R value measurement at BESIII

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(On behalf of the BESIII Collaboration)

The 13th International workshop on e^+e^- collisions from phi to psi

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Introduction: Definition of R value

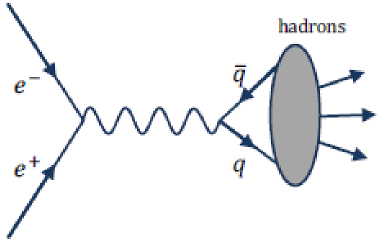
Theoretical definition

The R value is defined as the leading-order production cross section ratio of hadron and muon pairs in the annihilation of electron-positron:

$$R \equiv \frac{\sigma^0(e^+e^- \to \text{hadrons})}{\sigma^0(e^+e^- \to \mu^+\mu^-)} \equiv \frac{\sigma^0_{\text{had}}}{\sigma^0_{\mu\mu}}$$

That is, according to Feynman diagrams

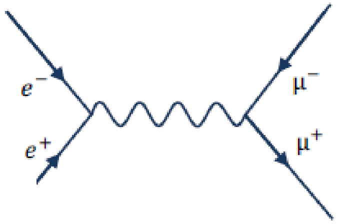
σ (



)

R ≡

σ (



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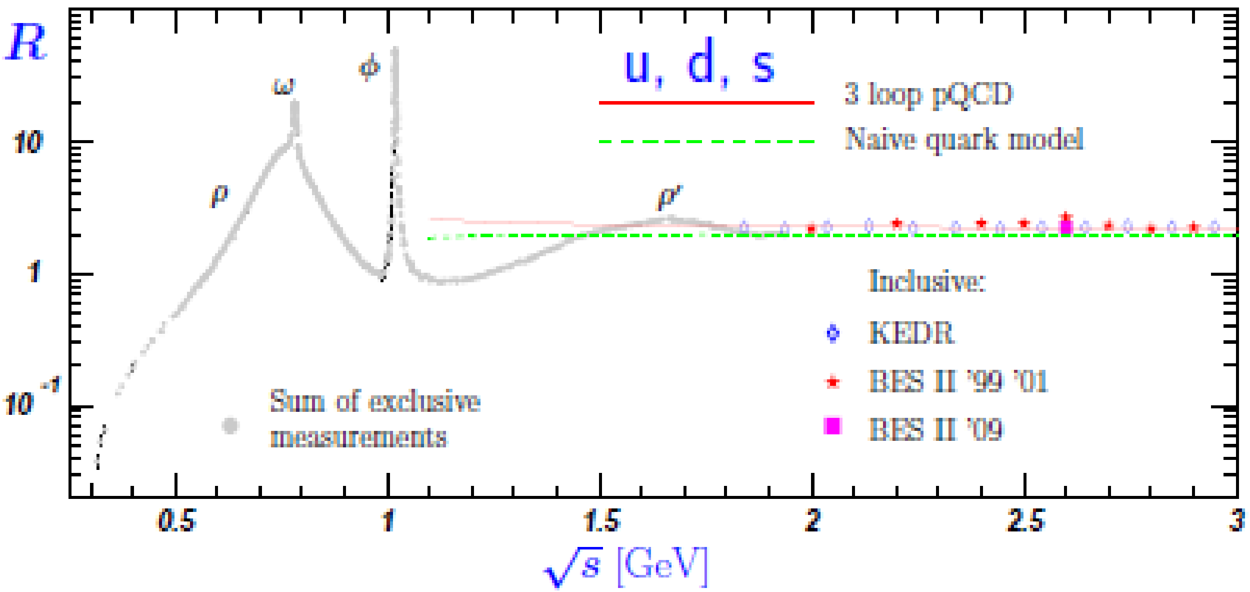
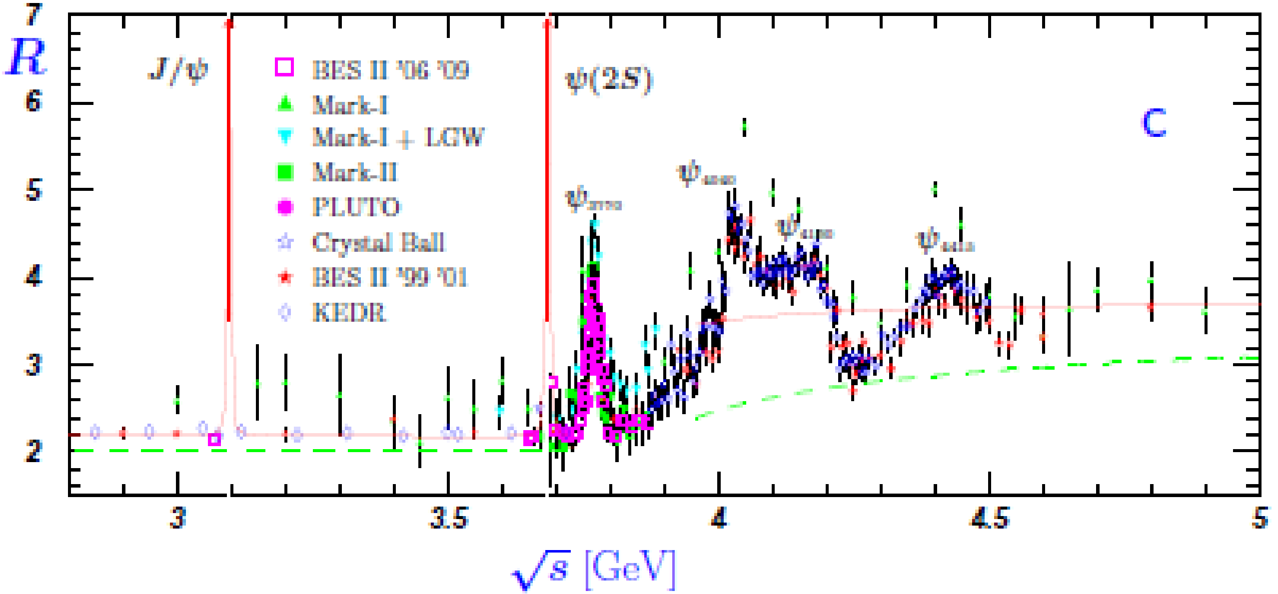
A direct result from the QED theory:

$$\sigma^0_{\mu\mu}(s) = \frac{4\pi\alpha^2}{3s}\,\frac{\beta_\mu(3-\beta_\mu^2)}{2}, \qquad \text{with } \beta_\mu = \sqrt{1-4m_\mu^2/s}$$

Introduction: R value by pQCD and experiments

PDG





R value were measured by many Collaborations:

BESII,

KEDR, VEPP,

DAΦNE, DM2, DASP, PLUTO, Crystal-Ball, MARKI, MARKII, CLEO-c, AMY, JADE,

TASSO, CUSB, MD-1, MARKJ, SLAC-LBL, MAC, γγ2, ……

BESIII

Introduction: Why R value important

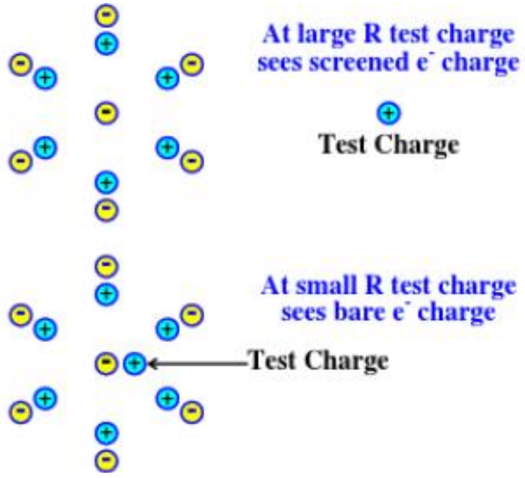
QED running coupling constant Δα(s) – one of the most important QED parameters

The contributions to $\Delta\alpha(s)$ can be distinguished to three pieces:

$$\Delta\alpha(s) = 1 - \alpha(0)/\alpha(s) = \Delta\alpha_{\text{lepton}}(s) + \Delta\alpha^{(5)}_{\text{had}}(s) + \Delta\alpha_{\text{top}}(s)$$

- $\Delta\alpha_{\text{lepton}}(s)$ can be calculated analytically using the perturbative theory.
- Since the top quark is heavy, $\Delta\alpha_{\text{top}}(s)$ is small ($10^{-7} \sim 10^{-10}$ for BESIII region).
- $\Delta\alpha^{(5)}_{\text{had}}(s)$ should be calculated by using the R value:

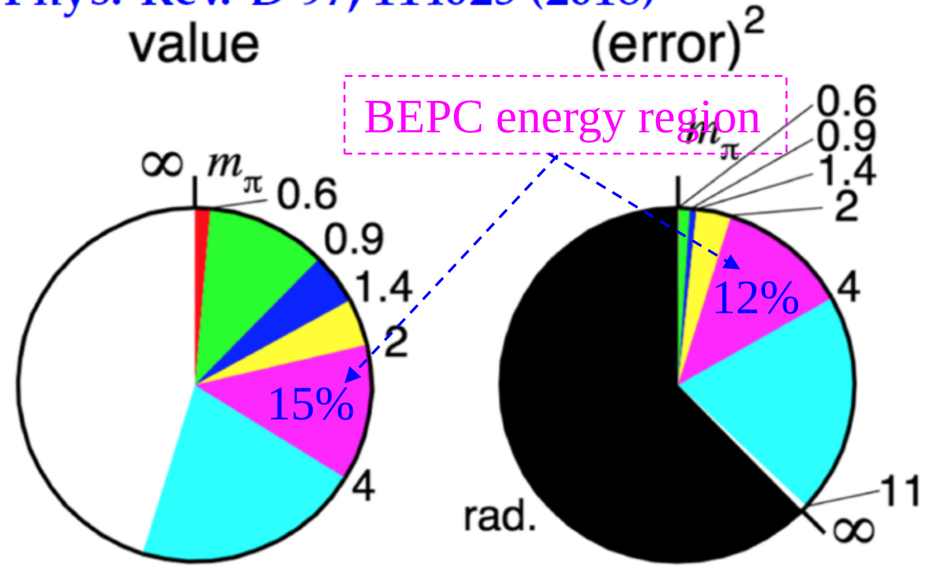
$$\Delta\alpha^{(5)}_{\text{had}}(s) = -\frac{\alpha s}{3\pi}\,\text{Re}\int_{E_{\text{th}}}^{\infty} ds' \frac{R(s')}{s'(s'-s-i\varepsilon)}$$



$$\alpha(s) = \frac{\alpha(0)}{1-\Delta\alpha(s)}$$

Fractional contribution to $\Delta\alpha^{(5)}_{\text{had}}(M_Z^2)$:

Phys. Rev. D 97, 114025 (2018)



Eur. Phys. J. C 80, 241 (2020)

Source	Contribution($\times 10^{-4}$)
$\Delta\alpha_{\text{lepton}}(M_Z^2)$	314.979 ± 0.002
$\Delta\alpha^{(5)}_{\text{had}}(M_Z^2)$	276.0 ± 1.0
$\Delta\alpha_{\text{top}}(M_Z^2)$	-0.7180 ± 0.0054

$\Delta\alpha^{(5)}_{\text{had}}(s)$ is sensitive with the R value over all energy region!

Muon anomalous magnetic moment a_μ – the most precision test of SM

- Magnetic moment of the muon: $\boxed{\vec{\mu} = g_\mu \frac{e}{2m_\mu} \vec{S}}$
- Dirac theory: $\boxed{g_\mu = 2}$ $\Rightarrow$ Quantum Field Theory: $\boxed{a_\mu = \frac{|g_\mu - 2|}{2}}$ $\Rightarrow$ **Muon Anomaly**

Anomalous Magnetic Moment:

1. Standard model prediction:

$$\boxed{a_\mu^{SM} = a_\mu^{QED} + a_\mu^{QCD} + a_\mu^{weak}}$$

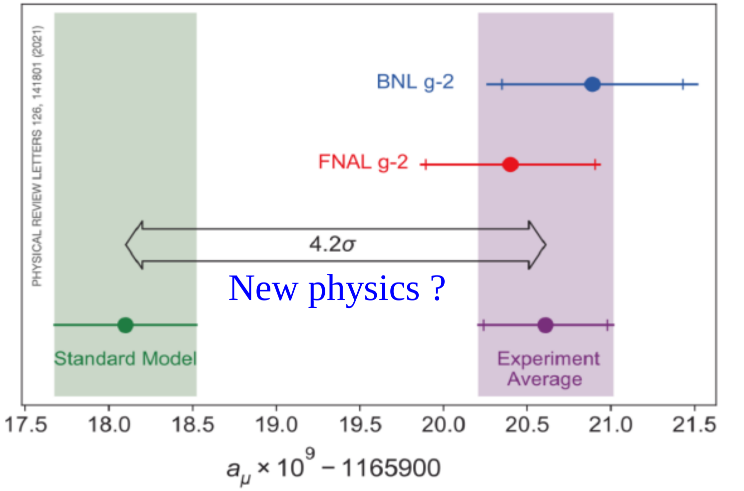
Phys. Rep. 887, 1 (2020)

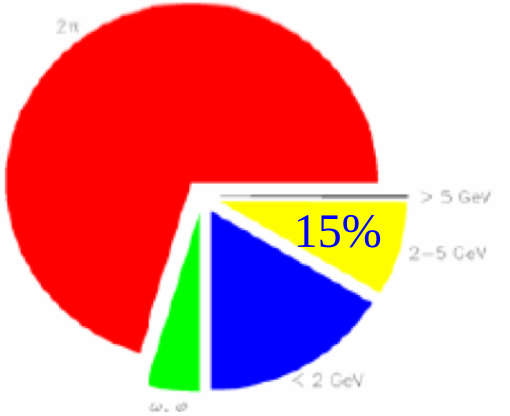
2. Direct measurement

(Exp. average BNL & FNAL)

Phys. Rev. Lett. 126, 141801 (2021)

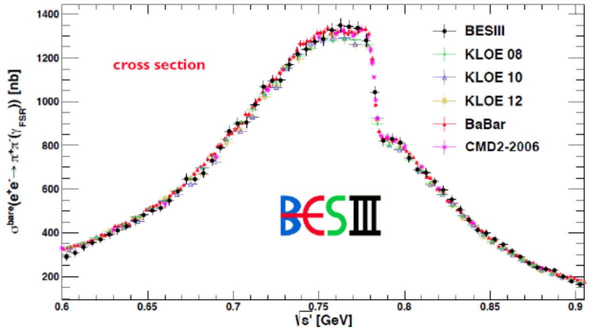
$\Rightarrow$ **Discrepancy of 4.2 σ!**





Uncertainty contribution fractions of $\delta(a_\mu)$ caused by error of R value from different region.

- Hadronic contributions dominate uncertainty of a_μ^{SM}
  - Hadronic Light-by-Light Scattering (HLbL) & **Hadronic Vacuum Polarization (HVP)**



The HVP contribution, i.e., $a_\mu^{\text{LO-HVP}}$, is calculated in terms of R value with the dispersion relation:

$$a_\mu^{\text{LO-HVP}} = \left(\frac{\alpha m_\mu}{3\pi}\right)^2 \int_{4m_\pi^2}^{\infty} \mathrm{d}s \frac{R(s)K(s)}{s^2}$$

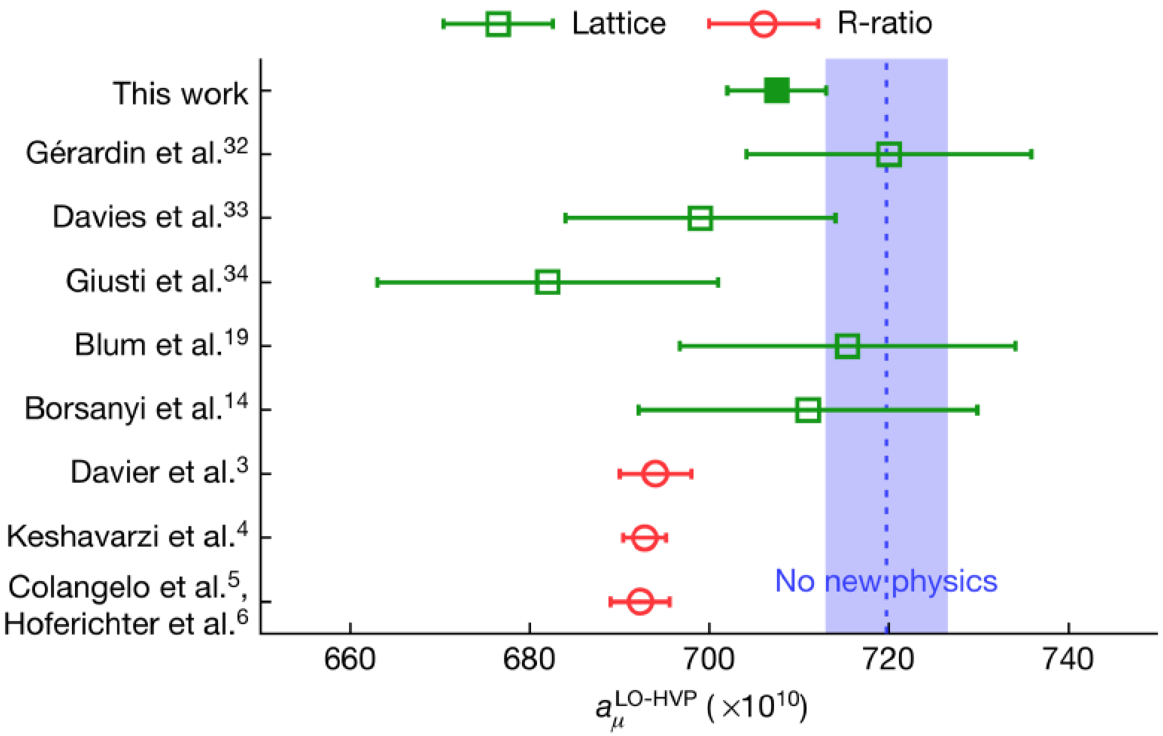
BESIII measured 2π cross section using ISR return method with $\psi(3770)$ data

Introduction: Why R value important

Muon anomalous magnetic moment a_μ – the most precision test of SM

New calculation of $a_\mu^{\text{LO-HVP}}$ from the lattice QCD approach decreases the discrepancy between a_μ^{SM} and a_μ^{exp}:

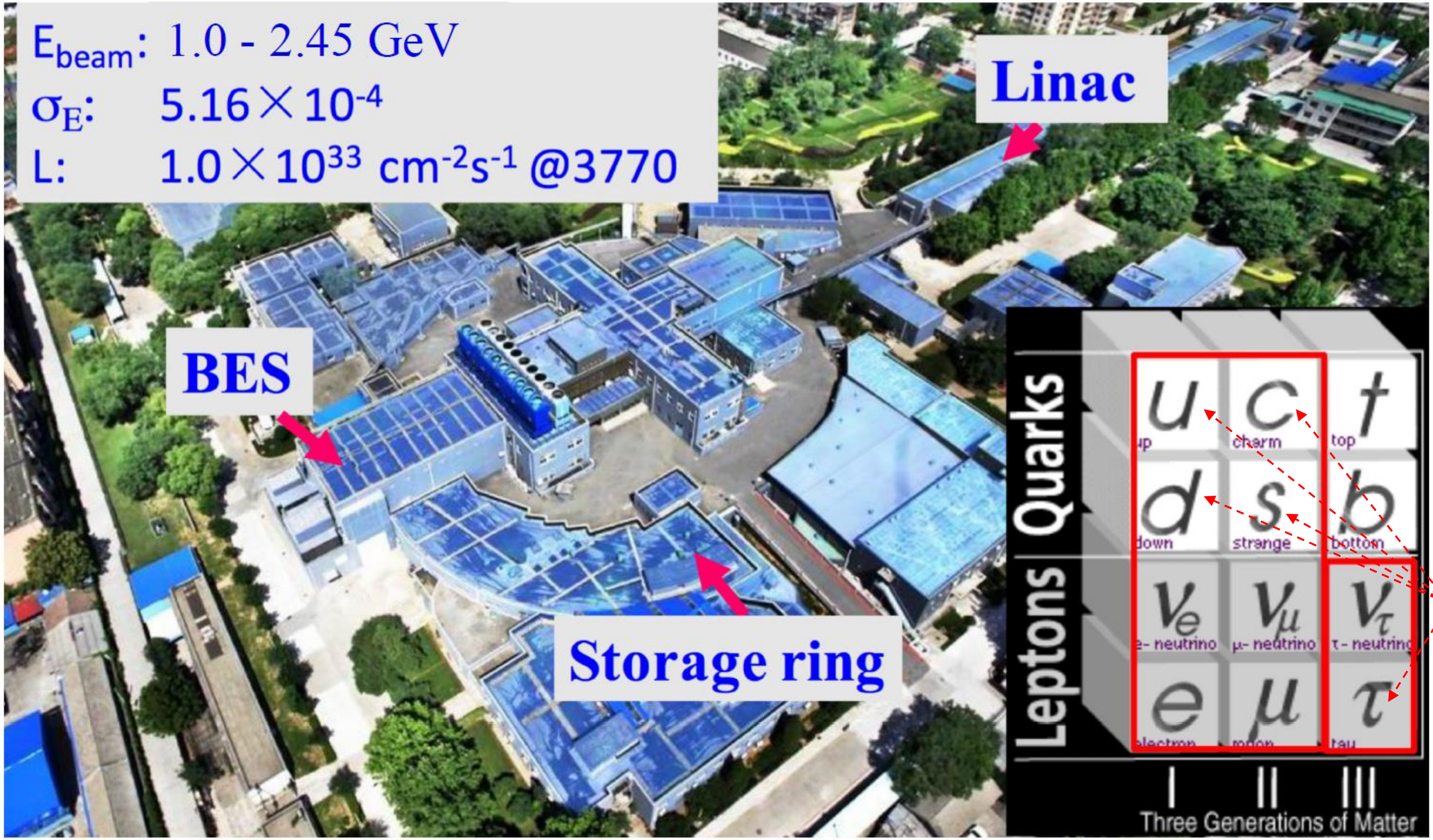
Nature (London) 593, 51 (2021)



Source	Contribution($\times10^{-11}$)
a_μ^{QED}	116584718.931 ± 0.104
a_μ^{Weak}	153.6 ± 1.0
$a_\mu^{\text{LO-HVP}}$ (R-ratio)	6931 ± 40
$a_\mu^{\text{LO-HVP}}$ (lattice)	7075 ± 55
$a_\mu^{\text{NLO-HVP}}$	-98.3 ± 0.7
$a_\mu^{\text{NNLO-HVP}}$	12.4 ± 0.1
a_μ^{HLbL}	92 ± 18
a_μ^{SM}	116591954 ± 58
a_μ^{exp}	116592061 ± 41
Δa_μ	107 ± 71 (1.5σ)

The R-ratio approach still gives the best prediction to $a_\mu^{\text{LO-HVP}}$

BEPCII and BESIII: BEPCII



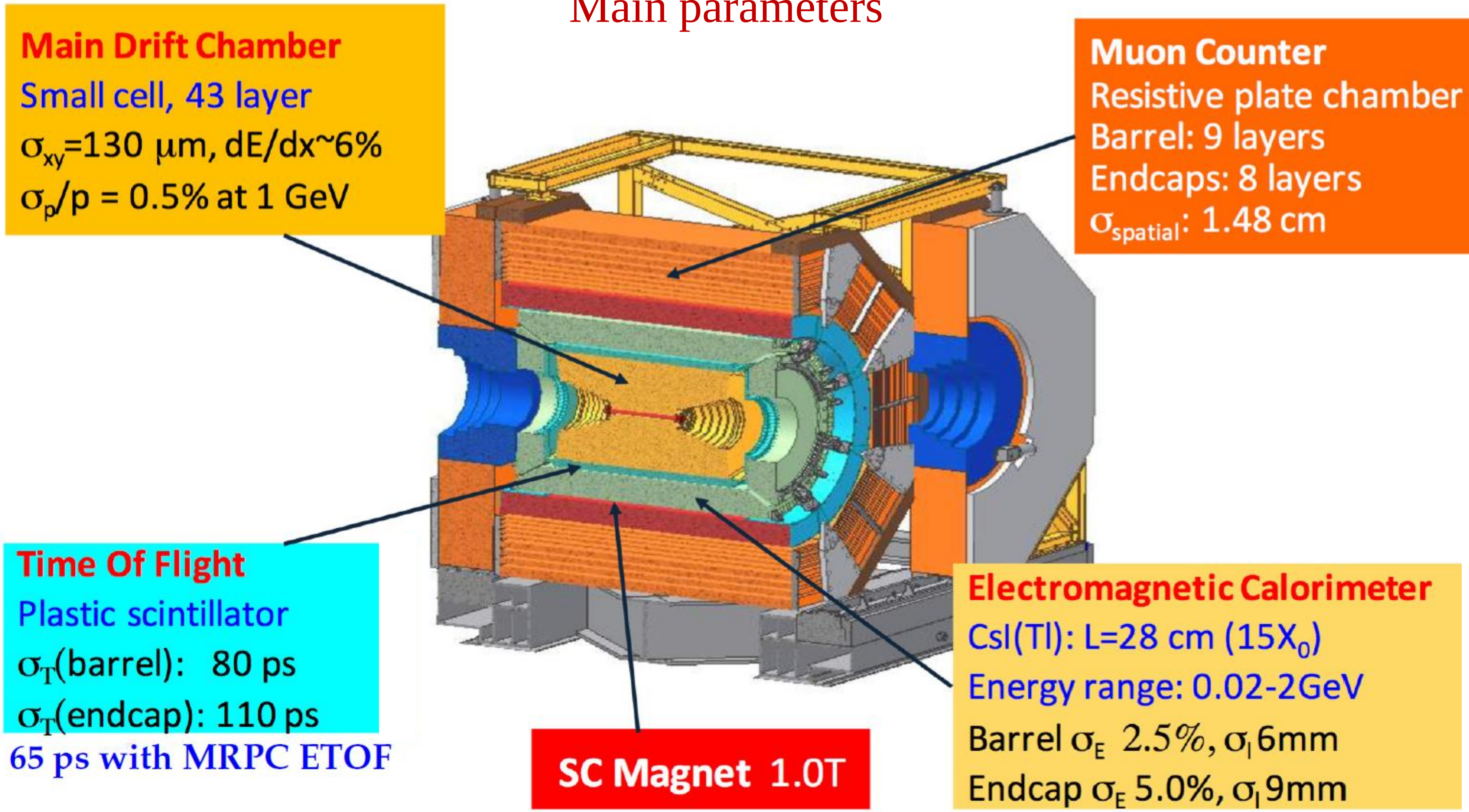
Bird's-eye view of BEPCII and BESIII

Physics energy region of BEPCII / BESIII

BEPCII: Beijing electron-positron collider II

BEPCII and BESIII: BESIII

Main parameters



BESIII: BEijing Spectrometer III

Methodology: R value measurement

Experimentally, the R value is determined by

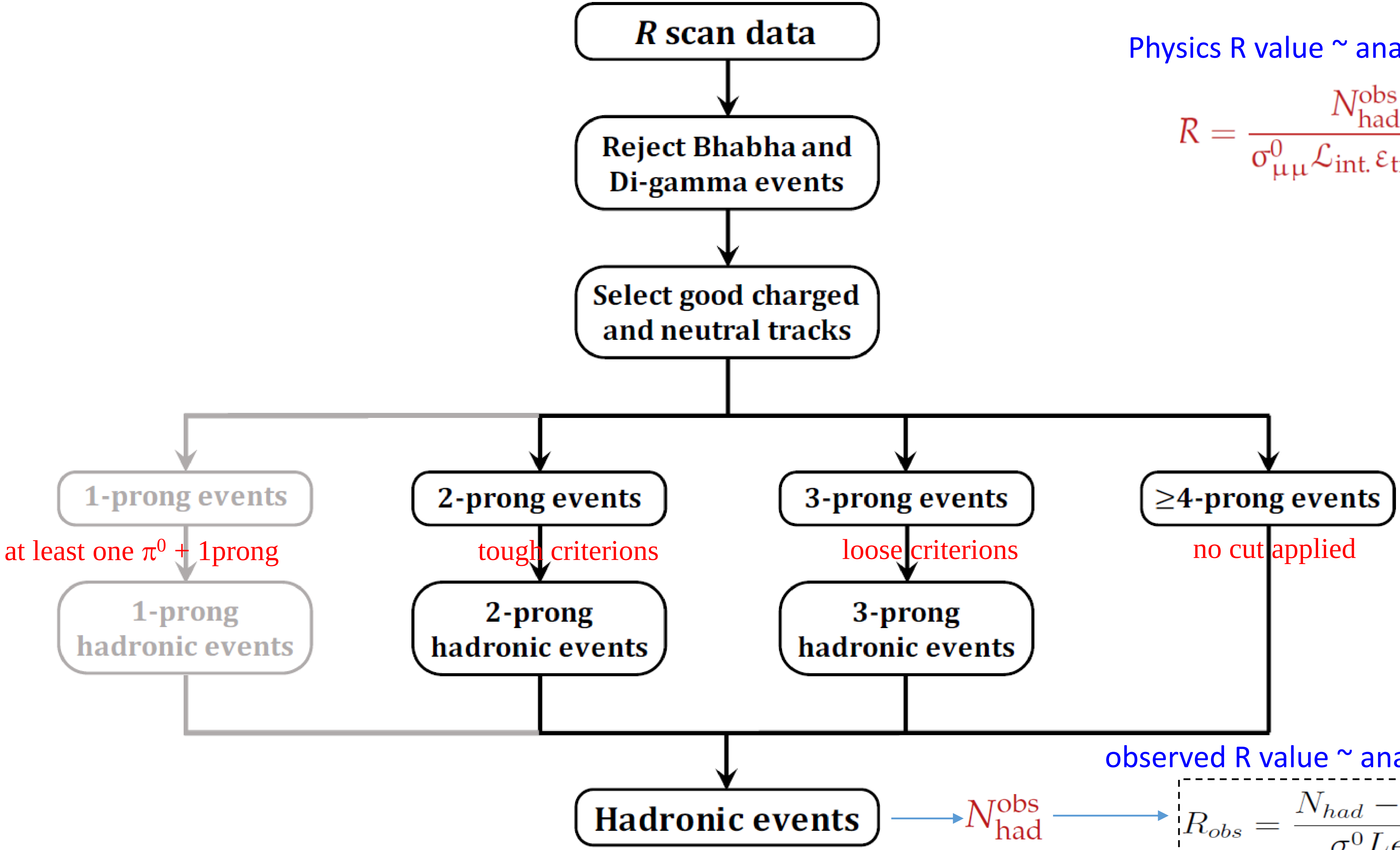
$$R = \frac{N_{\text{had}}^{\text{obs}} - N_{\text{bkg}}}{\sigma^0_{\mu\mu}\mathcal{L}_{\text{int.}}\varepsilon_{\text{trig}}\varepsilon_{\text{had}}(1+\delta)}$$

- $N_{\text{had}}^{\text{obs}}$: Numbers of observed hadronic events.
- N_{bkg}: Number of the residual background events.
- $\sigma^0_{\mu\mu}(s) = 86.85\ \text{nb}/s$: Leading order QED cross section for $e^+e^- \to \mu^+\mu^-$.
- $\mathcal{L}_{\text{int.}}$: Integrated luminosity is measured by analyzing Bhabha events.
- $\varepsilon_{\text{trig}}$: Trigger efficiency $\sim 100\%$.
- ε_{had}: Detection efficiency of the hadronic events.
- $(1+\delta)$: ISR correction factor.

► **Determination of ε_{had} is the most challenging task!**

► **Two different signal simulation models are developed and investigated intensively.**

Methodology: data analysis strategy



$N_{\rm had}^{\rm obs}$

Physics R value ~ analysis independent

$$R = \frac{N_{\rm had}^{\rm obs} - N_{\rm bkg}}{\sigma_{\mu\mu}^{0}\mathcal{L}_{\rm int.}\varepsilon_{\rm trig}\varepsilon_{\rm had}(1+\delta)}$$

$\varepsilon_{\rm had}$?

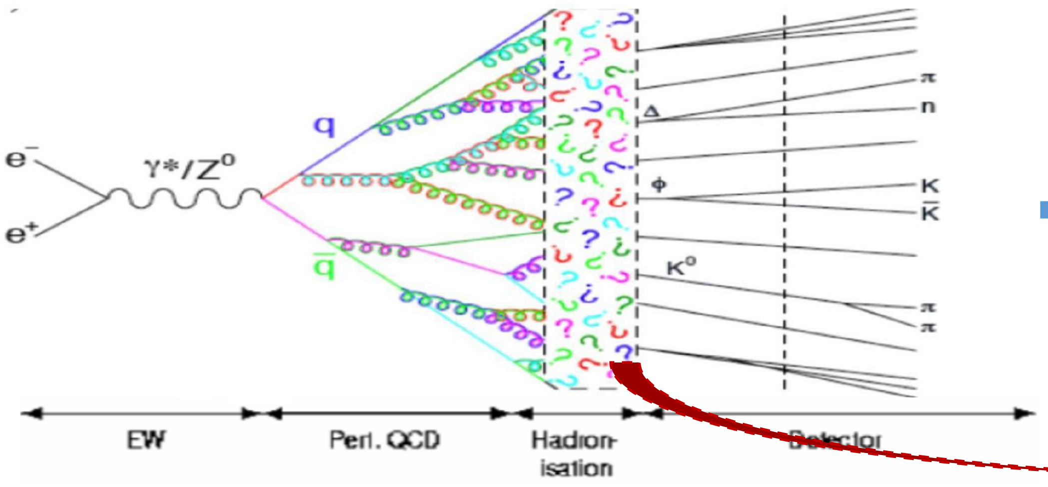
$(1+\delta)$?

observed R value ~ analysis dependent

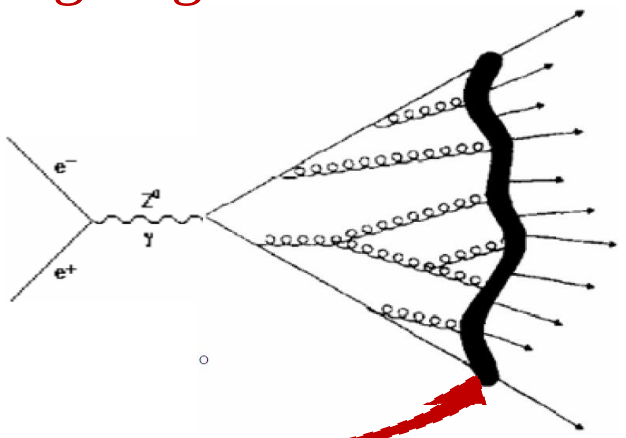
$$R_{obs} = \frac{N_{had} - N_{bkg}}{\sigma_{\mu}^{0} L \epsilon_{trg}}$$

Signal simulation: hadronic generator

General hadronization picture



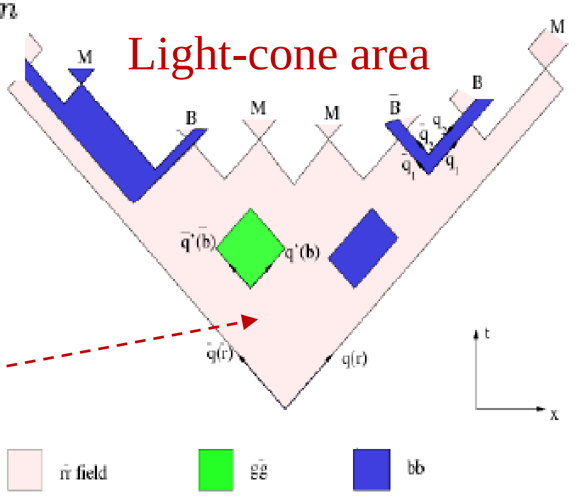
Lund string fragmentation model



At BEPC energy region, Lund area law formula:

$$d\wp_n(q\bar{q}\rightarrow m_1,m_2,\cdots m_n)=(2\pi)^4\delta(1-\sum_{j=1}^{n}\frac{m_{\perp j}^2}{sz_j})\delta(1-\sum_{j=1}^{n}z_j)\delta(\sum_{j=1}^{n}\vec{k}_j)\sum|\mathcal{M}_{LUND}|^2 d\Phi_n$$

$$z_j \equiv (E_j \pm p_{zj})/(E_0 \pm P_{z0}) \qquad \vec{k}_j \equiv \frac{\vec{p}_{\perp j}}{2\sigma}$$



Transverse momentum (Gaussian-like form)： $\mathcal{M}_{\perp}=\exp(-\sum_{j=1}^{n}\vec{k}_j^{\,2})$

Longitudinal momentum (Lund area law)： $\mathcal{M}_{//}=\exp(i\xi\mathcal{A}_n)$ $\quad \xi=\frac{1}{2\kappa}+i\frac{b}{2}$

Signal simulation: LUARLW

hep-ph/9910285

Few-Body States in Lund String Fragmentation Model

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Abstract

The well-known Monte Carlo simulation packet JETSET is not built in order to describe few-body states (in particular at the few GeV level in e^+e^- annihilation as in BEPC). In this note we will develop the formalism to use the basic Lund Model area law directly for Monte Carlo simulations.

Main features of the LUARLW model:

- A self-consistent inclusive generator.
- Initial-state radiation (ISR) process is implemented from $2m_\pi$ to 5 GeV.
- Kinematic quantities of initial hadrons are sampled by the Lund area law.
- Phenomenological parameters are tuned based on comparisons between data and MC.

Signal simulation: LUARLW

Function of LUARLW: it can simulate ISR inclusive continuous channels and resonant $J^{PC} = 1^{--}$ resonances from $2m_\pi$ –5 GeV, parameters need tuning by data.

$$e^+e- \Rightarrow \gamma^* \Rightarrow \rho(770), \omega(782), \phi(1020), \omega(1420), \rho(1450), \omega(1650), \phi(1680), \rho(1700)$$

$$e^+e^- \Rightarrow \gamma^* \Rightarrow \begin{cases} q\bar{q} \Rightarrow \text{string} \Rightarrow \text{hadrons} \\ gq\bar{q} \Rightarrow \text{string} + \text{string} \Rightarrow \text{hadrons} \\ ggq\bar{q} \Rightarrow \text{string} + \text{string} + \text{string} \Rightarrow \text{hadrons} \end{cases}$$

$$e^+e^- \Rightarrow \gamma^* \Rightarrow J/\psi \Rightarrow \begin{cases} \gamma^* \Rightarrow e^+e^-,\ \mu^+\mu^- \\ q\bar{q} \Rightarrow \text{string} \Rightarrow \text{hadrons} \\ ggg \Rightarrow \text{string} + \text{string} + \text{string} \Rightarrow \text{hadrons} \\ \gamma gg \Rightarrow \gamma + \text{string} + \text{string} \Rightarrow \gamma + \text{hadrons} \\ \gamma\eta_c \end{cases}$$

$$e^+e^- \Rightarrow \gamma^* \Rightarrow \psi(2S) \Rightarrow \begin{cases} \gamma^* \Rightarrow e^+e^-,\ \mu^+\mu^-,\ \tau^+\tau^- \\ \gamma^* \Rightarrow q\bar{q} \Rightarrow \text{string} \Rightarrow \text{hadr} \\ ggg \Rightarrow \text{string} + \text{string} + \text{string} \Rightarrow \text{hadrons} \\ \gamma gg \Rightarrow \gamma + \text{string} + \text{string} \Rightarrow \gamma + \text{hadrons} \\ \pi^+\pi^- J/\psi,\ \pi^0\pi^0 J/\psi,\ \pi^0 J/\psi,\ \eta J/\psi,\ \gamma\chi_{cJ},\ \phi\eta \end{cases}$$

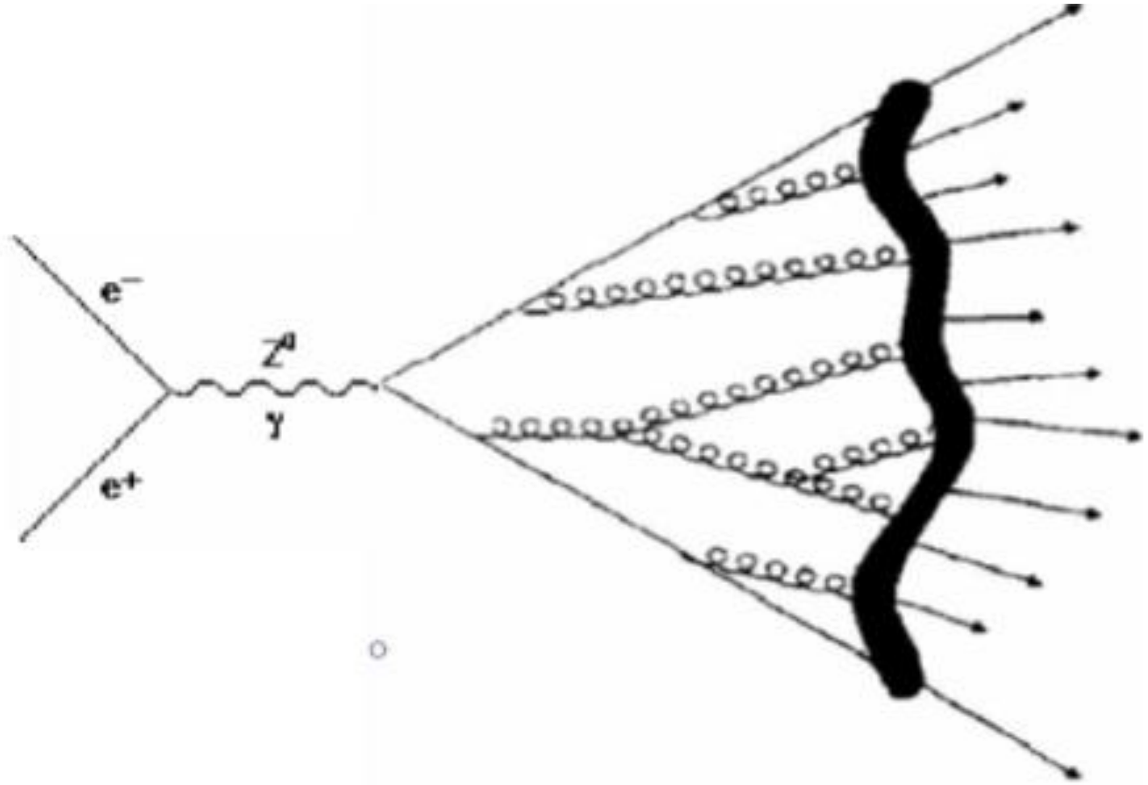
$$e^+e^- \Rightarrow \gamma^* \Rightarrow \psi(3770) \Rightarrow \begin{cases} \gamma^* \Rightarrow e^+e^-,\ \mu^+\mu^-,\ \tau^+\tau^- \\ D^0\bar{D}^0,\ D^+\bar{D}^- \\ \gamma^* \Rightarrow q\bar{q} \Rightarrow \text{string} \Rightarrow \text{hadrons} \\ ggg \Rightarrow \text{string} + \text{string} + \text{string} \Rightarrow \text{hadrons} \\ \gamma gg \Rightarrow \gamma + \text{string} + \text{string} \Rightarrow \gamma + \text{hadrons} \\ \pi^+\pi^- J/\psi,\ \pi^0\pi^0 J/\psi,\ ,\ \pi^0 J/\psi,\ \eta J/\psi,\ \gamma\chi_{cJ} \end{cases}$$

$$e^+e^- \Rightarrow \gamma^* \Rightarrow \begin{cases} \psi(4040) \Rightarrow D\bar{D}, D^*\bar{D}^*, D\bar{D}^*, \bar{D}D^*, D_s\bar{D}_s; \\ \psi(4160) \Rightarrow D\bar{D}, D^*\bar{D}^*, D\bar{D}^*, \bar{D}D^*, D_s\bar{D}_s, D_s\bar{D}_s^*; \\ \psi(4415) \Rightarrow D\bar{D}, D^*\bar{D}^*, D\bar{D}^*, \bar{D}D^*, D_s\bar{D}_s, D_s\bar{D}_s^*, D_s^*\bar{D}_s^*. \end{cases}$$

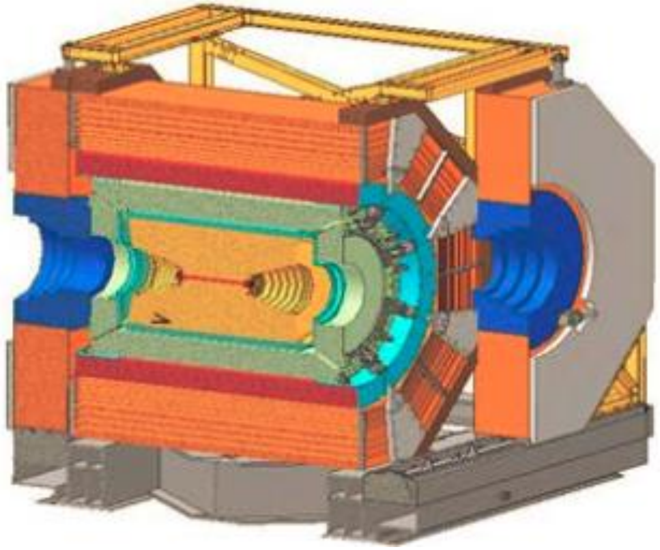
$$e^+e- \Rightarrow \gamma^* \Rightarrow X(4160), X(4260)\cdots \quad \text{with} \quad J^{PC} = 1^{--}$$

Good generator: MC simulations and data agree well for many final state distributions.

Methodology: Monte Carlo simulation



BESIII



Hadron production at vertex:
LUARLW

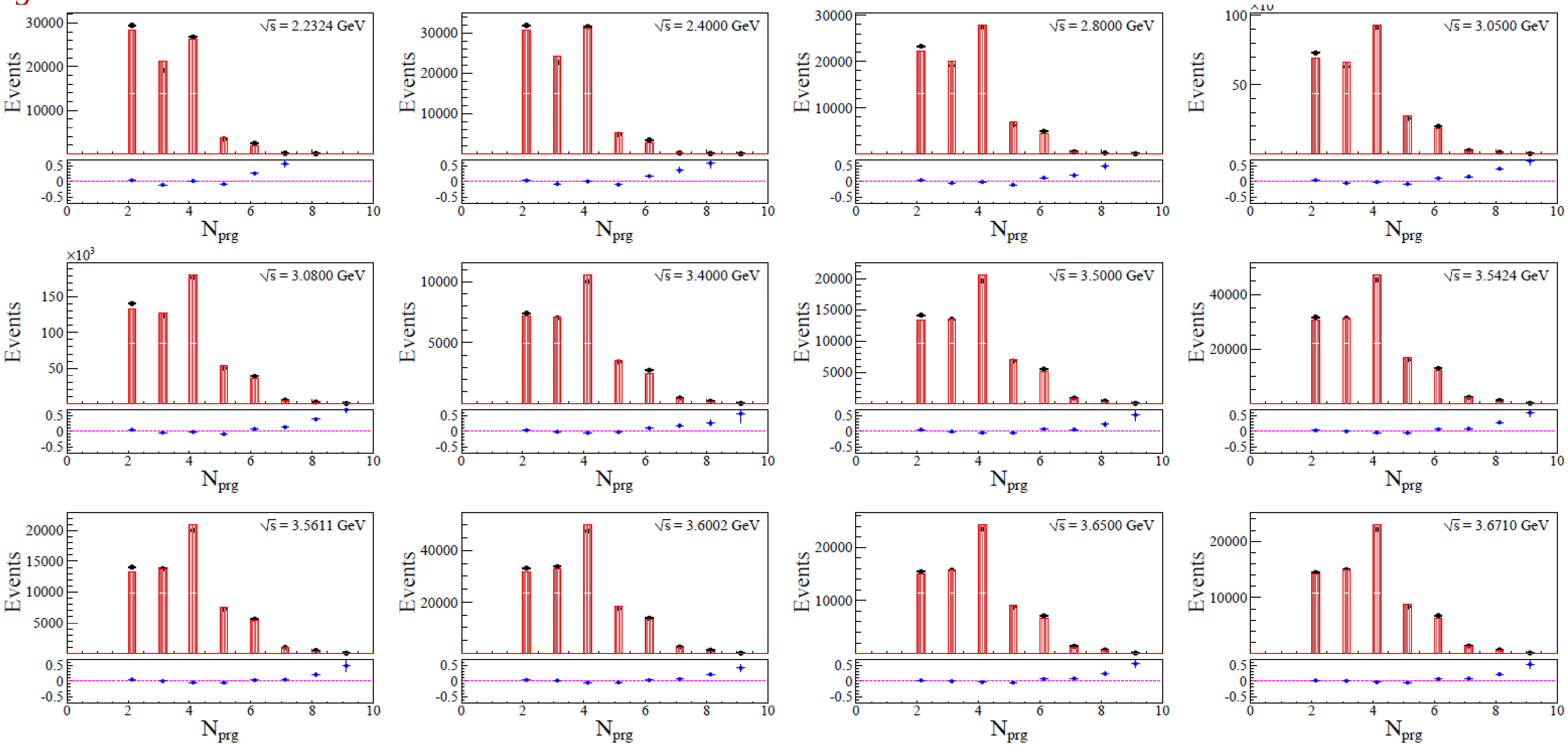
Particles decay:
JETSET table

Detector simulation:
GEANT4

BESIII MC data

Signal simulation: MC data production by LUARLW

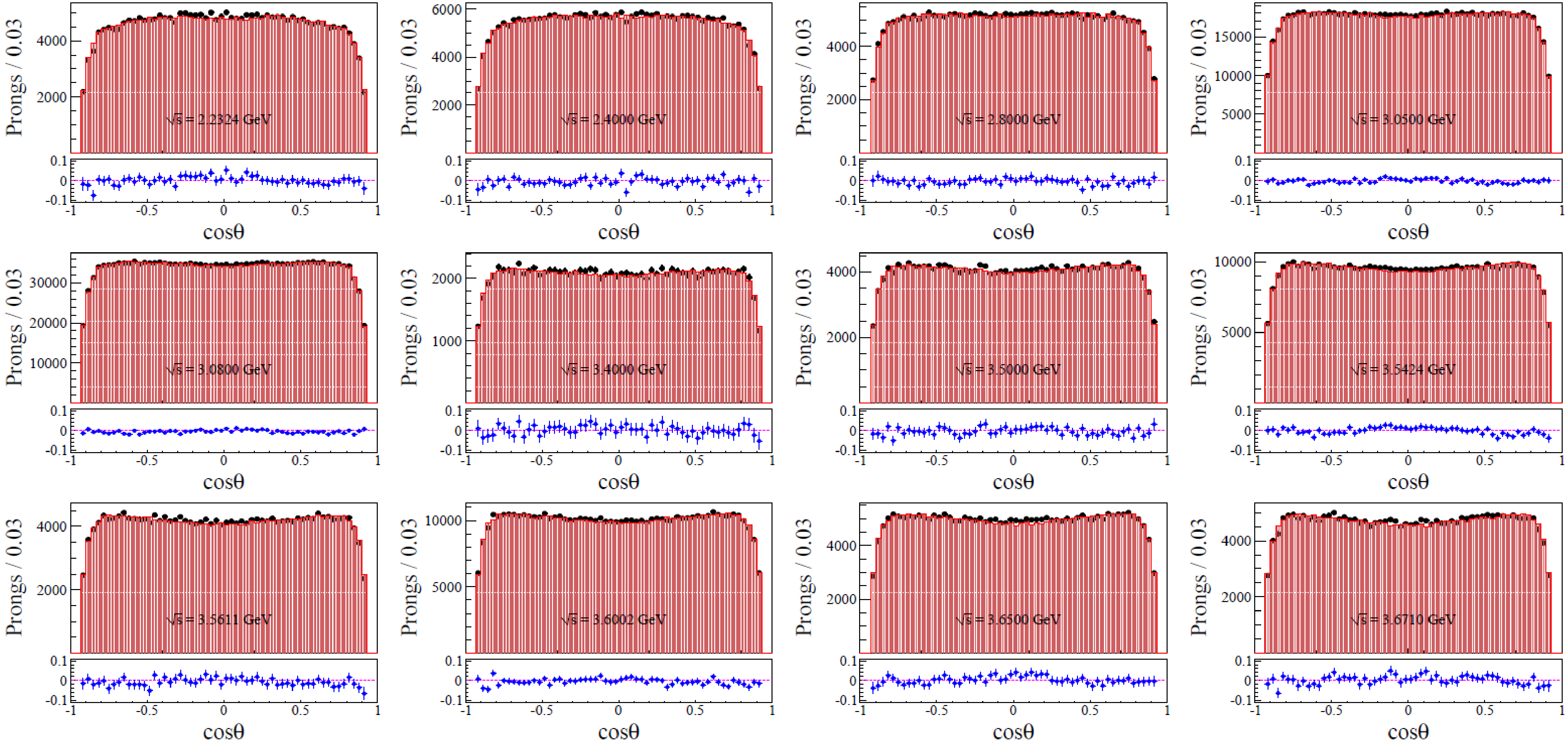
N_{prg} is the multiplicity of good charged tracks at detector level



The LUARLW model can reasonably reproduce the N_{prg} distributions in data

Signal simulation: MC data production by LUARLW

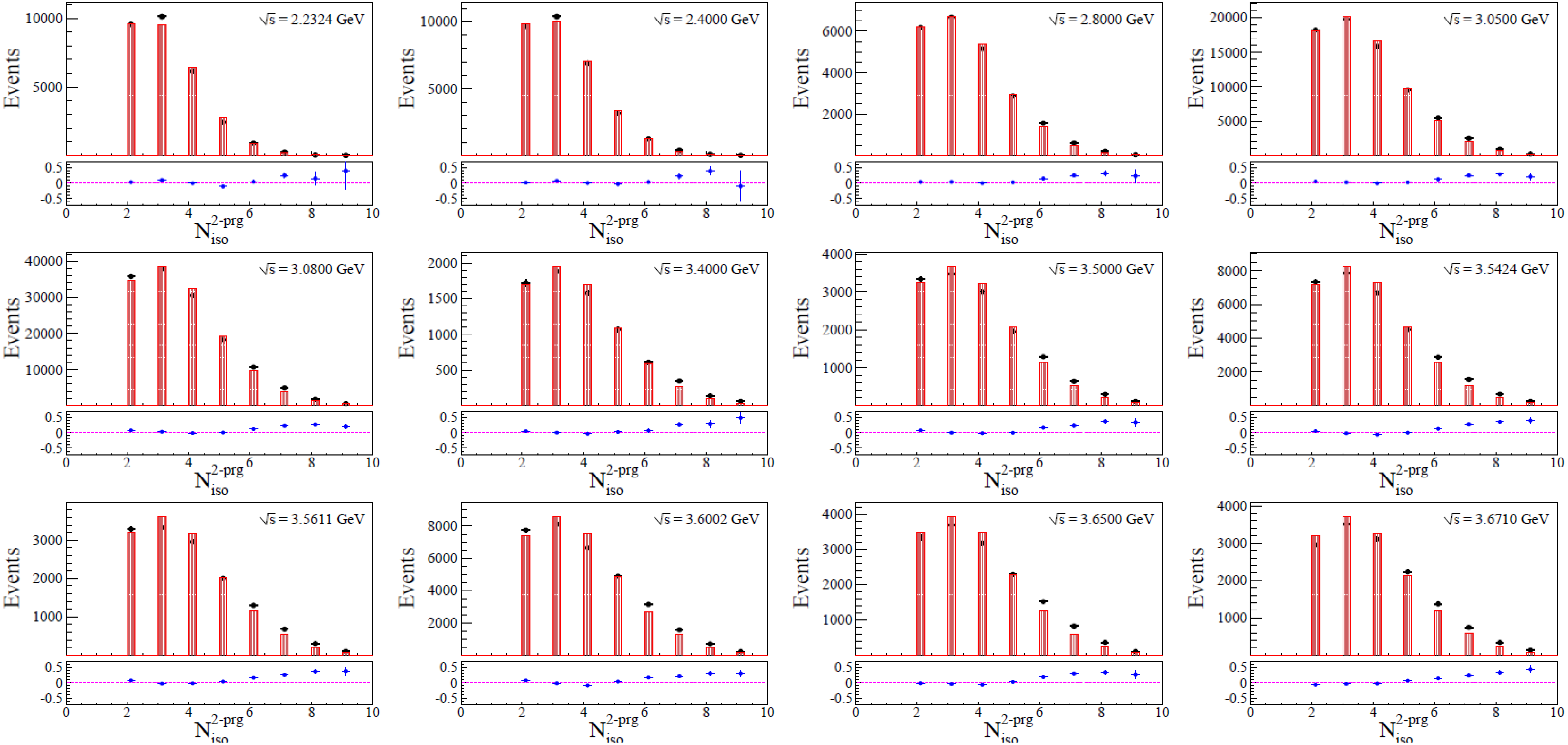
cosθ is the polar angle of good charged tracks at detector level



Good agreement between data and MC means the simulated hadronic event efficiency is reliable

Signal simulation: MC data production by LUARLW

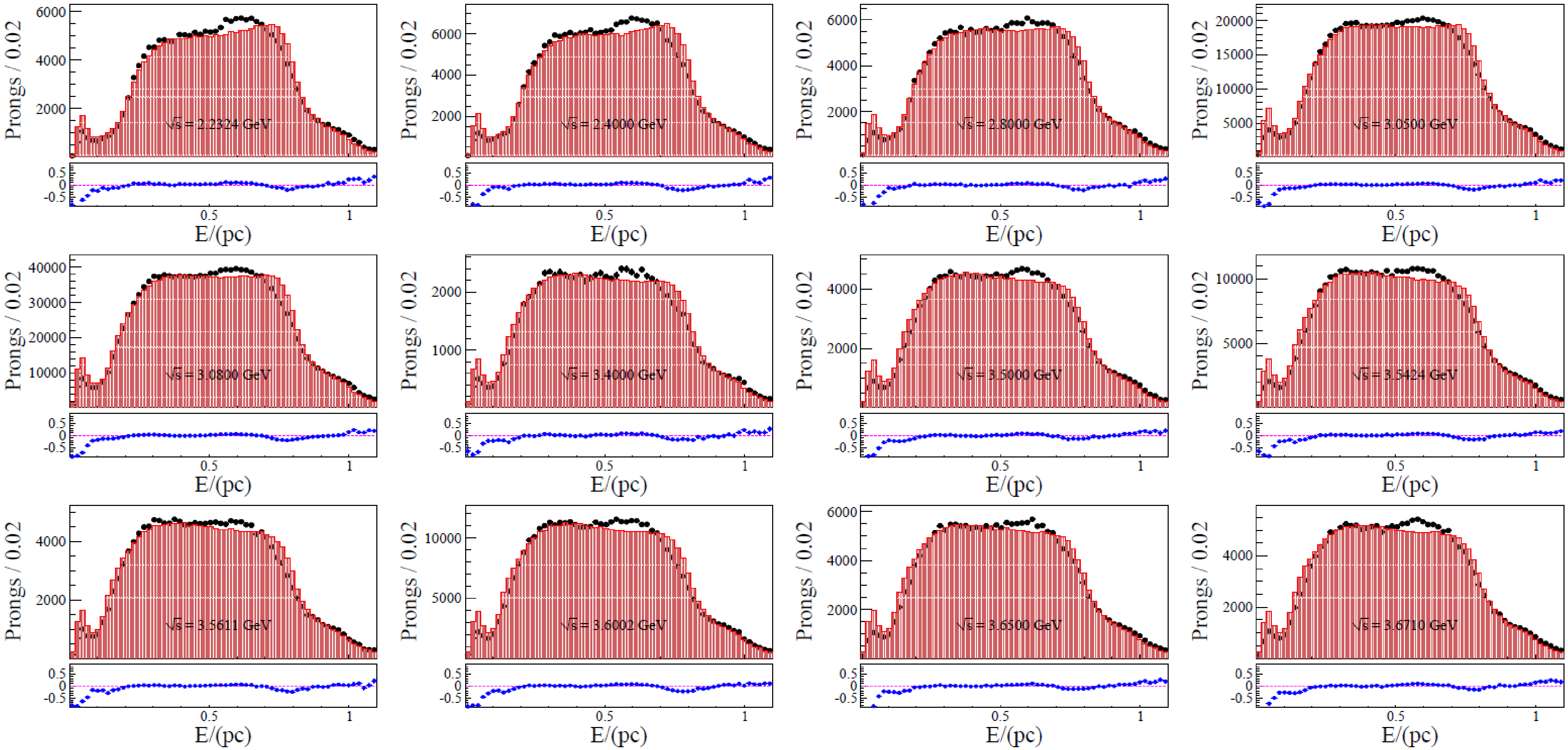
$N_{iso}^{2\text{-}prg}$ is the number of isolated photon in 2-prong events at detector level



$N_{iso}^{2\text{-}prg}$ distribution is crucial to suppress backgrounds in 2-prong events

Signal simulation: MC data production by LUARLW

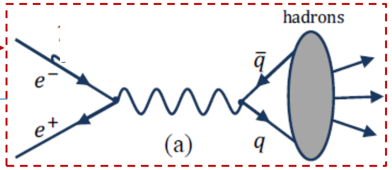
E/(*pc*) is the ratio of deposited energy and momentum of charged tracks



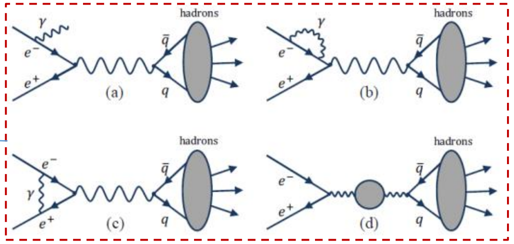
Background with $E/(pc)$ close to 1 is significantly suppressed in data.

Signal simulation: calculation of ISR correction factor in LUARLW

R definition: $R = \dfrac{\sigma^0_{had}(e^+e^- \to \gamma^* \to \text{hadrons})}{\sigma^0_{\mu\mu}(e^+e^- \to \gamma^* \to \mu^+\mu^-)}$

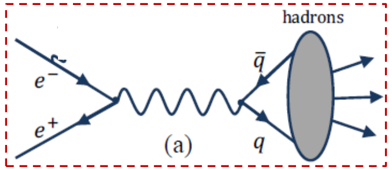


R measurement: $R = \dfrac{N_{had} - N_{bg}}{\sigma^0_{\mu\mu} L \epsilon_{trg} \epsilon_{had} (1+\delta)}$



Definition of ISR factor

（1+δ） =



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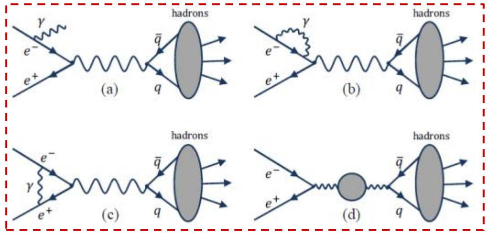
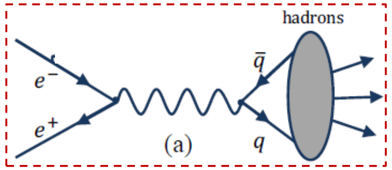




Radiator

Input of line-shape of R in full energy region

Vertex correction

Total hadronic cross section: $\sigma^{tot}_{had}(s) = \delta_{vert} \dfrac{\sigma^0_{had}(s)}{|1-\Pi(s)|^2} + \int_0^{x_m} F_{FD}(x,s) \dfrac{\sigma^0_{had}(s')}{|1-\Pi(s')|^2} dx$

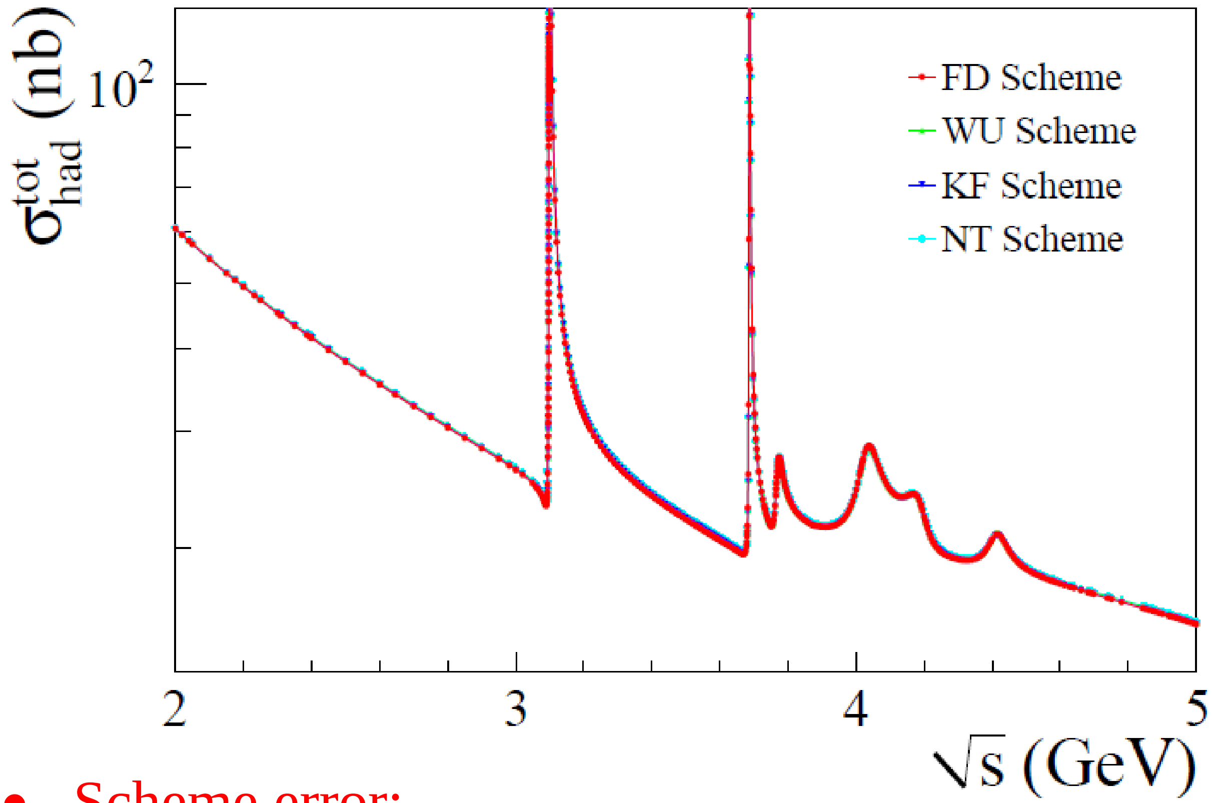
$$(1+\delta)(s) \equiv \sigma^{tot}_{had}(s) / \sigma^0_{had}(s)$$

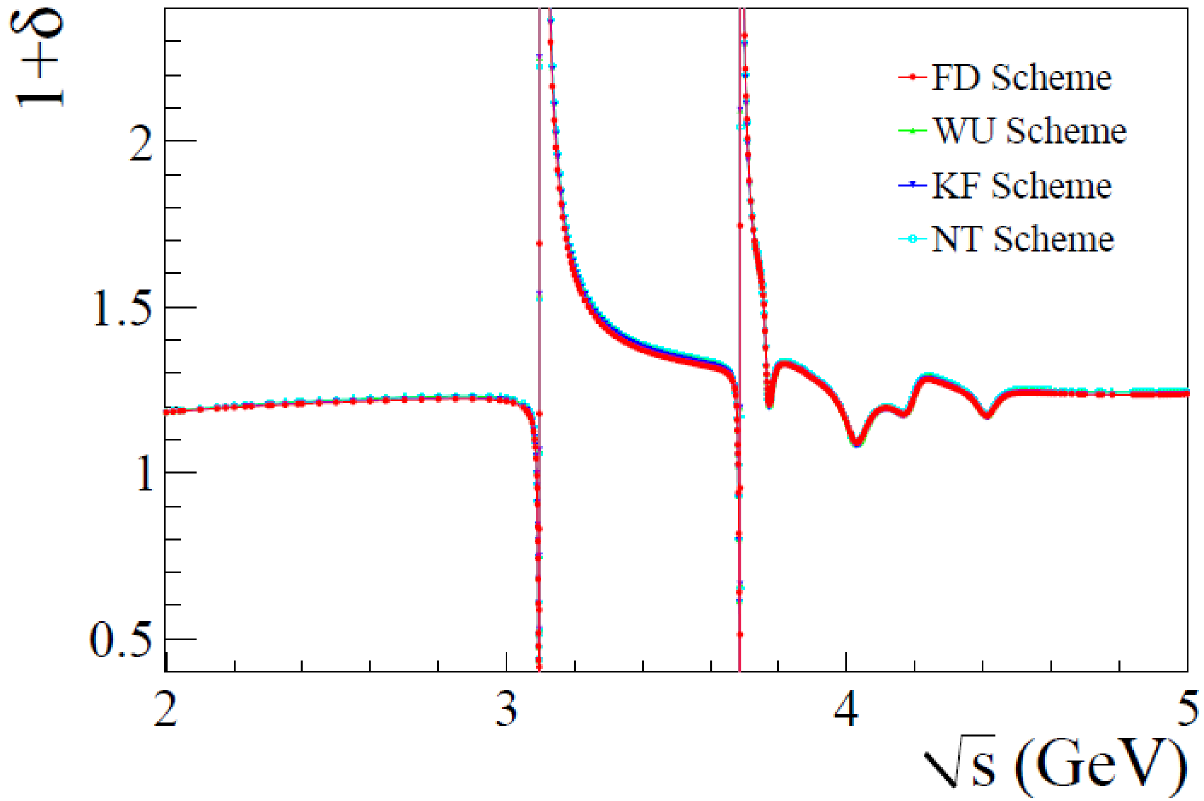
Line-shape of vacuum polarization factor

Maximum fraction of radiative initial pjoton $x_m = 1 - 4m_\pi^2/s$

Signal simulation: calculation of ISR correction factor in LUARLW

Line-shape of total hadronic cross section and (1+δ) by different schemes





- Scheme error:
  for same input $\sigma^0(s')$, difference between different scheme is considered as theoretical uncertainty
- Input error:
  for the nominal scheme, the change of (1+ δ) by error of $\sigma^0(s')$ line-shape is accounted as input error

Systematic uncertainty

According to the experimental definition of R, its uncertainty is roughly expressed as

$$\left(\frac{\Delta R}{R}\right)^2_{\mathrm{sys}} = \left(\frac{\Delta \tilde{N}}{\tilde{N}}\right)^2 + \left(\frac{\Delta \sigma^0_{\mu\mu}}{\sigma^0_{\mu\mu}}\right)^2 + \left(\frac{\Delta \mathcal{L}_{\mathrm{int.}}}{\mathcal{L}_{\mathrm{int.}}}\right)^2 + \left(\frac{\Delta \varepsilon_{\mathrm{trig}}}{\varepsilon_{\mathrm{trig}}}\right)^2 + \left(\frac{\Delta \varepsilon_{\mathrm{had}}}{\varepsilon_{\mathrm{had}}}\right)^2 + \left[\frac{\Delta(1+\delta)}{(1+\delta)}\right]^2,$$

where

$$\tilde{N} = \frac{N^{\mathrm{net}}_{\mathrm{had}}}{\varepsilon_{\mathrm{had}}} = \frac{N^{\mathrm{obs}}_{\mathrm{had}} - N_{\mathrm{bkg}}}{\varepsilon_{\mathrm{had}}}$$

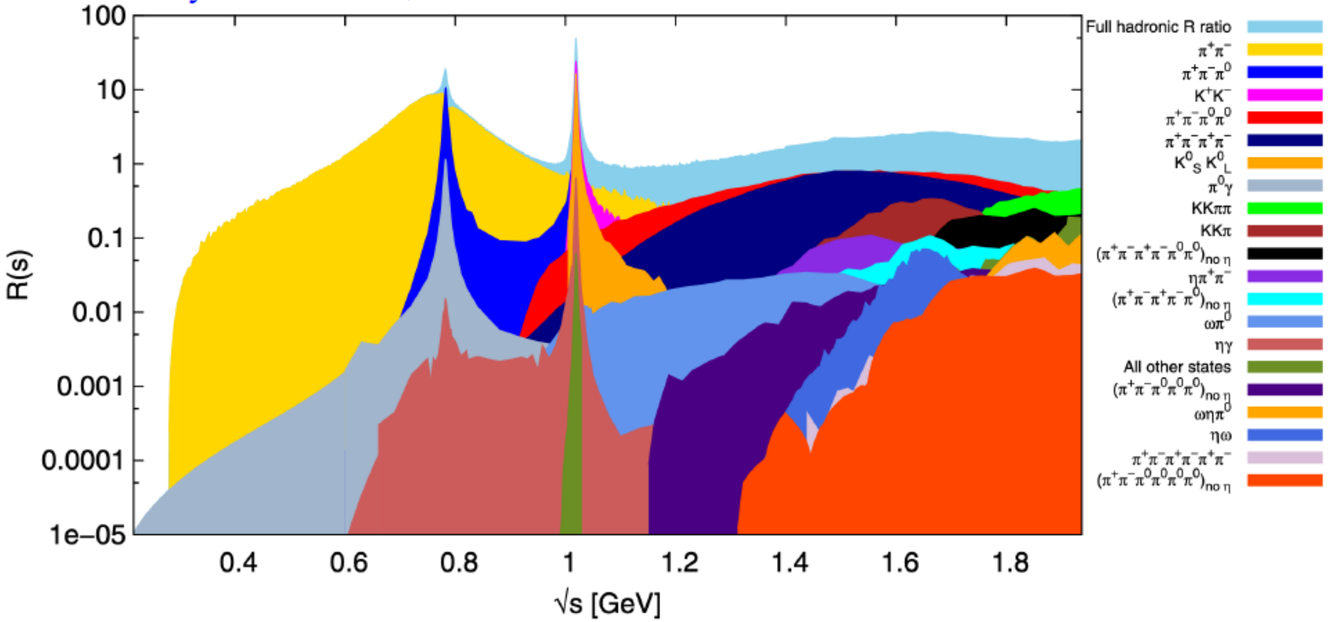
In practice, the uncertainties are addressed in following different aspects:

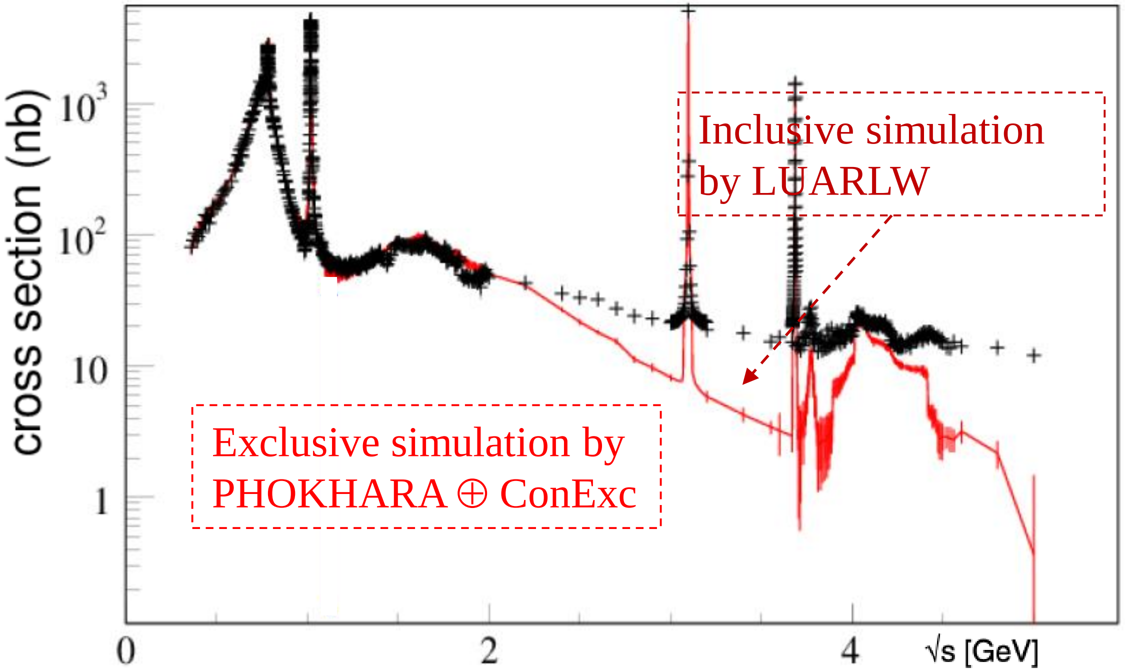
- Event selection: all implemented selection criteria are slightly varied.
- Background estimation: different methods and background simulation models are used.
- $\sigma^0_{\mu\mu}$: uncertainty is negligible due to the high precision of QED.
- $\mathcal{L}_{\mathrm{int.}}$: uncertainty is directly cited from published results.
- $\varepsilon_{\mathrm{trig}}$: $\varepsilon_{\mathrm{trig}}$ approaches to 100% with an uncertainty less than 0.1%.
- Signal simulation: A different signal simulation model, HYBRID, is developed.
- ISR correction factor: considered in calculation precision and uncertainty in $\sigma^0_{\mathrm{had}}(s)$.

Systematic uncertainty: the hybrid model

The first attempt of exclusive simulations in determination of hadronic efficiency

Phys. Rev. D 97, 114025 (2018)





+ : inclusively measured hadronic cross section

+ : sum of exclusively measured cross section

HYBRID = PHOKHARA ⊕ ConExc ⊕ LUARLW

The main features of the HYBRID model:

- Combination of THREE different well-established simulation models.
- As much as currently known experimental knowledges are implemented.
- Different ISR and VP correction schemes are adopted.

Systematic uncertainty: the hybrid model

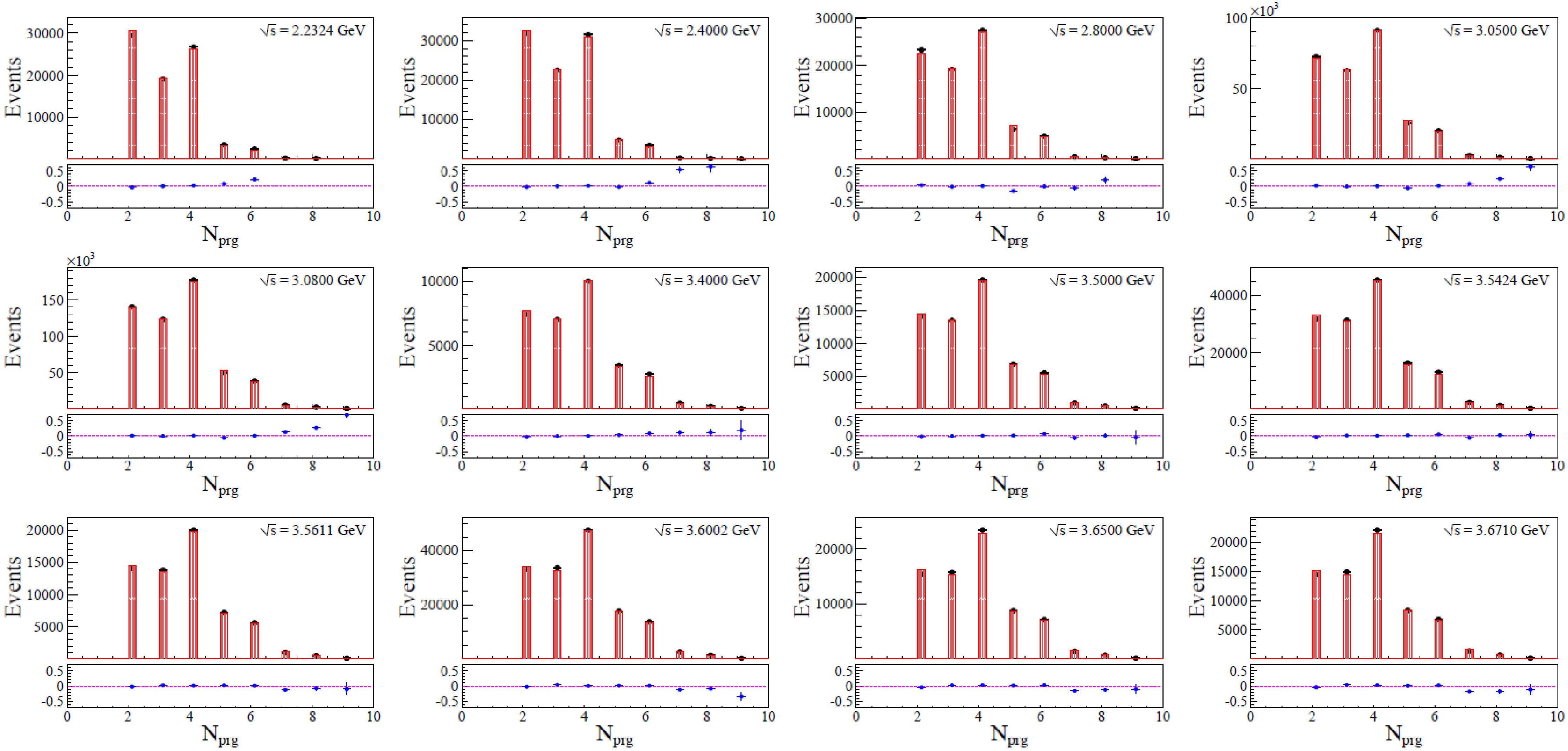
Construction of HYBRID generator

- HYBRID is consisted of CONEXC, PHOKHARA and LUARLW components.
- PHOKHARA is used to simulate 10 exclusive processes with known cross sections and intermediate states, $e^+e^- \to 2\pi, 3\pi, 4\pi$ etc..
- CONEXC simulates 47 exclusive processes with known cross sections according to PHSP model, such as $e^+e^- \to K^+K^-\pi^0, K_S^0K^\pm\pi^\mp, K^+K^-\pi\pi, 5\pi, 6\pi$ and $\gamma_{\mathrm{ISR}}J/\psi$.
- As much as exclusive channels containing intermediate states are implemented in the CONEXC with their contributions to the related inclusive channels are excluded.
- LUARLW model is partially used to simulate remain unknown processes, in which a set of chosen parameters are tuned after comparing HYBRID simulations with data.
- Processes simulated by PHOKHARA or CONEXC are prohibited in LUARLW to avoid excessive generation of some specific processes.
- The residual double-generatings among the three components are negligible.

A lot of efforts have gone into engineering the HYBRID generator!

Systematic uncertainty: the HYBRID model

N_{prg} is the multiplicity of good charged tracks at detector level



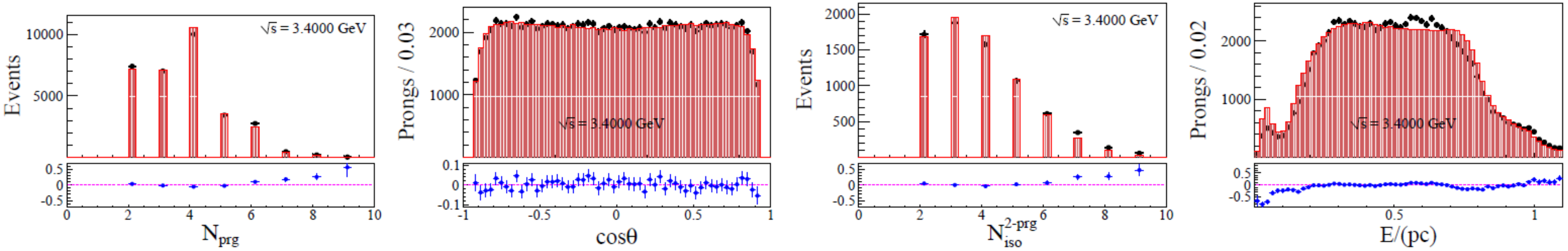
The HYBRID model gives better reproduction of the N_{prg} distributions.

Systematic uncertainty: comparison between LUARLW and HYBRID

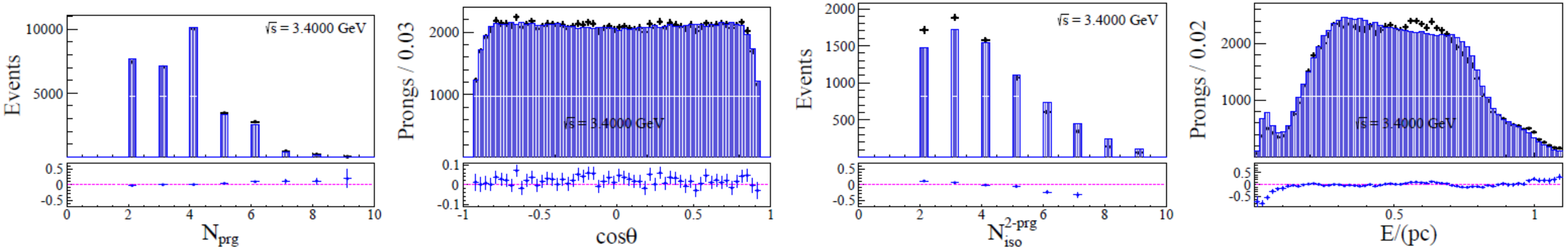
Comparison between LUARLW/HYBRID and data for a few observables

- N_{prg}: The number of detected the good charged tracks (prong).
- $\cos\theta$, E, and p: polar angle, deposited energy in EMC, and measured momentum in MDC.
- $N_{\text{iso}}^{\text{2-prg}}$: number of isolated photons of two-prong events.

LUARLW



HYBRID

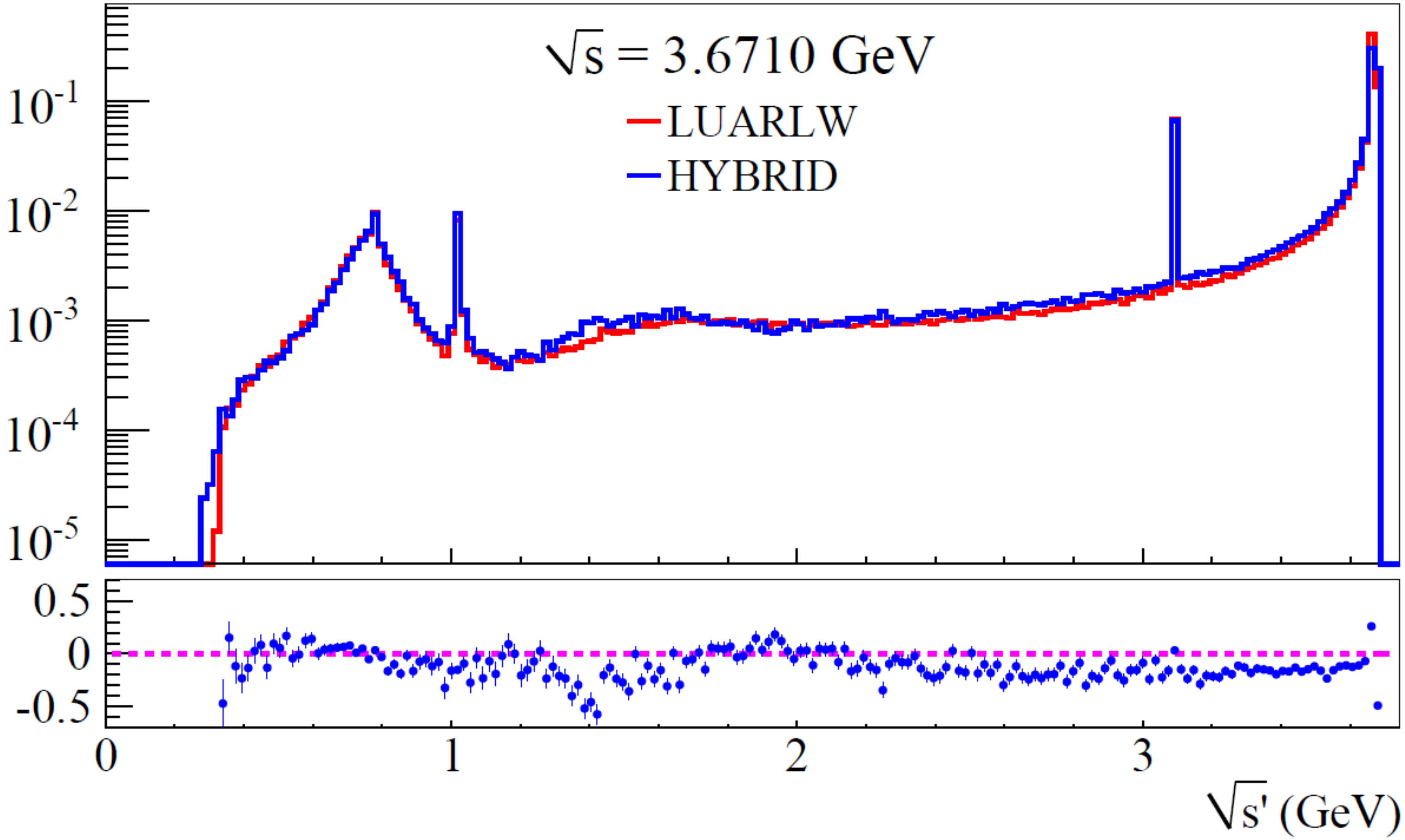


Both the two simulation models give good consistency with data!

Systematic uncertainty: comparison between LUARLW and HYBRID

Effective ISR energy distributions in LUARLW and HYBRID simulations

The comparisons of the $\sqrt{s'}$ spectrum between LUARLW and HYBRID



These two different simulation schemes result in consistent $\sqrt{s'}$ spectra!

Systematic uncertainty: LUARLW and HYBRID

Comparisons of resulted ε_{had} and $(1+\delta)$ between LUARLW and HYBRID:

$\sqrt{s}$ (GeV)	LUARLW ε_{had} (%)	HYBRID ε_{had} (%)	Diff. (%)	LUARLW $(1+\delta)$	HYBRID $(1+\delta)$	Diff. (%)
2.2324	64.45	64.50	-0.09	1.1955	1.2016	-0.52
2.4000	67.29	67.62	-0.49	1.2043	1.2118	-0.62
2.8000	72.25	73.16	-1.25	1.2185	1.2276	-0.74
3.0500	73.91	74.54	-0.85	1.1929	1.2040	-0.93
3.0600	73.88	74.54	-0.90	1.1825	1.1940	-0.97
3.0800	73.98	74.11	-0.18	1.1228	1.1357	-1.15
3.4000	74.81	75.19	-0.50	1.3817	1.4009	-1.39
3.5000	75.32	75.88	-0.75	1.3509	1.3690	-1.33
3.5424	75.58	76.17	-0.78	1.3413	1.3587	-1.30
3.5538	75.50	76.23	-0.97	1.3384	1.3557	-1.29
3.5611	75.50	76.27	-1.02	1.3368	1.3542	-1.30
3.6002	75.73	76.52	-1.05	1.3285	1.3453	-1.26
3.6500	76.00	76.89	-1.16	1.3082	1.3234	-1.16
3.6710	76.11	77.11	-1.30	1.2597	1.2718	-0.96

- Same input $\sigma^0_{\text{had}}(s)$ but different ISR correction schems and VP operators $\Pi(s)$.
- The two simulation models are consistent both in ε_{had} and $(1+\delta)$.
- Since there are correlations between ε_{had} and $(1+\delta)$, the differences in the final R values are taken as systematic uncertainties.

Systematic uncertainty: summary of uncertainty terms

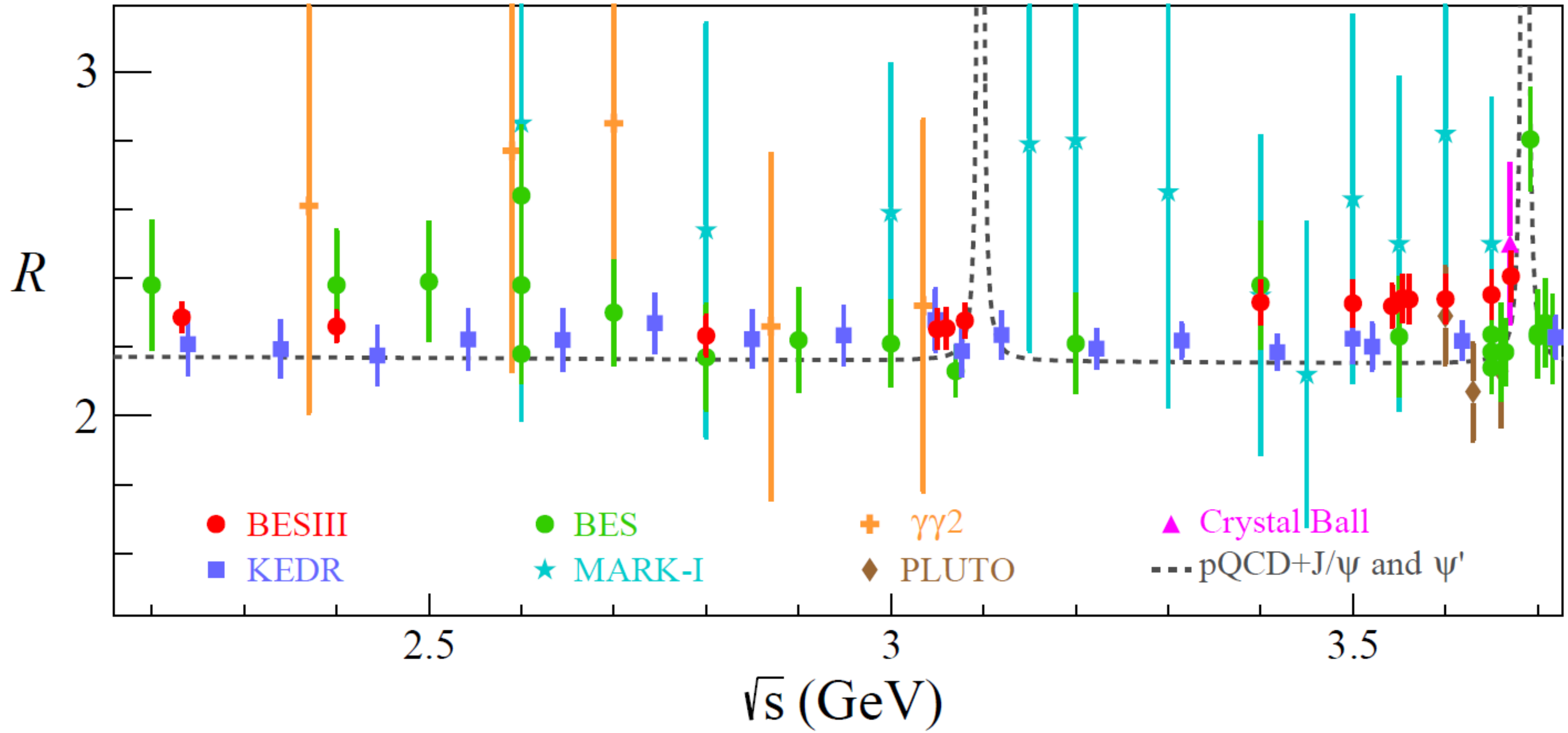
$\sqrt{s}$ (GeV)	Event selection	QED background	Beam background	Luminosity	Trigger efficiency	Signal model	ISR correction	Total
2.2324	0.41	0.23	0.28	0.80	0.10	0.60	1.15	1.62
2.4000	0.55	0.27	0.15	0.80	0.10	1.11	1.10	1.87
2.8000	0.58	0.28	0.34	0.80	0.10	1.97	1.06	2.48
3.0500	0.61	0.33	0.41	0.80	0.10	1.76	1.01	2.33
3.0600	0.60	0.34	0.48	0.80	0.10	1.84	1.00	2.39
3.0800	0.61	0.35	0.35	0.80	0.10	1.31	1.05	2.02
3.4000	0.65	0.33	0.16	0.80	0.10	1.86	1.24	2.49
3.5000	0.60	0.35	0.62	0.80	0.10	2.05	1.16	2.66
3.5424	0.61	0.37	0.01	0.80	0.10	2.05	1.14	2.58
3.5538	0.66	0.31	0.39	0.80	0.10	2.22	1.13	2.74
3.5611	0.74	0.34	0.34	0.80	0.10	2.28	1.12	2.81
3.6002	0.66	0.33	0.38	0.80	0.10	2.27	1.09	2.77
3.6500	0.53	0.35	0.69	0.80	0.10	2.28	1.13	2.83
3.6710	0.61	0.42	0.63	0.80	0.10	2.23	1.04	2.77

- Systematic uncertainties dominated by the uncertainty of the signal simulation model.
- Last four sources are regarded as completely correlated between different energies.

Summary: results

Comparing BESIII R values with previously published results:

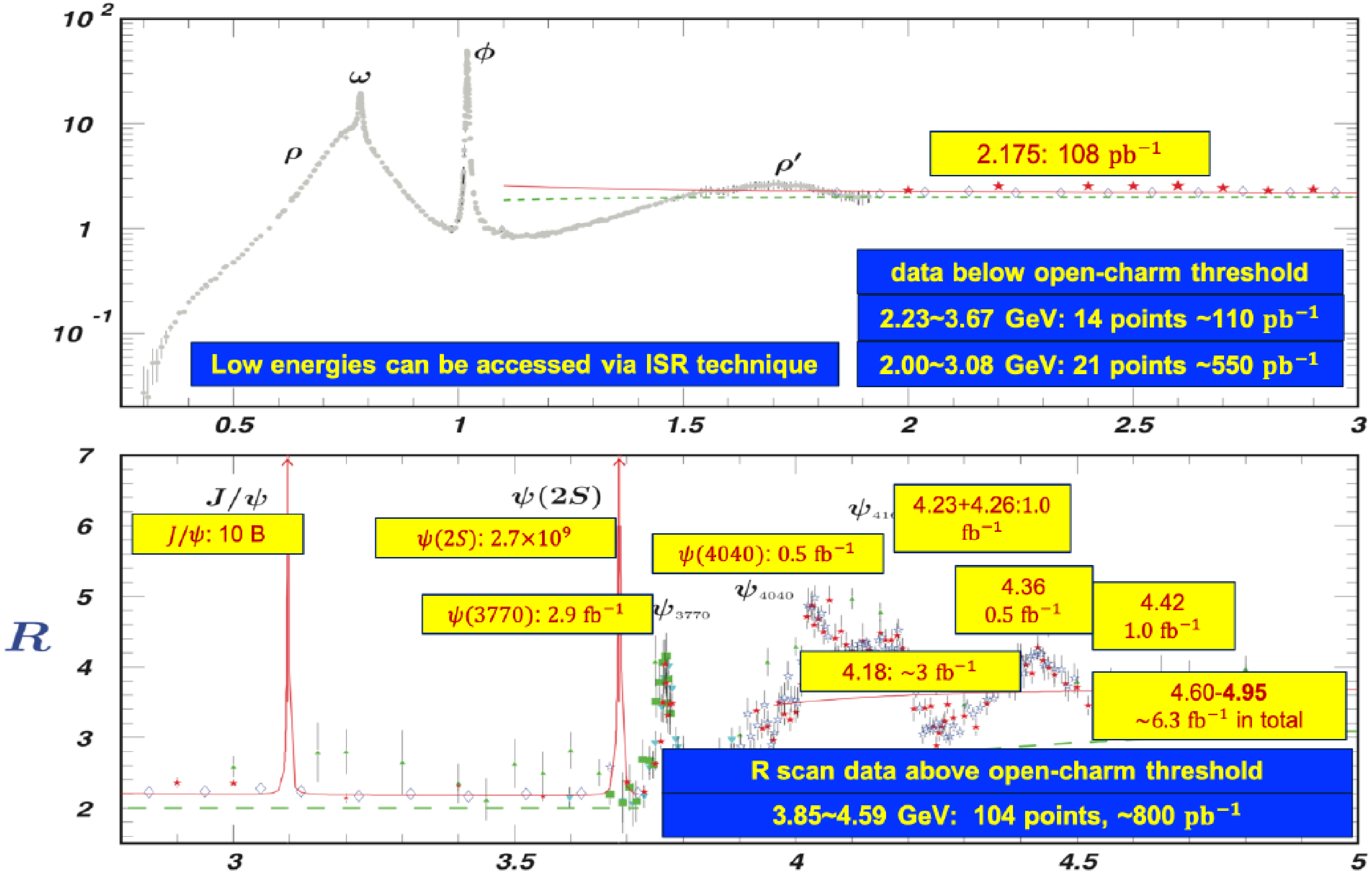
PRL128(2022)06200



- ► **The accuracy is better than 2.6% below 3.1** GeV **and 3.0% above.**
- ► **Larger than the pQCD prediction by 2.7σ between** 3.4 ~ 3.6 GeV.

Summary: prospect

Data samples taken at BESIII

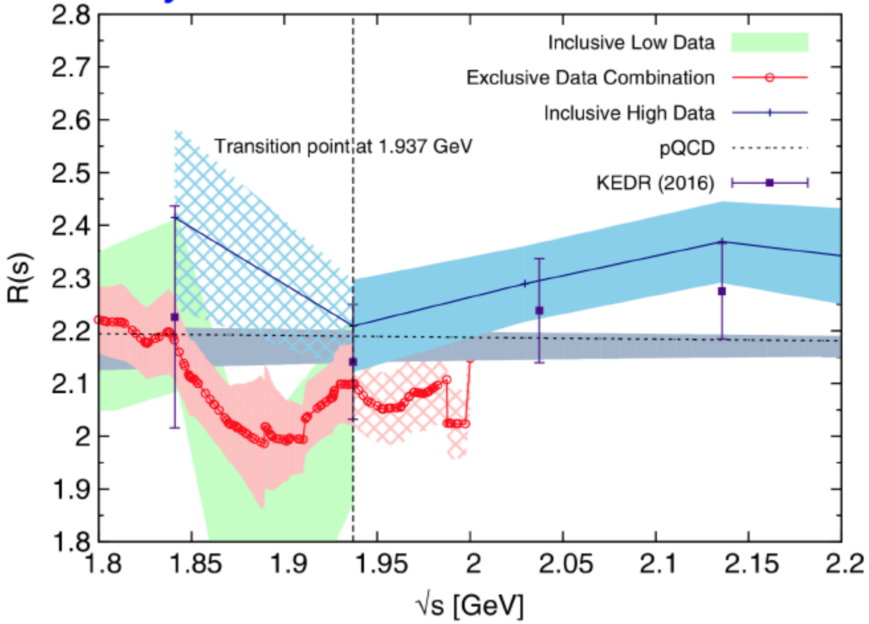


- BESIII has collected data from 2.00 to 4.95 GeV, which can be used for R measurement.
- R measurement both in the continuum and open-charm regions has significant impacts.
- Energy scan data samples below 2.0 GeV are desired at BESIII.

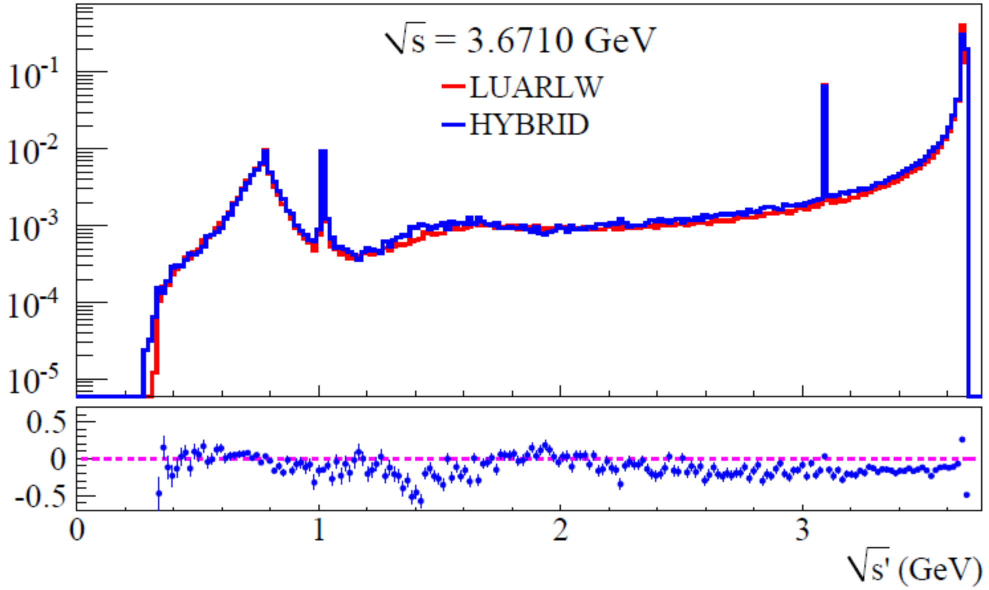
Summary: prospect

Different methods: inclusive, exclusive, ISR return

Phys. Rev. D 97, 114025 (2018)



Effective energy spectrum after ISR at 3.67 GeV



- R measured inclusively and exclusively at or below 2.0 GeV, and a comparison between them would be interesting.
- R measured via the ISR technique taking advantage of BESIII $\psi(3770)$ data, the R value from $\pi^+\pi^-$ threshold to continuum region can be accessed.
- Both of these two attempts will contribute to understanding the discrepancy of muon anomaly between SM calculation and experiment measurement.

Summary and outlook

- Improving the accuracy of R value is of great importance for precision test of standard model.
- The first round measurement of R value at BESIII is published and more results are coming soon.
- There are many possibilities of R measurement at BESIII.

Thanks for your attention!