R Measurement at BES

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IHEP, Beijing

Hadron 99

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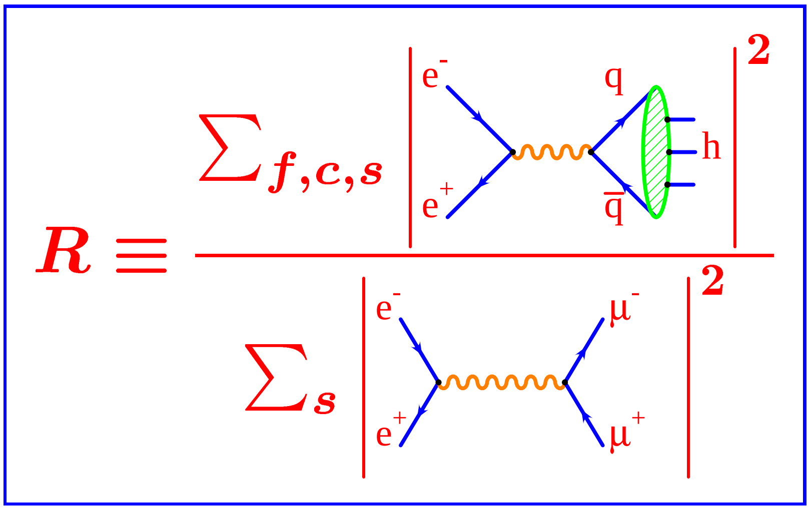
Introduction

Definition of R



Quark parton model predicts that

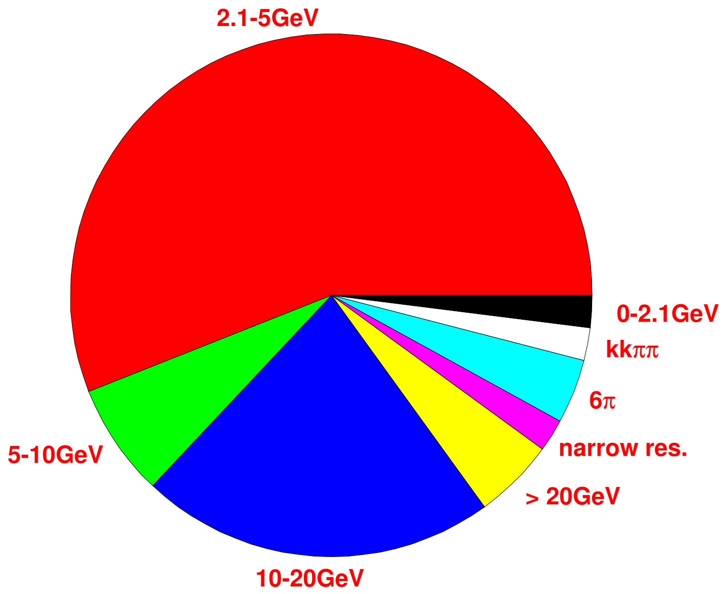
$$\boxed{R = 3\sum_f Q_f^2}$$

Why R?

- To reduce uncertainty of $\alpha(M_Z^2)$
  - Accurate $\alpha(M_Z^2)$ is crucial to precise test of SM like Higgs search

- Low-energy hadronic contribution to vacuum polarization dominates $\Delta\alpha(M_Z^2)$

$$\boxed{\Delta\alpha(M_Z^2) \rightarrow \int_{4m_\pi^2}^{\infty} ds \frac{R(s)}{s(s - M_Z^2 - i\epsilon)}}$$



- a_μ
  - Anomoulous magnetic moment

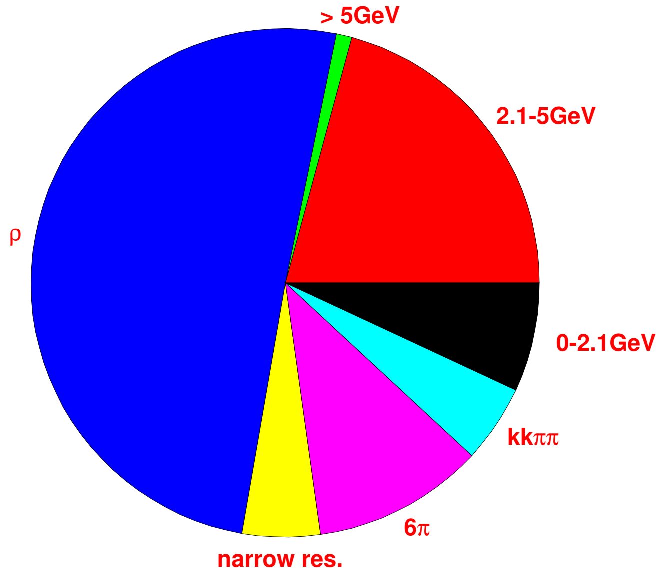
$$\boxed{a \equiv \frac{g-2}{2}}$$

- Why a_μ?
  - Test of $e - \mu$ universality
  - New physics?

$$\begin{aligned} a_\mu^{exp} &= (116,592,350 \pm 730) \times 10^{-11}, \\ a_\mu^{SM} &= a_\mu^{QED} + a_\mu^{weak} + a_\mu^{had} \\ &= (116,591,594.7 \pm 70) \times 10^{-11} \end{aligned}$$

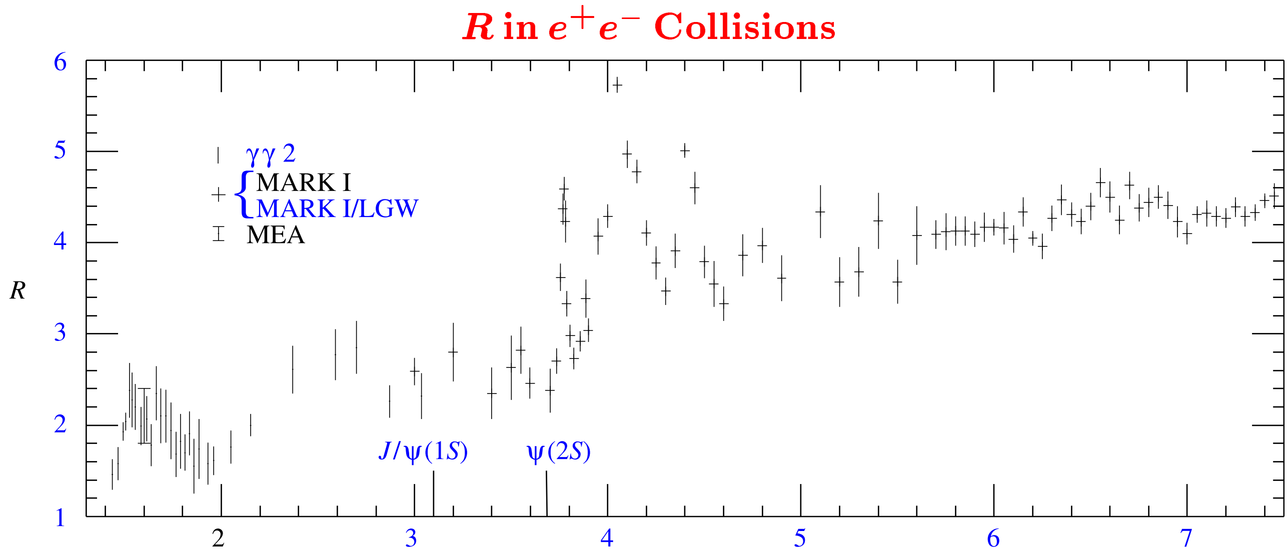
- a_μ^{had} is dominated by R in low s

$$a_\mu^{had} = \left(\frac{\alpha m_\mu}{3\pi}\right)^2 \int_{4m_\pi^2}^{\infty} ds \frac{R(s)K(s)}{s^2}$$



- To understand structure of hadrons
  - Quark flavors and colors
    Quark parton model
  - Hadronic states

Previous R Experiments at Low Energy



- Consistent with parton model predictions like the open of charm threshold

- Latest Exp. in 1982, uncertainties $\sim$ **15%**

- Ambiguious structure in **$3.7 - 4.5$** GeV

Error contributions to R

$$R = \frac{N_{had}^{sel} - N_{bg}}{\sigma^0_{\mu^+\mu^-} \cdot \epsilon_{trg} \cdot L \cdot \epsilon_{had} \cdot (1+\delta)}$$

- $\sigma^0_{\mu^+\mu^-}$ can be calculated from QED
- Statistical error can be controlled by N_{had}
- R is limited by systematic errors

Typical systematic error contribution to R

Item	δ_{sys}	Comments
N_{had}^{sel}	2%	
N_{bg}	3%	
ϵ_{trg}		Low
L	6%	Small angle Bhabha
ϵ_{had}	$8-15\%$	Phase space generation
$1+\delta$		

Strategy of R scan with BESII at BEPC

- BEPC covers CMS energy between $\mathbf{2-5}$GeV
- BEPC Luminosity increased by a factor of $\mathbf{1.5-2}$
- Beam associated background reduced significantly
- BES detector has advantages to measure $\boldsymbol{R}$ as compared with previous experiments (See Prof. Z.G. Zhao's presentation)
- BES planned to measure $\boldsymbol{R}$ among $\mathbf{2-5}$GeV several years ago
- Goal: Reduce error of $\boldsymbol{R}$ by a factor of $\mathbf{2}$

Three steps to measure R at BES

Prestudy
By BESI τ Data
12 Points

→ Analysis Framework
- Event Selection
- ISR
- Lund Model

↓

First R Scan
Between 2.6-5.0 GeV
6 Points

→ To Understand
- Trigger
- Beam Associated Bg.
- Beam Time Estimation

To Fix the Framework

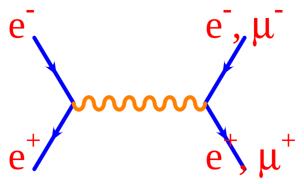
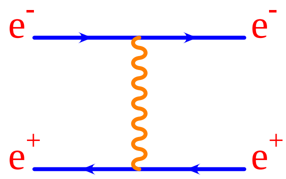
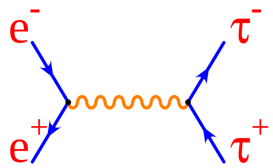
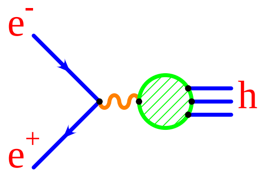
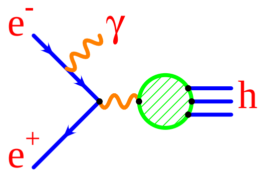
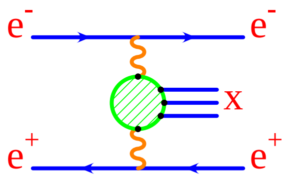
↓

Finer R Scan
Between 2.0-4.8 GeV
85 Points

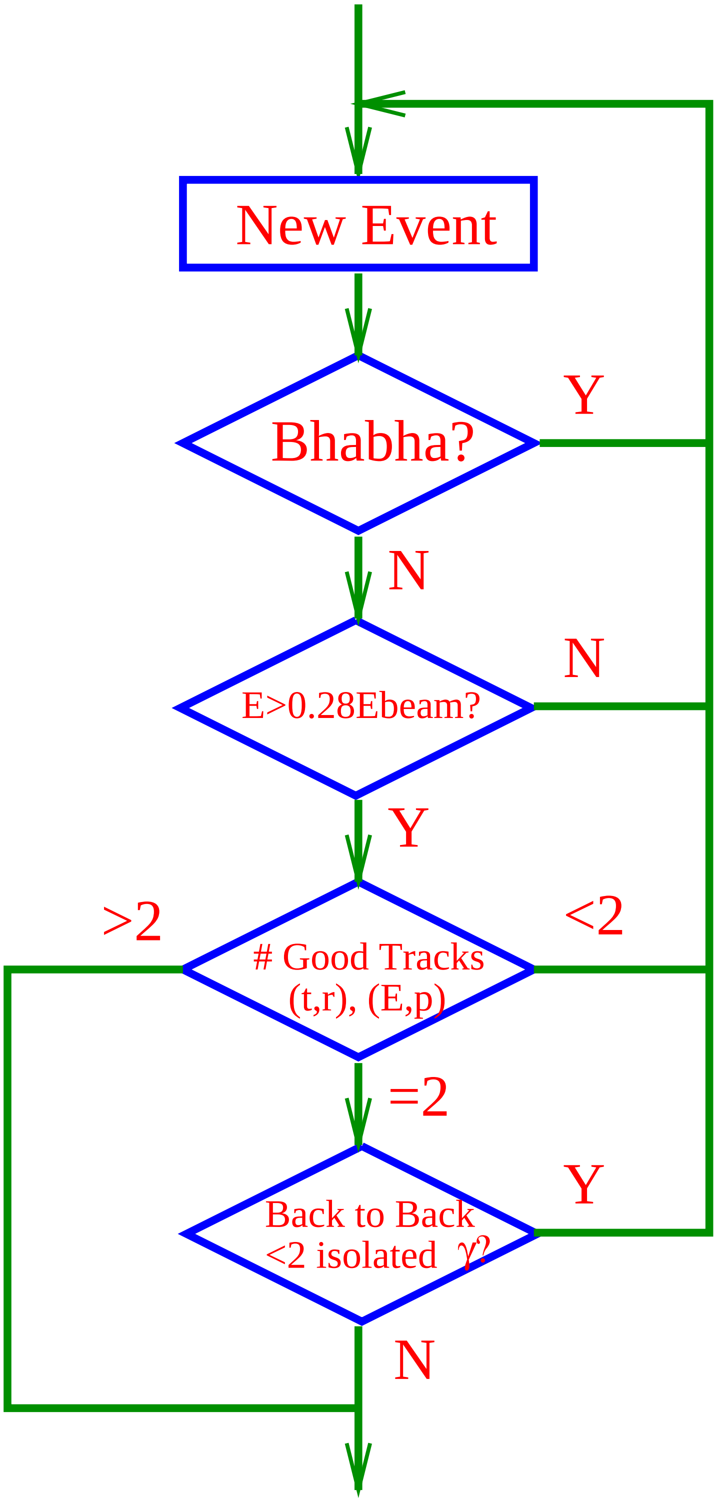
→ Final Analysis
- R Uncertainty ~7-10%
- Structure in 3.7-4.5 GeV
- $\Delta\alpha$, a_μ

Event Selection

Events

Event types	Characteristics
 	easily identified
	τ decay background
	required
	corrected by ISR
	$< 1\%$ to h
beam-associated	flat vertex distr. small energy
cosmic rays	flat vertex distr. big ΔTOF

Selection


New Event
Bhabha?
Y
N
E>0.28Ebeam?
N
Y
>2
Good Tracks
(t,r), (E,p)
<2
=2
Back to Back
<2 isolated γ?
Y
N

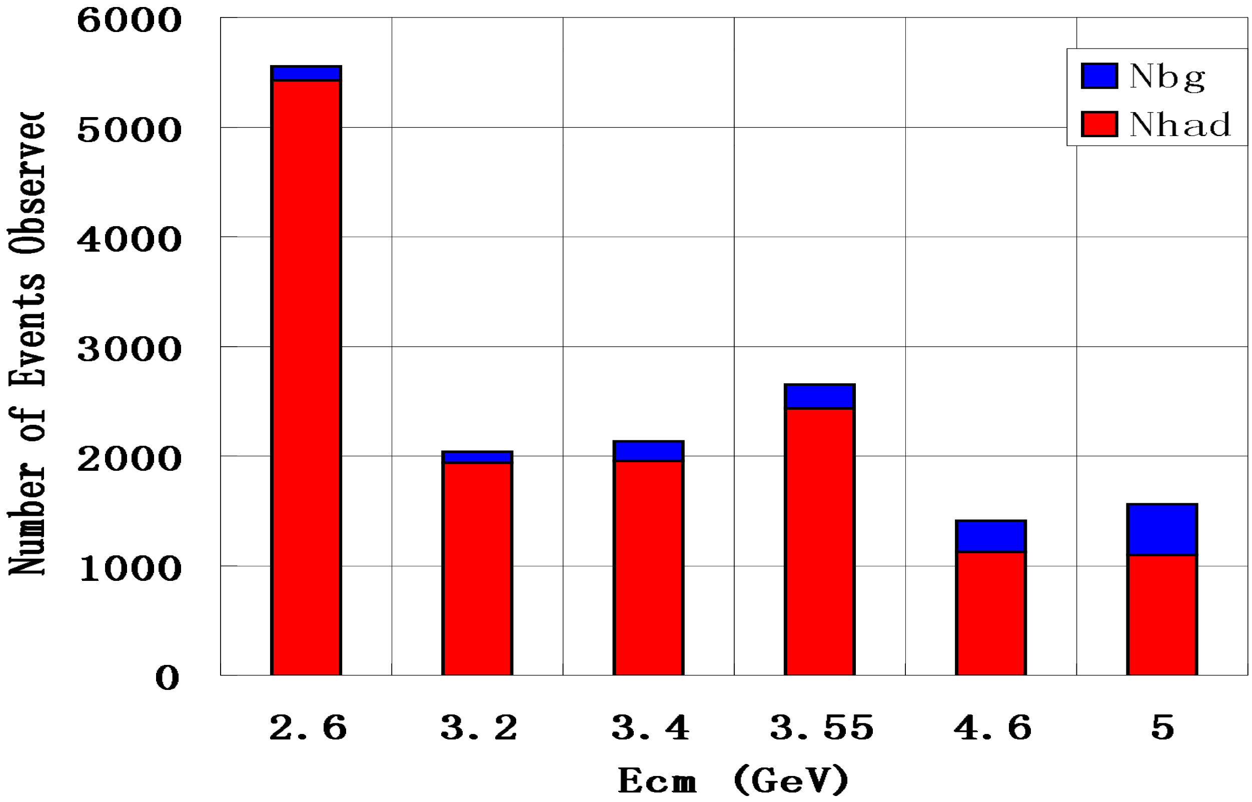
Background Subtraction

- Beam-associated background
  - Most of them are removed by vertex/energy cut
  - Subtract rest by separated beam runs

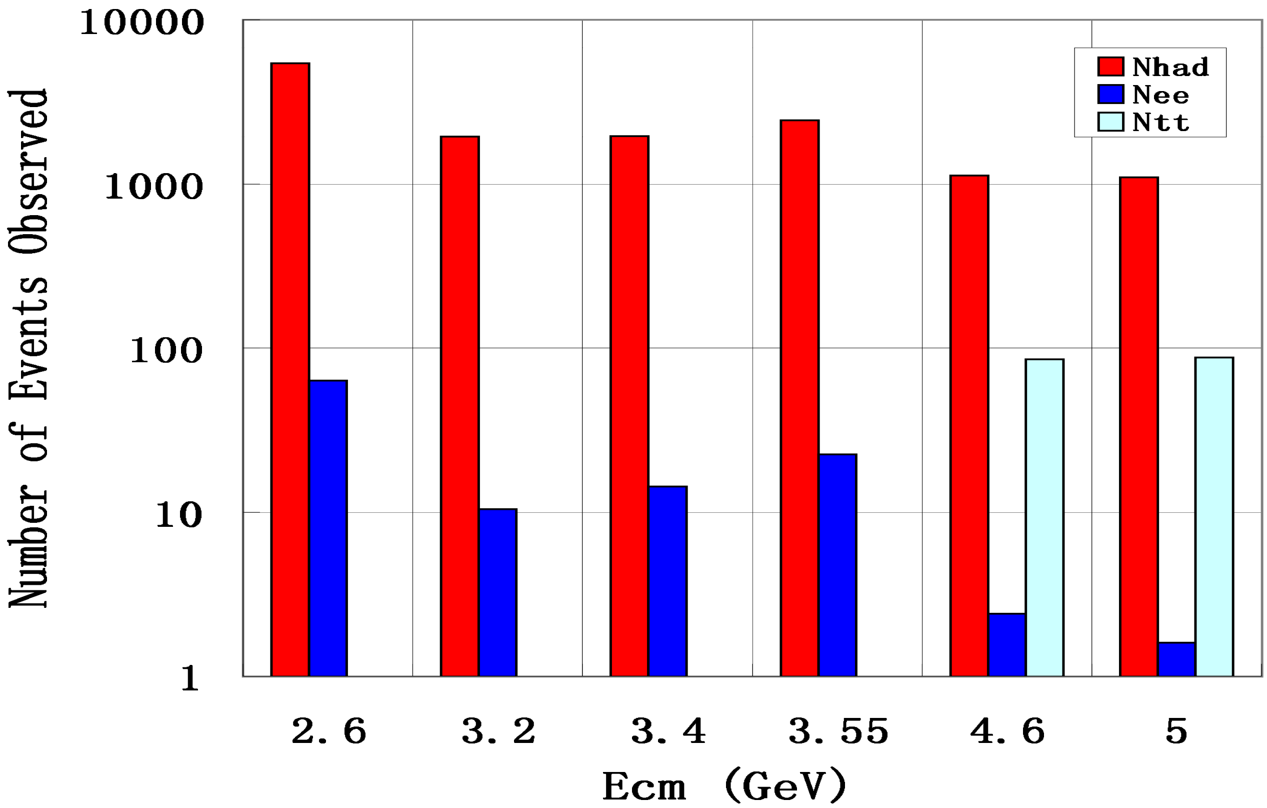
$$N_{bg} = f \cdot N_{sep},$$
$$f = \frac{\int_{col} dt P(t) \cdot \left[I_{e^+}(t) + I_{e^-(t)}\right]}{\int_{sep} dt P(t) \cdot \left[I_{e^+}(t) + I_{e^-(t)}\right]}$$

- Remained Bhabha events
  Subtracted by Monte-Carlo simulation

- Production and decay of τ lepton
  - Subtract τ lepton background from sample of hadrons
  - τ decay simulated by KORALB



Number of Events Observe
6000
5000
4000
3000
2000
1000
0
Nbg
Nhad
2.6
3.2
3.4
3.55
4.6
5
Ecm (GeV)



Number of Events Observed
10000
1000
100
10
1
Nhad
Nee
Ntt
2.6
3.2
3.4
3.55
4.6
5
Ecm (GeV)

Trigger Efficiency

- Trigger efficiency is the probability that a good event is recorded, will be used in calculations of L and R

- Several trigger channels were opened in R data taken

$$\boxed{\begin{array}{c}\text{Trigger Channel} = \prod(\text{Trigger Condition}) \\ \epsilon_{trg} \Longrightarrow \epsilon_{cod}\end{array}}$$

ϵ_{con} determined by irrelevent subdetectors with special trigger study runs at J/ψ

- Trigger efficiencies and errors in '98

Event type	Trigger efficiency	Error
Bhabha	99.96%	0.5%
Dimuon	99.33%	
Hadronic	99.76%	

Luminosity

Principle for luminosity determination

$$\boxed{\frac{L}{L_{MC}} = \frac{N^{obs}/\epsilon_{trg}}{N^{obs}_{MC}}}$$

$$\Downarrow$$

$$\boxed{L = \frac{N^{obs}}{\sigma\epsilon\epsilon_{trg}}}$$

suppose that the data and MC have the same detection efficiency ϵ

L@BES

- Small angle luminosity monitor unreliable
- Wide angle Bhabha (selected by BSC) is applied

- Can MC simulate data so good? BSC may have different selection efficiencies for data and MC

$$\boxed{\epsilon \to \epsilon \frac{\epsilon^{BSC}_{data}}{\epsilon^{BSC}_{MC}}}$$

ϵ^{BSC}_{data} and ϵ^{BSC}_{MC} are determined by a BSC-independent subdetector (*e.g.* MDC) samples

- Dimuon and diphoton used for crosscheck

Luminosity and errors in '98

E_{cm} (GeV)	e^+e^- L (nb)	δ_{sta}	δ_{sys}	$\mu^+\mu^-$ L (nb)	$\gamma\gamma$ L (nb)
2.6	292.9	**0.8%**	**2.1%**	268.2	266.7
3.2	109.3	**1.5%**	**2.8%**	109.0	106.0
3.4	135.3	**2.0%**	**3.0%**	124.6	130.7
3.55	200.2	**1.2%**	**2.3%**	192.1	191.1
4.6	87.7	**2.3%**	**2.0%**	100.6	87.3
5.0	102.3	**2.3%**	**2.6%**	96.6	103.1

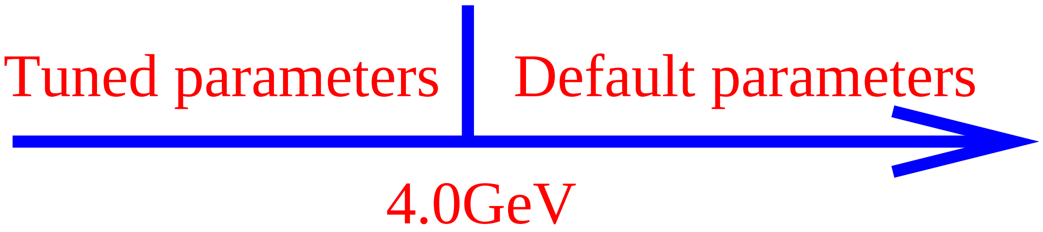
Detection Efficiency

Lund Model

- JETSET was tuned at high energy
- BES has big hadron samples @2.6/3.55GeV
- Lund model Jetset74 was tuned at low energy to have consistent sphericity, thrust, rapidity, multiplicity, momentum, and angular momentum distributions with experiment

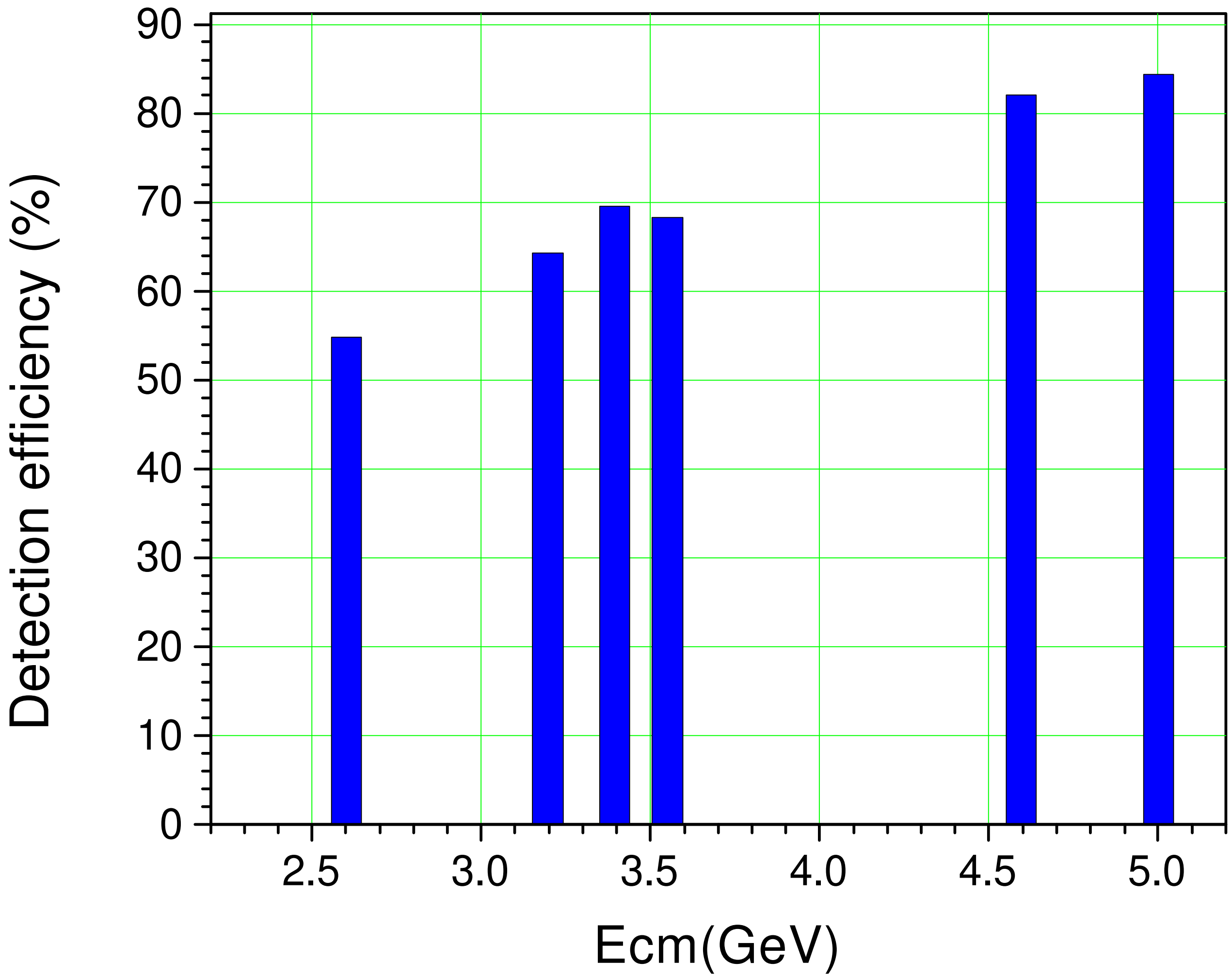
Default and BES-tuned parameters of JETSET74

Parameter	a	b/GeV^{-2}	σ/GeV	W_{min}/GeV
Default	0.3	0.58	0.36	0.8
BES-tuned	1.5	0.78	0.45	0.5



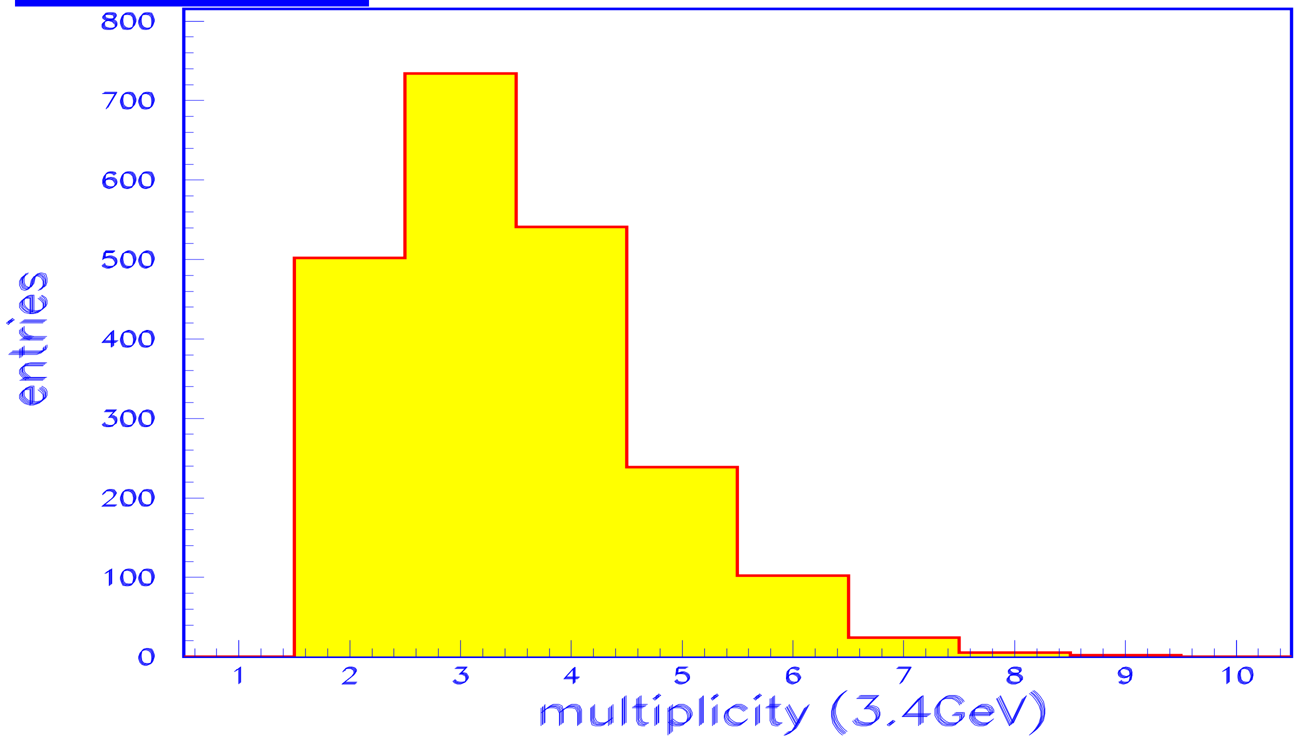
Detection efficiency and systematic errors

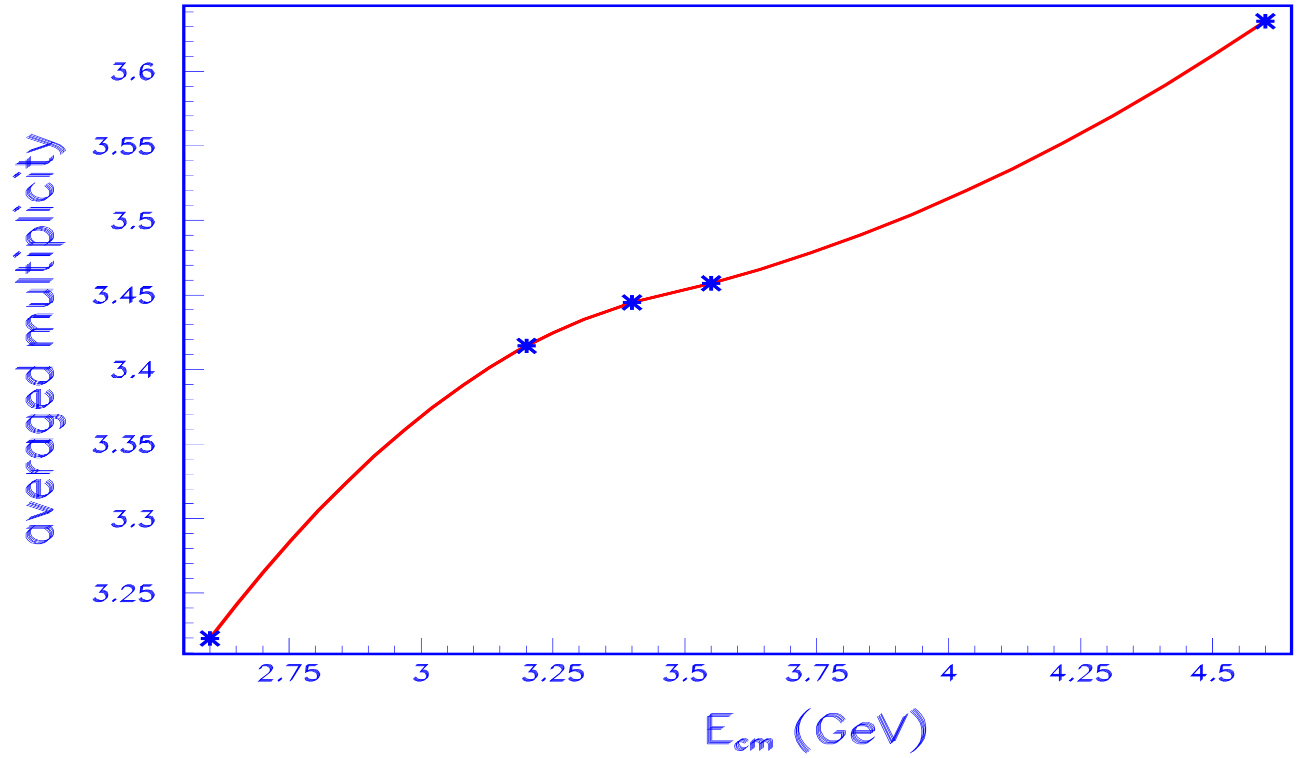
$$\epsilon_{had} = \frac{N_{MC}^{obs}}{N_{MC}^{gen}}$$



$\sqrt{s}$ (GeV)	2.6	3.2	3.4	3.55	4.6	5.0
error (%)	2.64	1.86	2.86	2.34	3.58	3.20

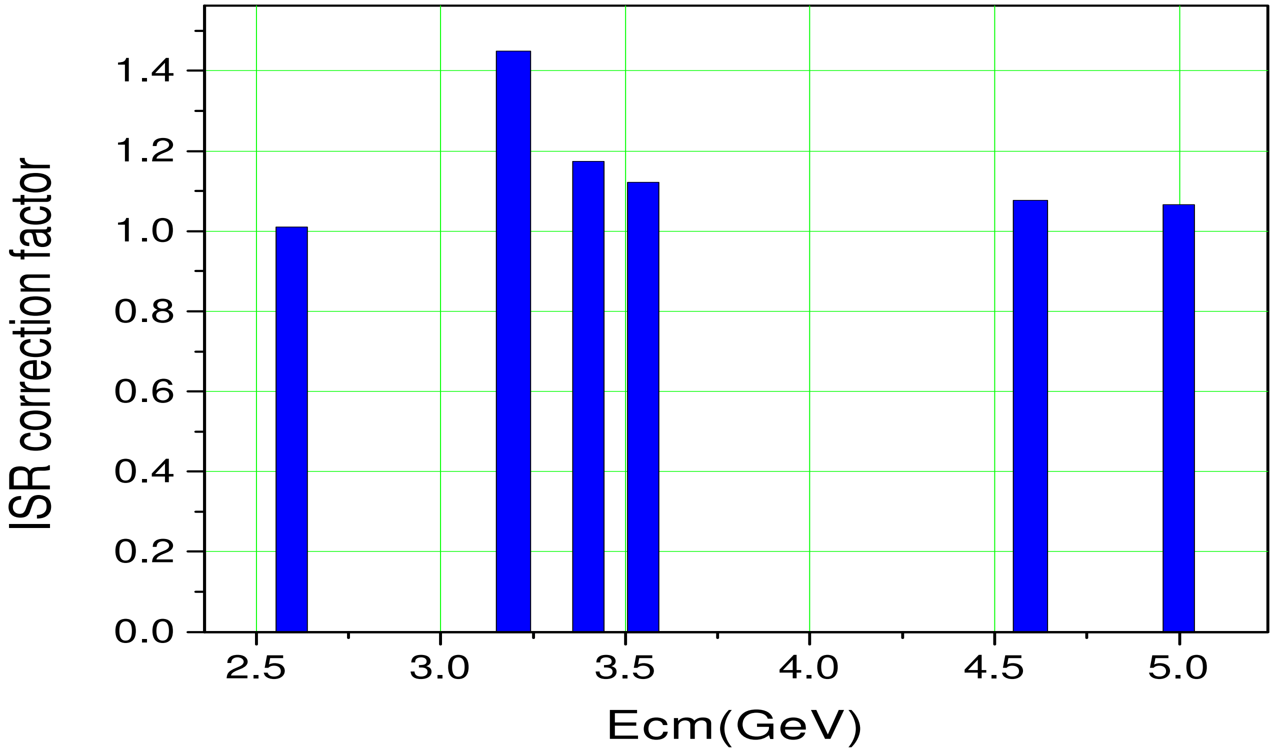
Multiplcity





Radiative Correction

- 4 schemes consistent within 1% off resonance
  - Berends and Kleiss
  - Bonneau and Martin (used)
  - Edwards, *et. al.*
  - Kureav and Fadin/Alexander
- Radiative correction and systematic errors



$\sqrt{s}$ (GeV)	2.6	3.2	3.4	3.55	4.6	5.0
error (%)	2.58	2.17	3.02	2.35	4.13	3.82

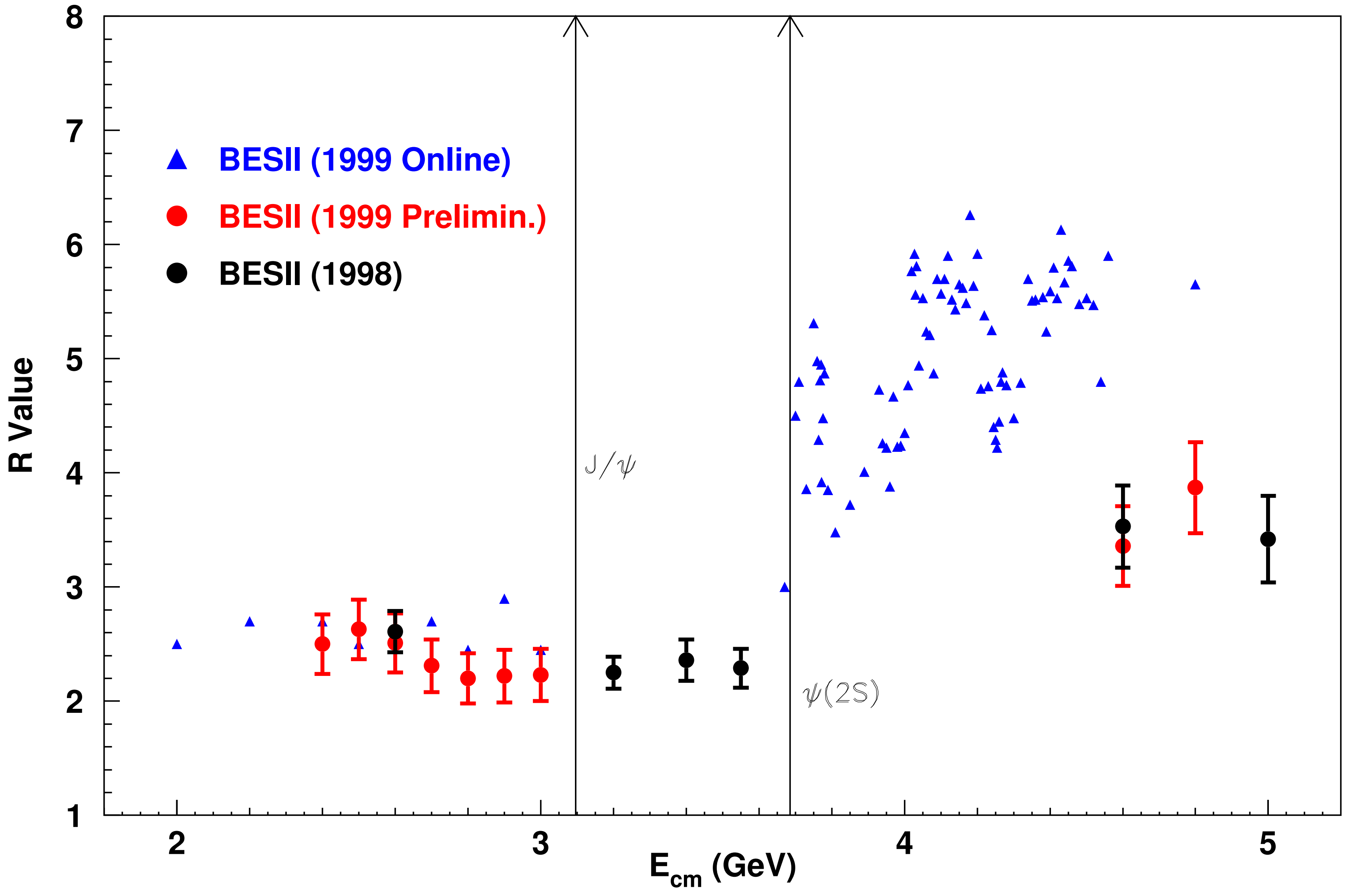
Results

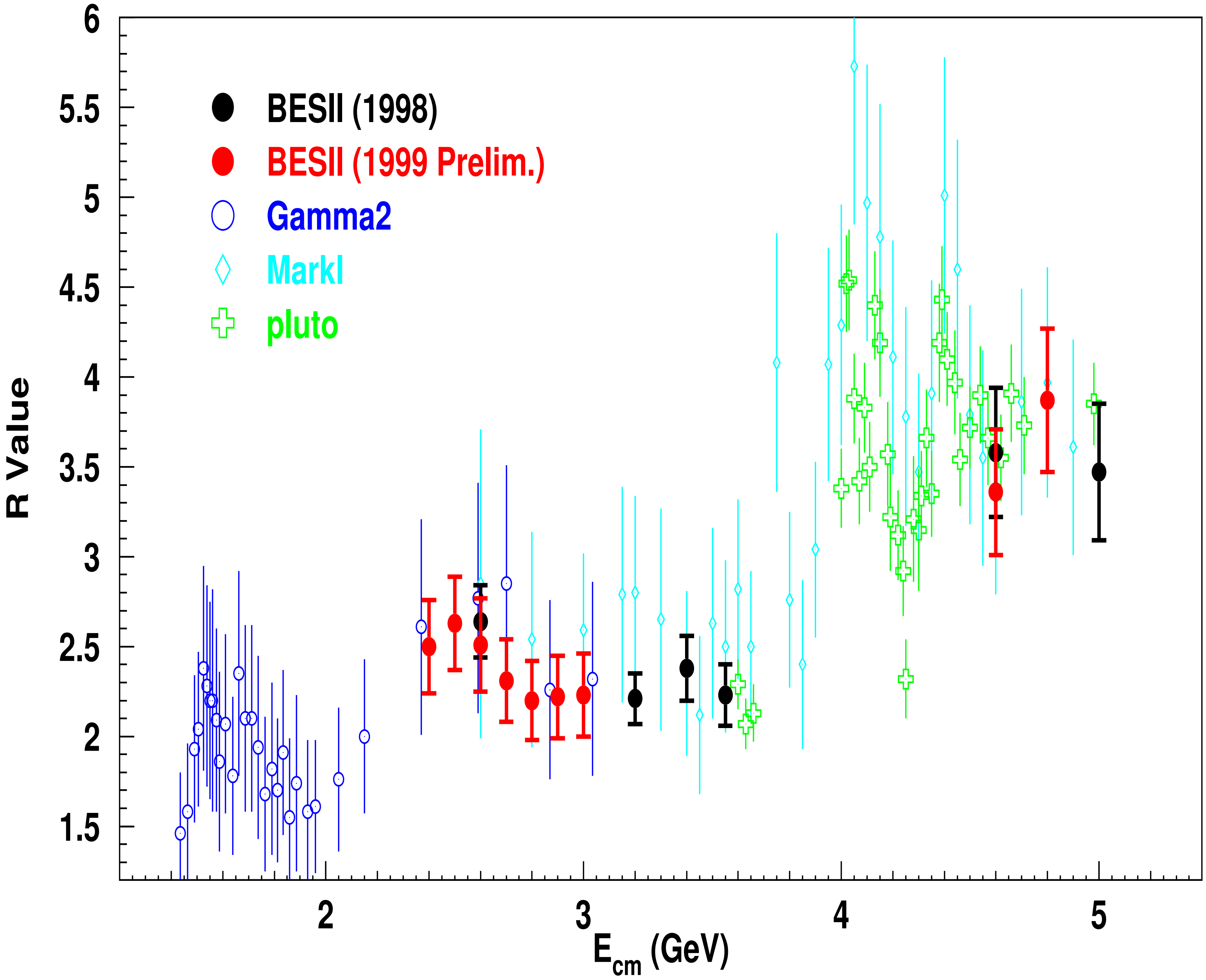
The 6 points in '98

E_{cm} (GeV)	R	ΔR			
		Stat.		Syst.	
2.6	2.61	0.05	**1.8%**	0.19	**7.3%**
3.2	2.26	0.07	**3.2%**	0.13	**5.6%**
3.4	2.37	0.07	**3.1%**	0.16	**6.8%**
3.55	2.30	0.07	**2.7%**	0.16	**6.9%**
4.6	3.56	0.20	**5.6%**	0.29	**8.2%**
5.0	3.45	0.32	**9.4%**	0.29	**8.4%**

- Consistent results with other experiments
- Small systematic errors reached
- Analysis frame for R physics created

Preliminary '99 Results




R Value
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
BESII (1998)
BESII (1999 Prelim.)
Gamma2
MarkI
pluto
2
3
4
5
E_{cm} (GeV)

Summary

- Experimental effort to reduce $\Delta R/R$ from $\sim 15\%$ to a few percent at low energy is important for the precision test of electro-weak theory

- BES at BEPC can improve $\Delta R/R$ to $6 \sim 10\%$ in 2-5GeV (1999-2000) and hence contribute to
  - $\alpha(M_Z^2)$
  - a_μ^{had}

- Further effort to improve the model for $e^+e^- \to hadrons$ is needed

- $\Delta R/R$ is limited by systematic error, a τCF is essential to settle the remaining problems in 2-5GeV