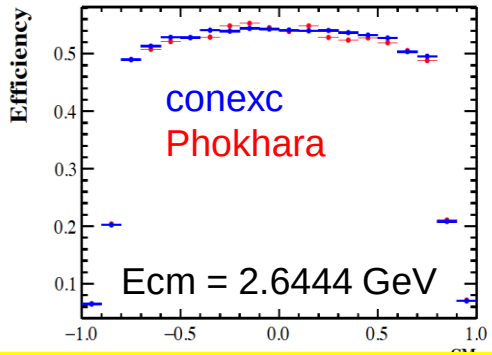


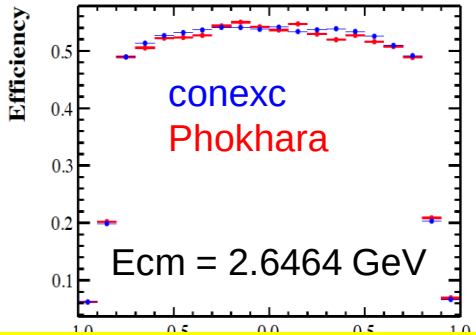


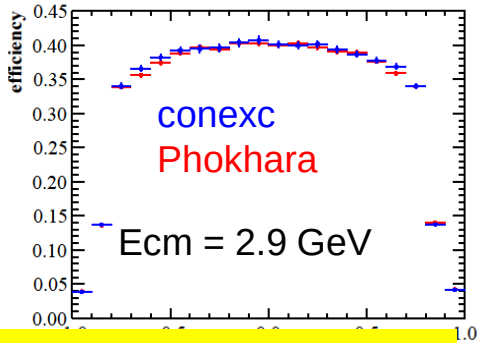


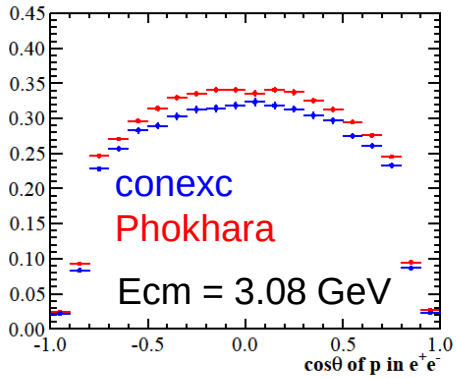






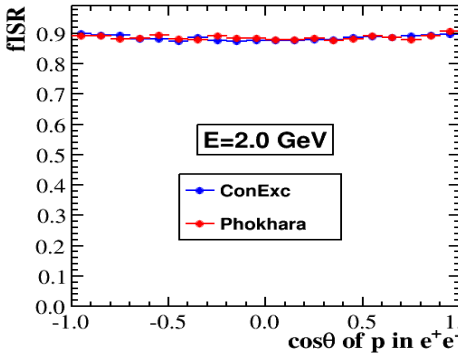


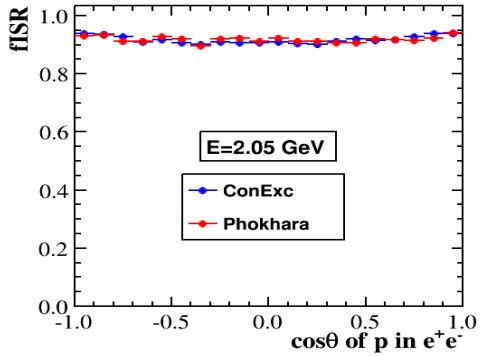


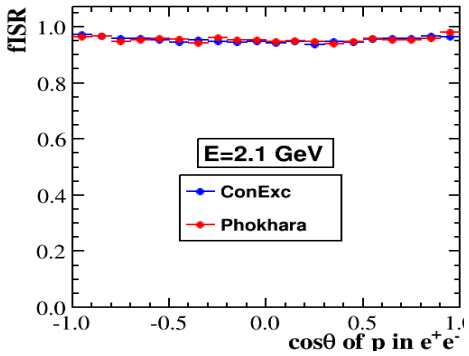


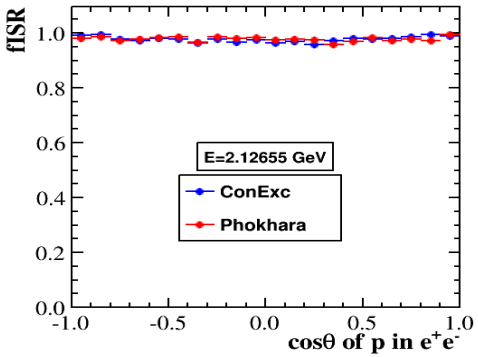
with the same input, consistent efficiencies are obtained.

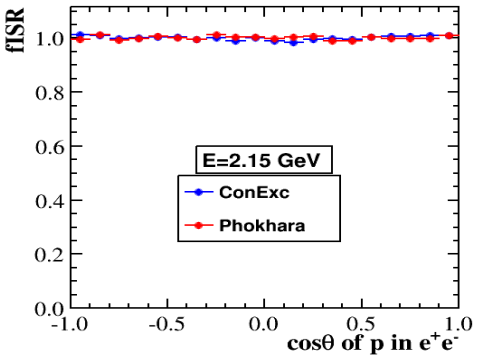
Comparison between ConExc (BesEvtGen-00-03-18) and Phokhara (v9.1) (Born+NLO)

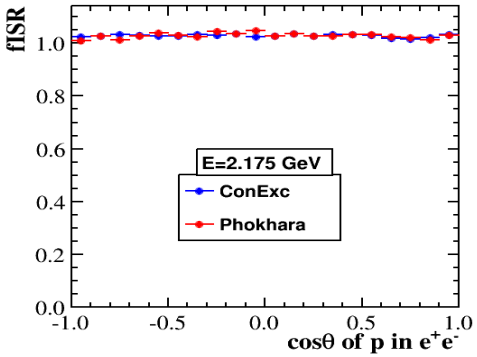


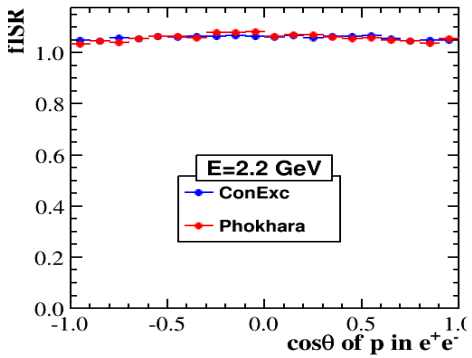


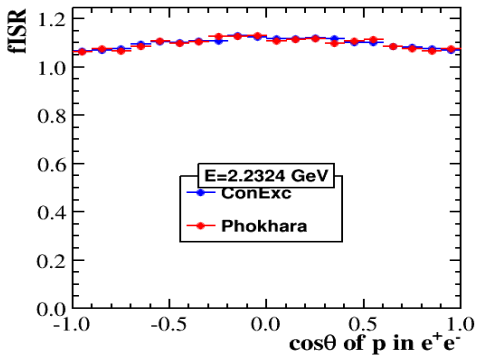


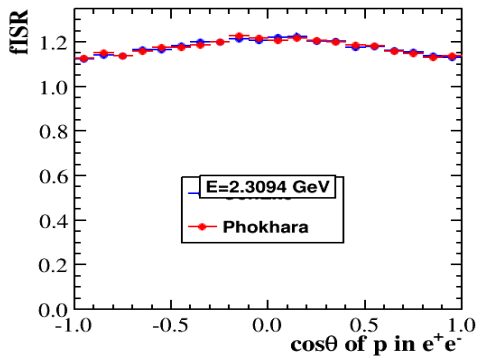


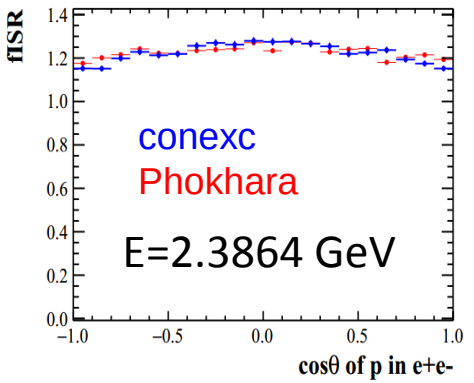


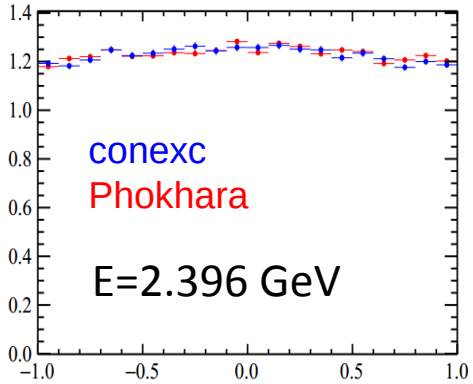


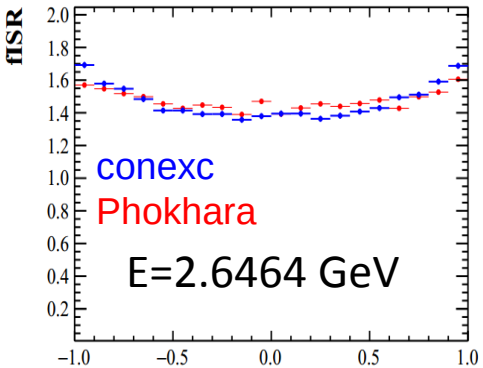


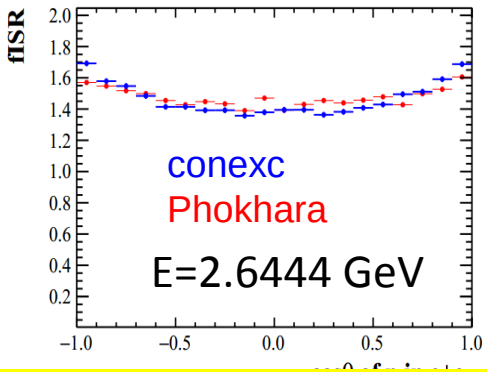


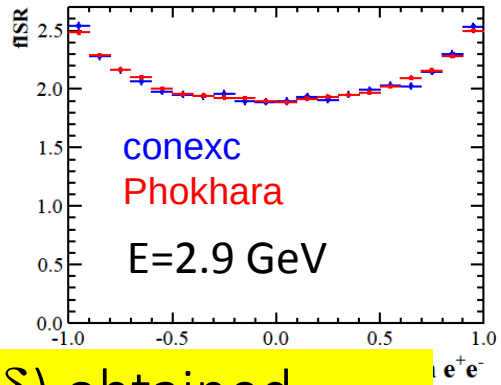


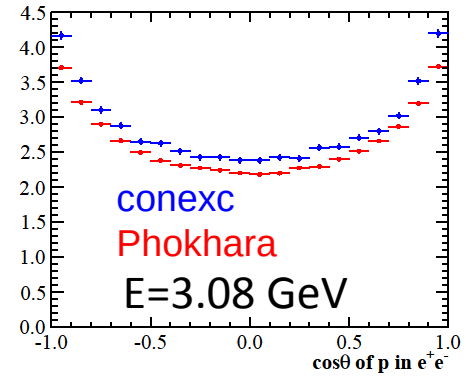






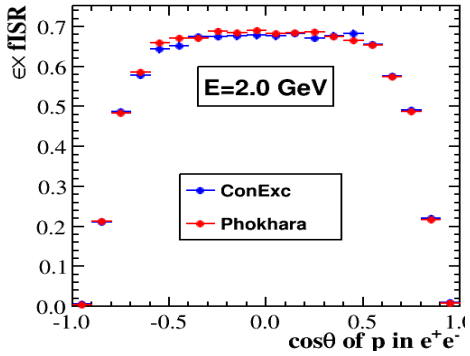


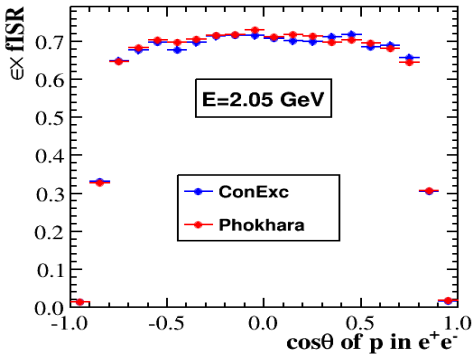


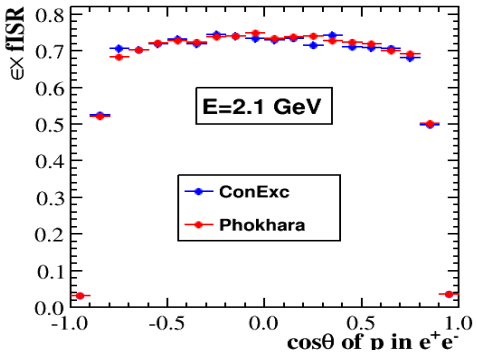


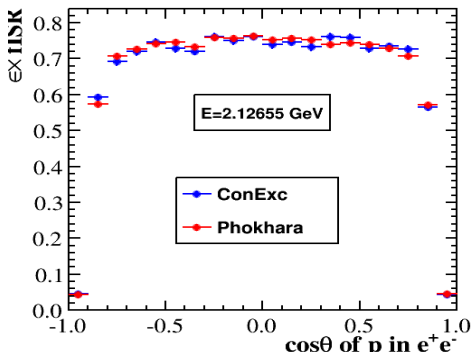
with the same input, consistent (1+δ) obtained.

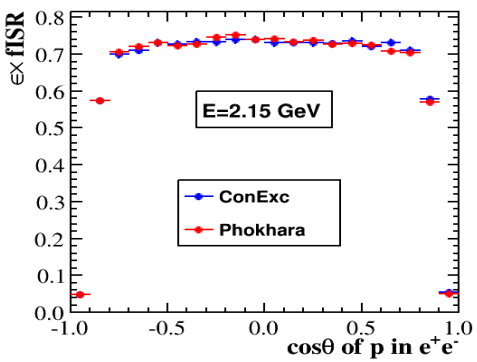
Comparison between ConExc (BesEvtGen-00-03-18) and Phokhara (v9.1) (Born+NLO)

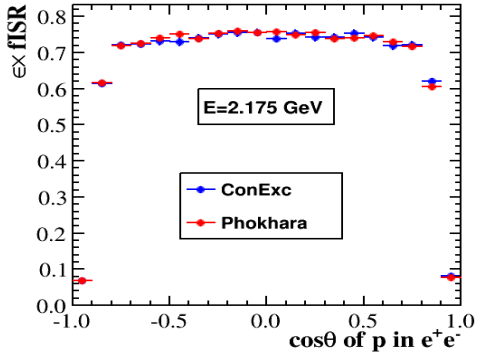


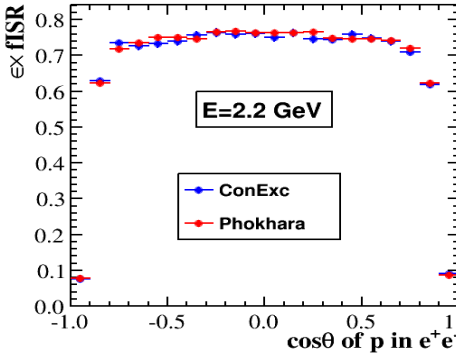


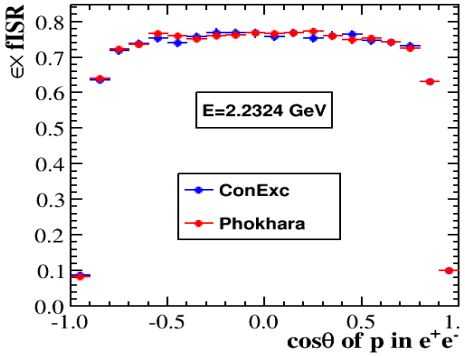


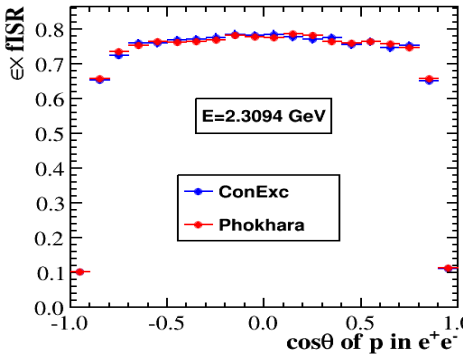


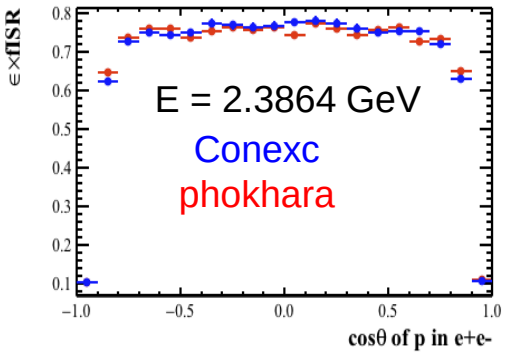


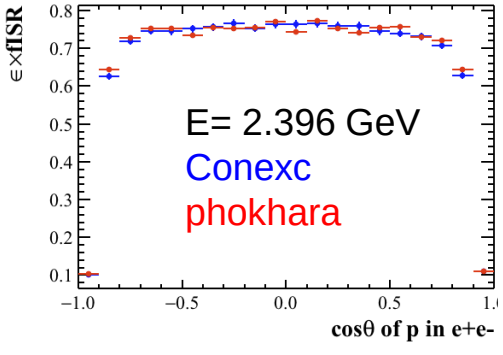


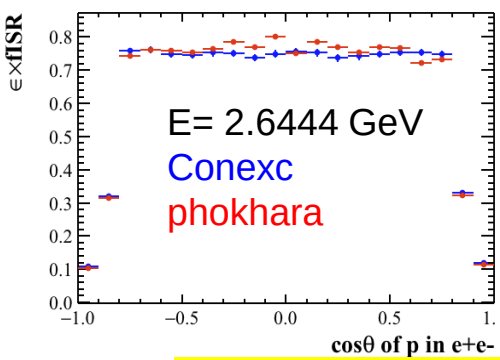


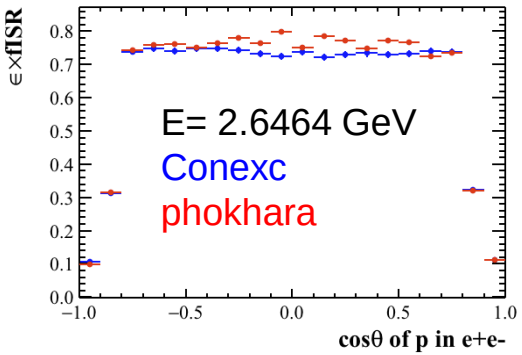


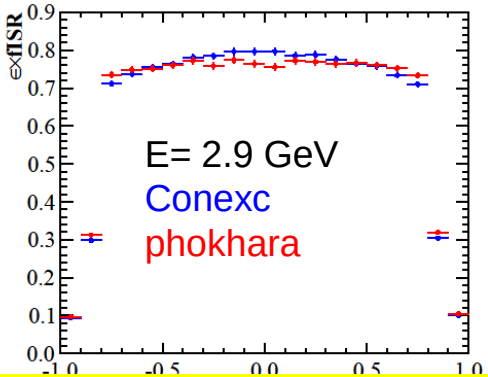


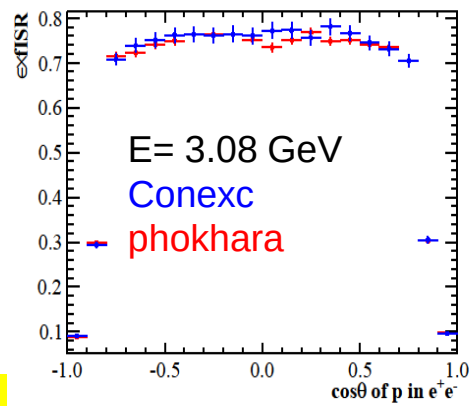












with the same input, consistent $\varepsilon(1+\delta)$ obtained.

Summary:

- The current version of ConExc has ~1% difference with PHOKHARA.
- ConExc and PHOKHARA can be very similar, like v-00-03-18.

Outlook:

- To understand the difference between ConExc and PHOKHARA.
- To understand the difference between ConExc (BesEvtGen-00-03-18) and ConExc (BesEvtGen-00-03-69) .

Thank you!