Measurement of R with BESII at BEPC

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- **Motivation**
- **Apparatus and Measurements**
- **Preliminary Results**
- **Summary**

☞ Motivation

- *R* value in the lowest order

$$R \equiv \frac{\sigma(e^+e^- \to hadrons)}{\sigma(e^+e^- \to \mu^+\mu^-)} = 3\sum_q Q_q^2$$

directly counts the number of quarks, their flavor and colors

- *R* with higher order QCD correction

$$R = 3\sum_q Q_q^2\left[1+\left(\frac{\alpha_s(s)}{\pi}\right)+1.411\left(\frac{\alpha_s(s)}{\pi}\right)^2-12.8\left(\frac{\alpha_s(s)}{\pi}\right)^3+\cdots\right]$$

determine $\alpha_s(s)$ at high energy

Experimentally,

$$R \equiv \frac{\sigma^0_{hadron}}{\sigma^0_{\mu^+\mu^-}} = \frac{1}{\sigma^0_{\mu^+\mu^-}\cdot\bar{\varepsilon}_{had}\cdot\varepsilon_{trg}\cdot(1+\delta)}\cdot\frac{N^{obs}_{had}-N^{total}_{bg}}{L}$$

Present $\Delta R/R$ below 5 GeV ~ 15%. BES is planning to reduce $\Delta R/R$ by a factor of two.

A precision measurement of *R* can

- Reduce the uncertainty of $\alpha(M_Z)$

  Essential for any precise test of the SM

$$\alpha(s) \equiv \frac{\alpha}{1+\prod_{\gamma\gamma}}, \quad \mathrm{Im}\prod_{\gamma\gamma}(s) = -\frac{\alpha}{3}R_{had}(s)$$

$$\mathrm{Re}\prod_{\gamma\gamma}(s) = \frac{\alpha s}{3\pi}P\int_{4m_\pi^2}^{\infty} ds' \frac{R_{had}(s')}{s'(s'-s)}$$

- Narrow the mass window of the Higgs boson

$$X \equiv f^{SM}[\alpha(M_Z),\ G_F,\ m_Z,\ \alpha_s,\ m_t,\ m_H)$$

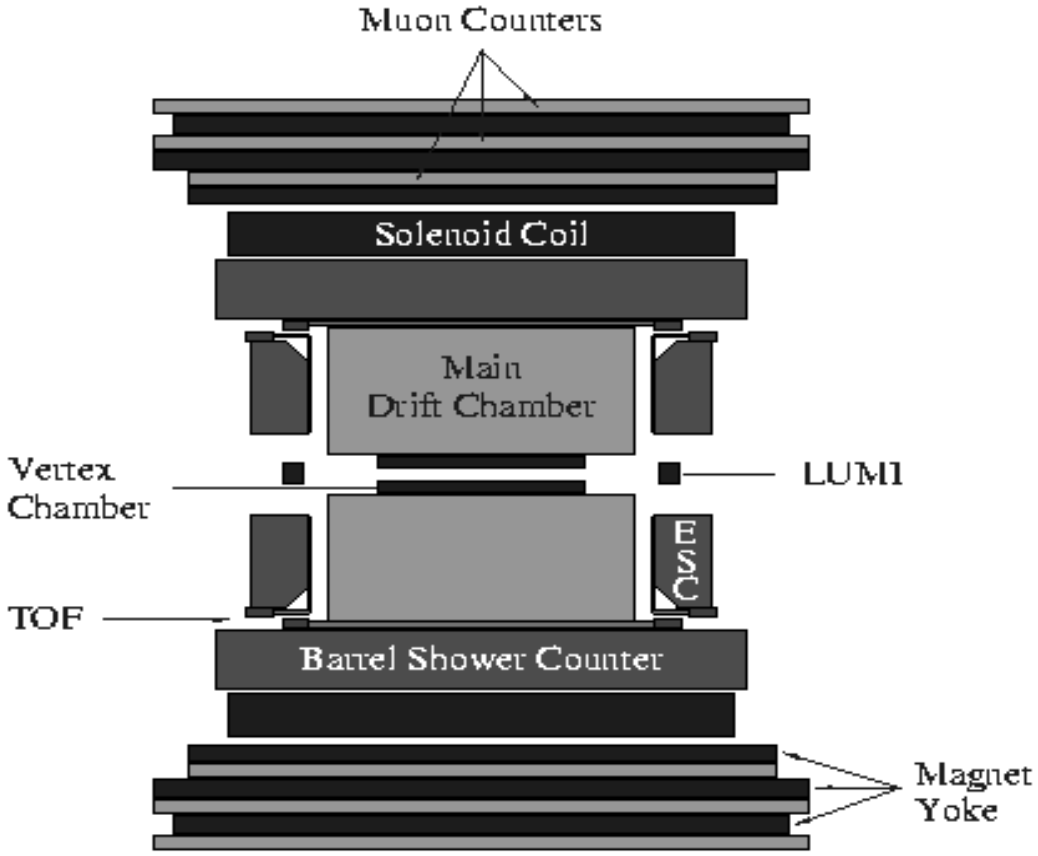
Indirectly determination of M_H depends critically on $\alpha(M_Z)$

- Contribute to the interpretation of a_μ

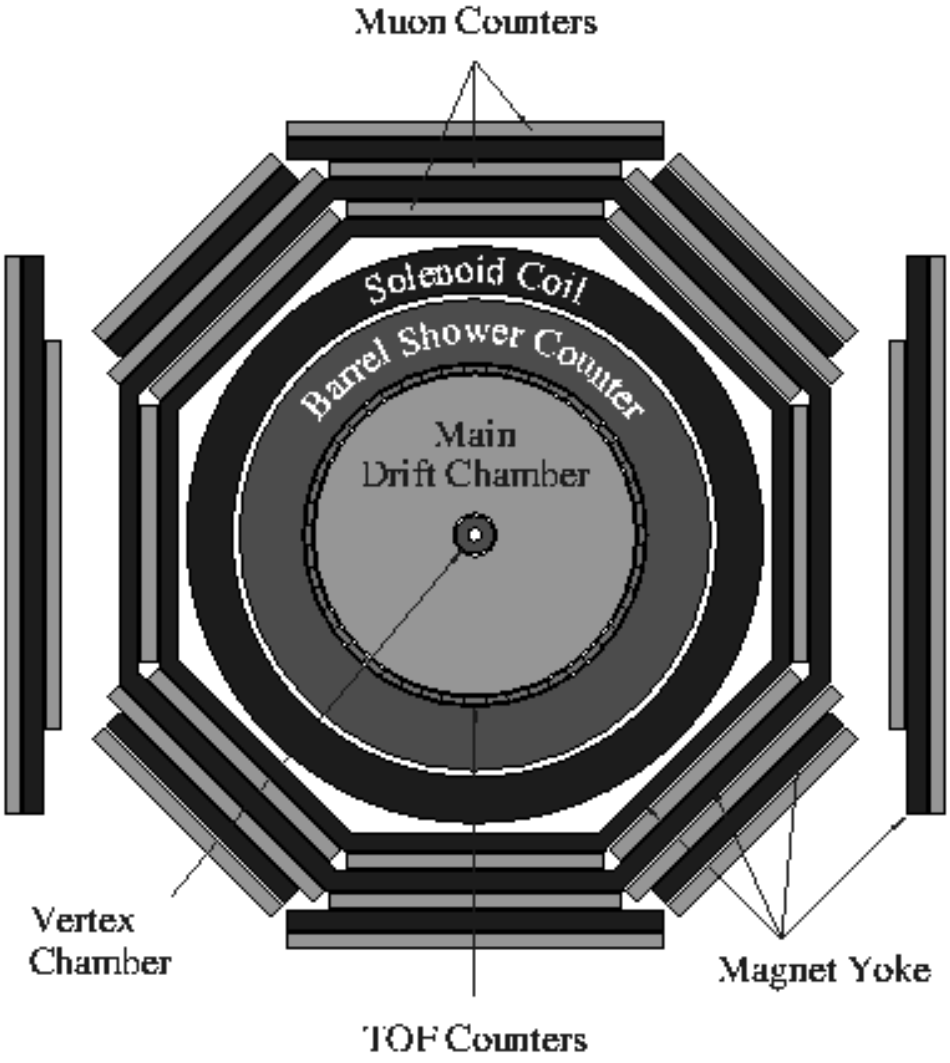
$$a_\mu = a_\mu^{QED} + a_\mu^{had} + a_\mu^{weak}$$

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

☞ Apparatus and Measurements



Side view of the BES detector

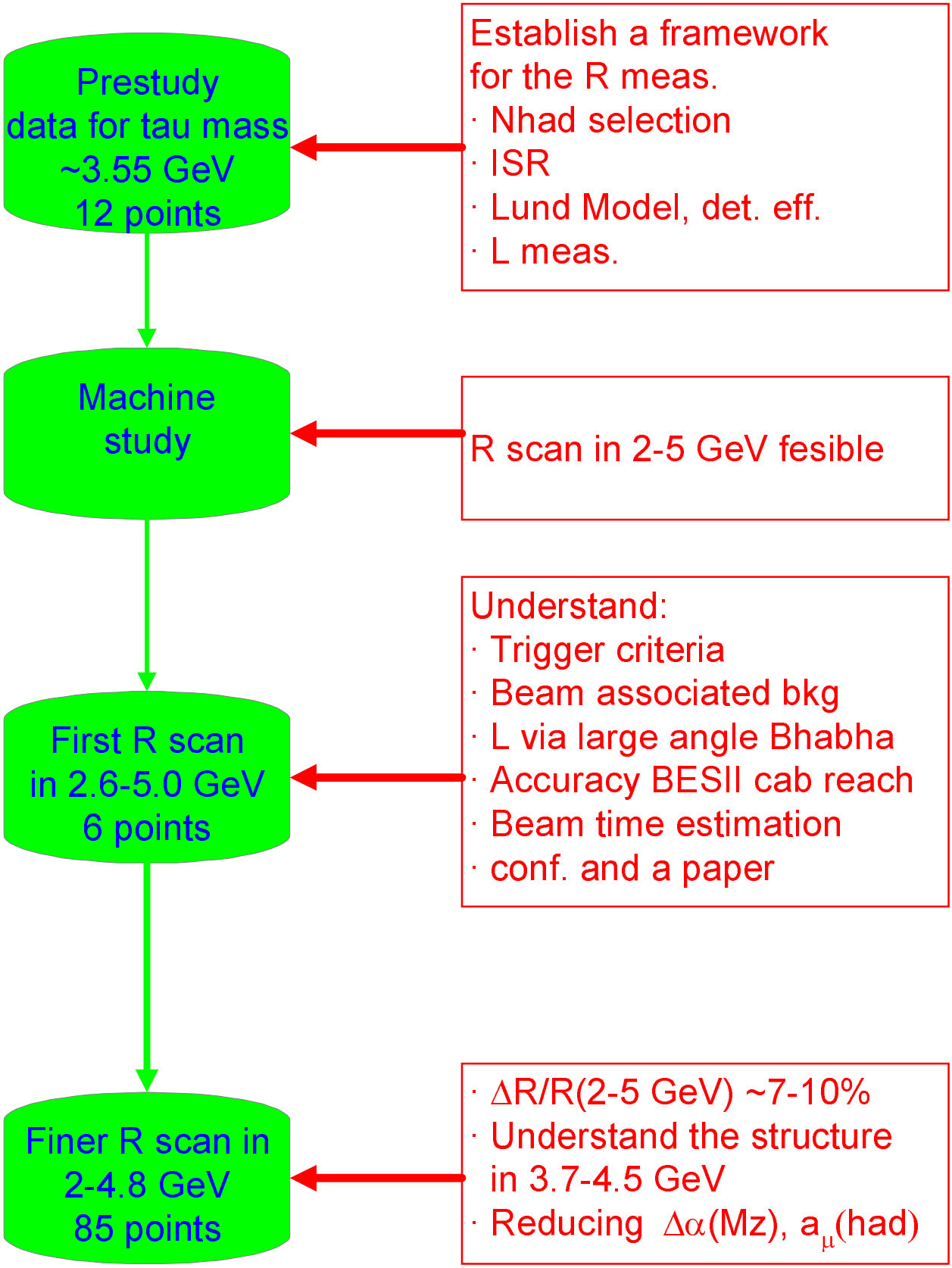


End view of the BES detector

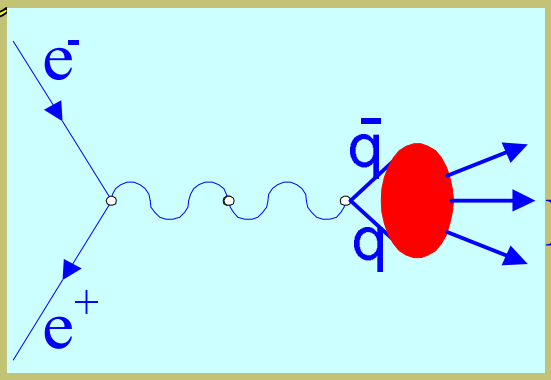
Table 1. Comparison between BESI and BESII

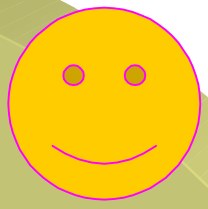
Detector	BESI	BESII
VC	CDC	
$\sigma_{x,y}$ (μm)	200	100
ε_{trk} (%)	no	97
MDC		
ε_{wire} (%)	96	96
σ_{xy} (μm)	200-250	200
$\Delta p/p$ (%)	$1.76\sqrt{(1+p^2)}$	$1.78\sqrt{(1+p^2)}$
$\sigma_{dE/dx}$ (%)	7.9	8.4
BTOF		
σ_T (ps)	375	180
L_{atten} (m)	1.0-1.2	3.5-5.5
ETOF		
σ_T (ps)		720
BSC		
$\Delta E/\sqrt{E}$ (%)	23.8	20.3
σ_z (cm)	4.5	2.3
ESC		
$\Delta E/\sqrt{E}$ (%)	24.4	22.1
μ counter		
ε_{trk} (%)	95	95
σ_z (cm)	5.5	5.5
DAQ dead time		
(ms)	20	8

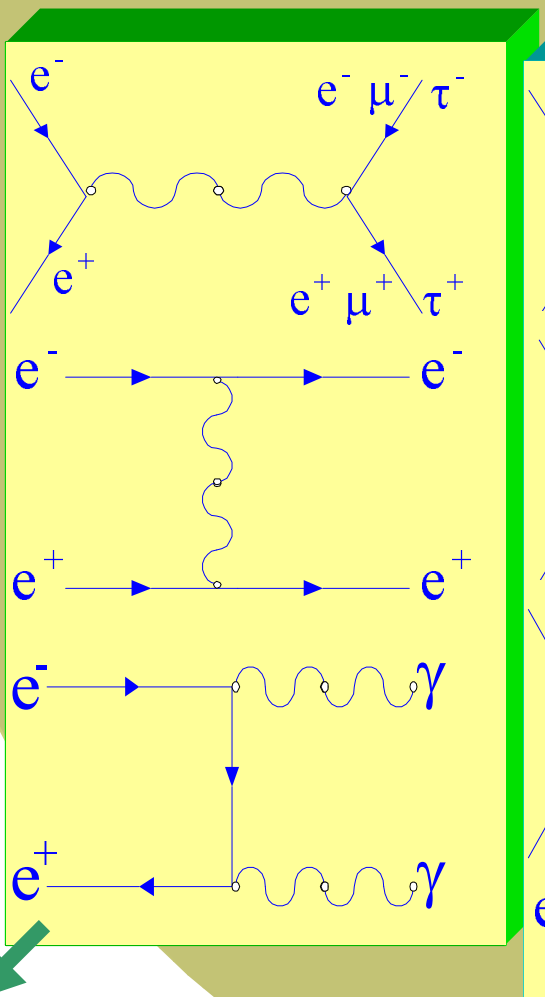
Strategy of the R scan with BESII at BEPC

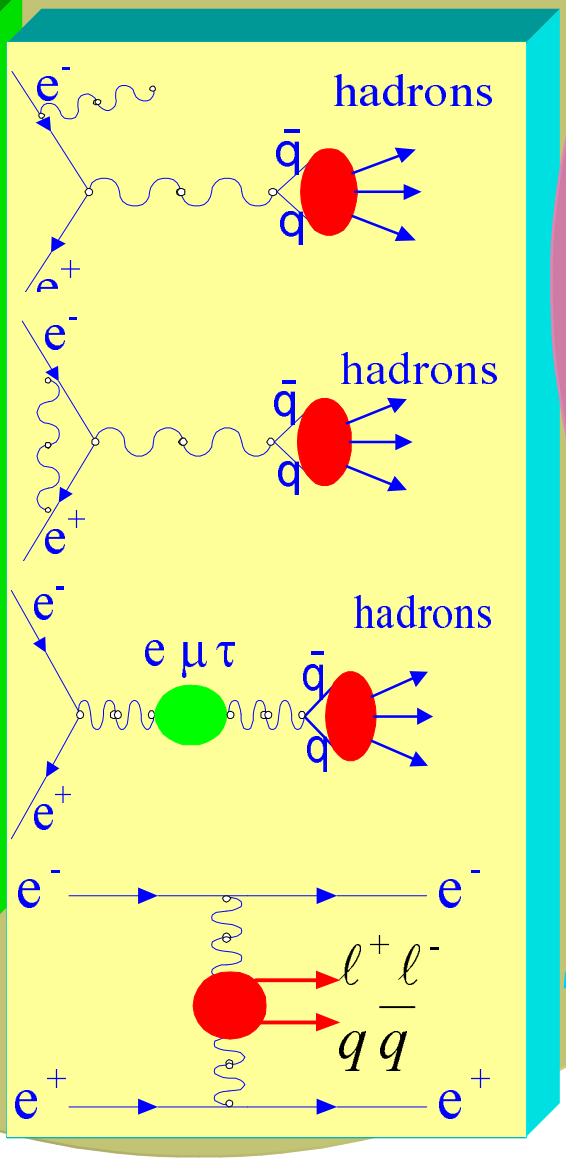


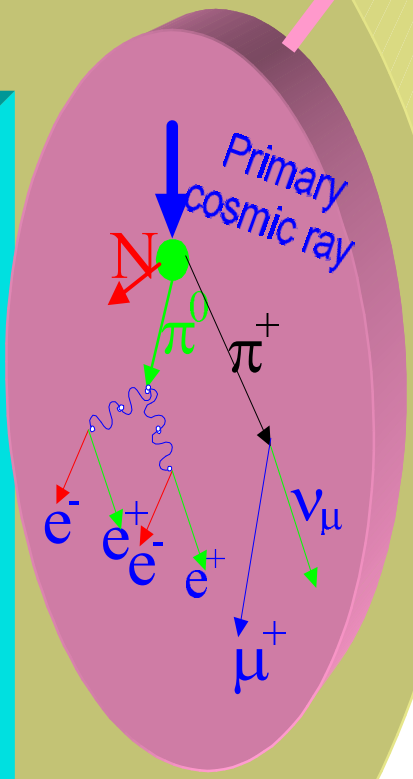
Events collected at BESII

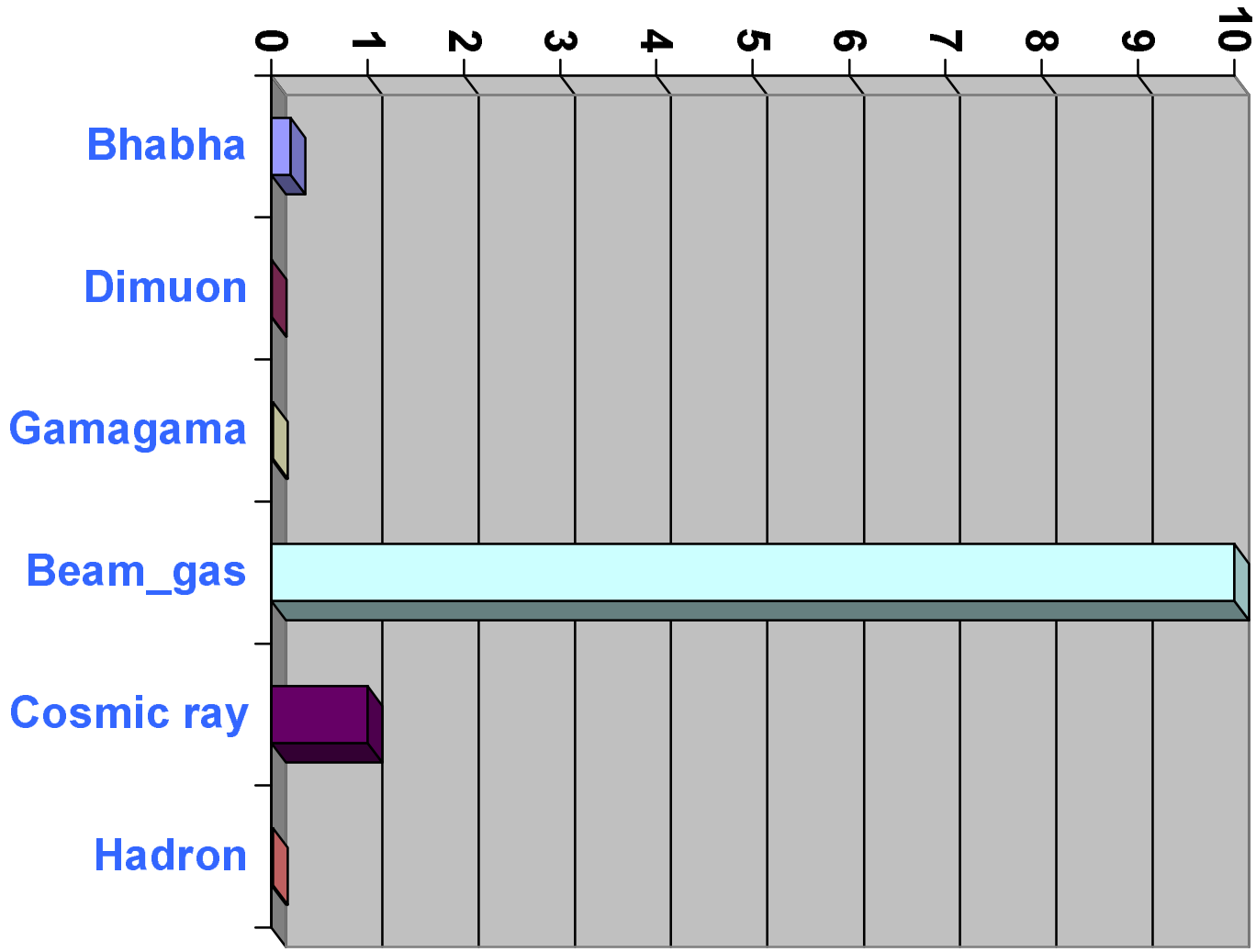


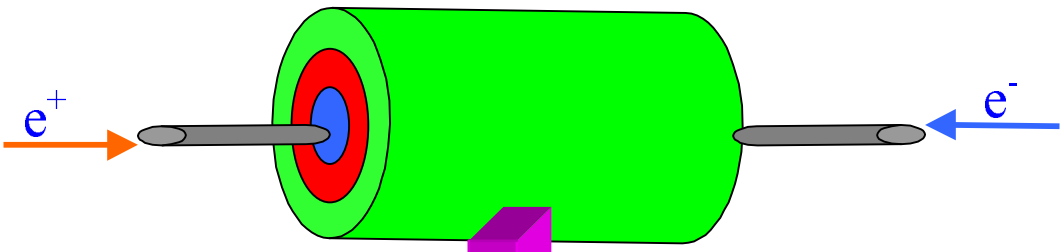









0
1
2
3
4
5
6
7
8
9
10
Bhabha
Dimuon
Gamagama
Beam_gas
Cosmic ray
Hadron



Remove Bhabha

- $E_1+E_2+E_3 \geq 1.15\ E_{beam}$; $E_1 \geq 0.6 E_{beam}$
- E_2, or $E_3 \geq 0.45\ E_{beam}$; $10^0 \geq |\Sigma\theta - 180^0|$
- $25^0 \geq \Delta\phi$

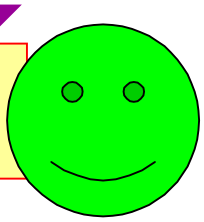
Select good charged tracks:

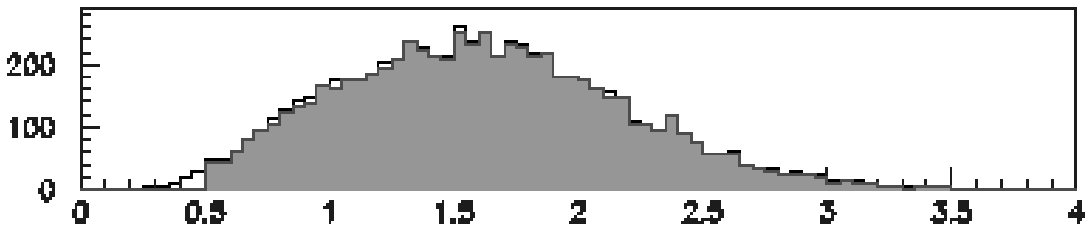
t	$2 < t < t_p + 5\sigma_{TOF}$
r	$\lvert\cos\theta\rvert < 0.84$ $r_0 < 2.0$ cm, $\lvert z_0\rvert < 18$ cm for MFIT=2 N_{hit} (dE/dx) ≥ 16 for MFIT=-19
p, E	$p < 0.6\ E_{beam} + 5\ \sigma_p$, $E < 0.6\ E_{beam}$

Select good hadronic events:

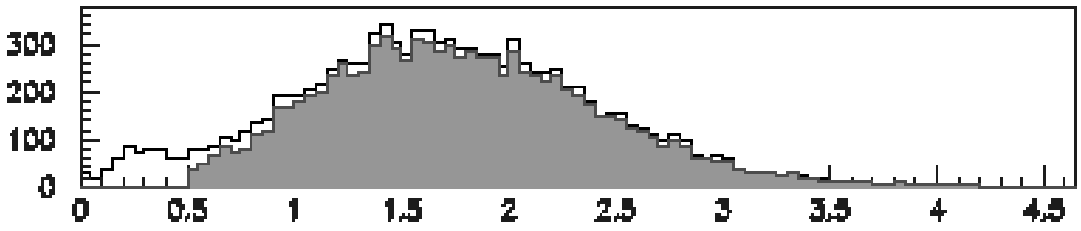
- $\geq$ 2-prong with $\geq$ 1 good track (MFIT=2)
- $\sum E > 0.28\ E_{beam}$
- Not back-to-back + $\geq$ 2 isolated γ's

N_{had}

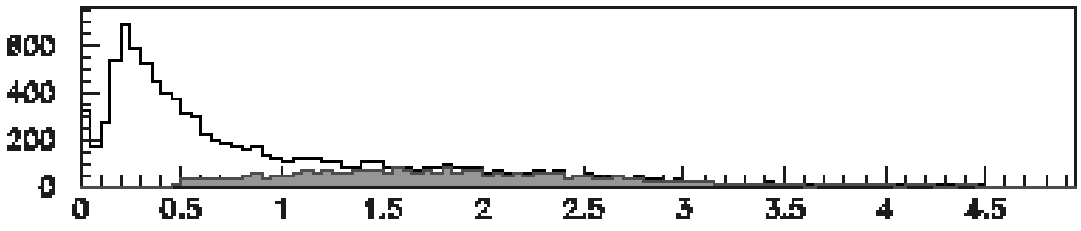




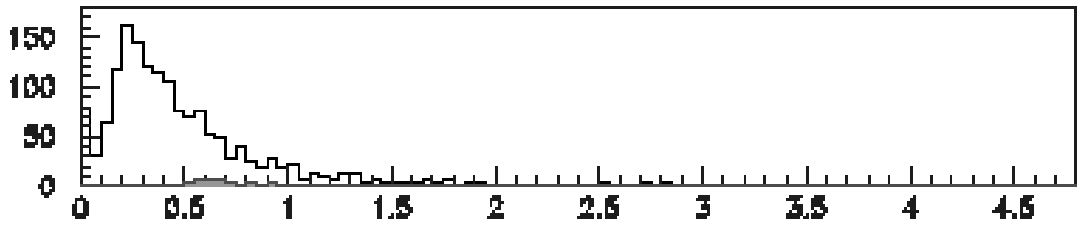
Esum (M.C. data)



Esum (J/ψ data)

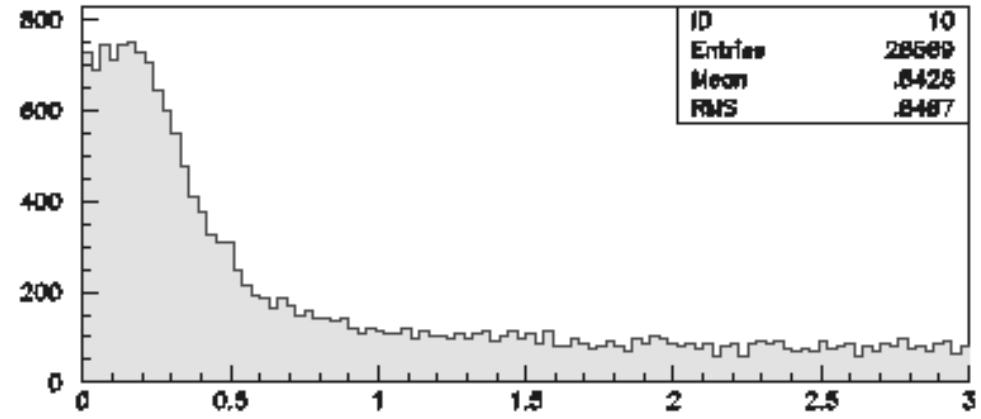


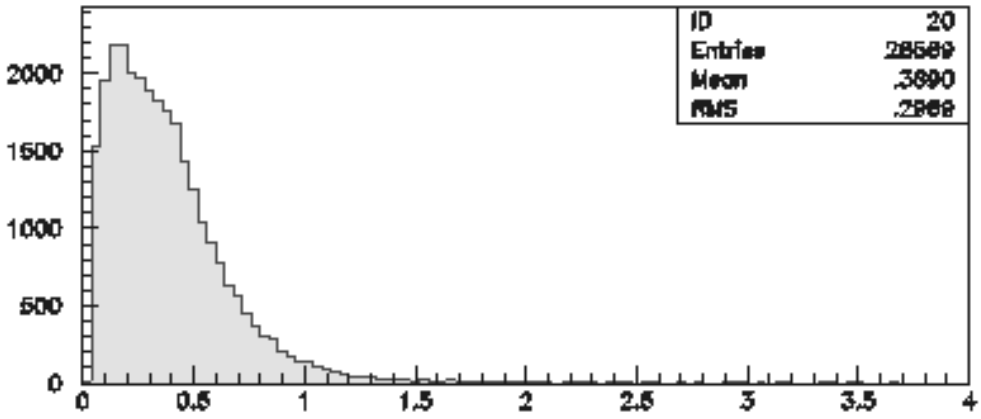
Esum (3.55GeV data)

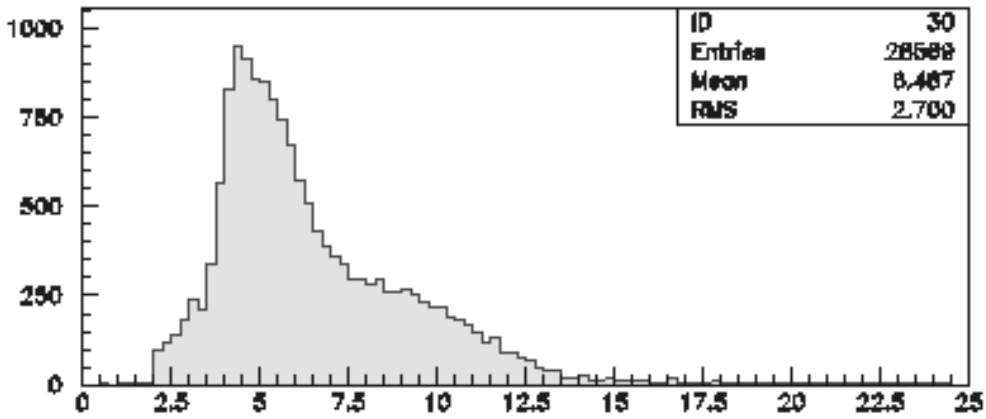


Esum (separated beam)

For R Scan Runs at 3.55GeV

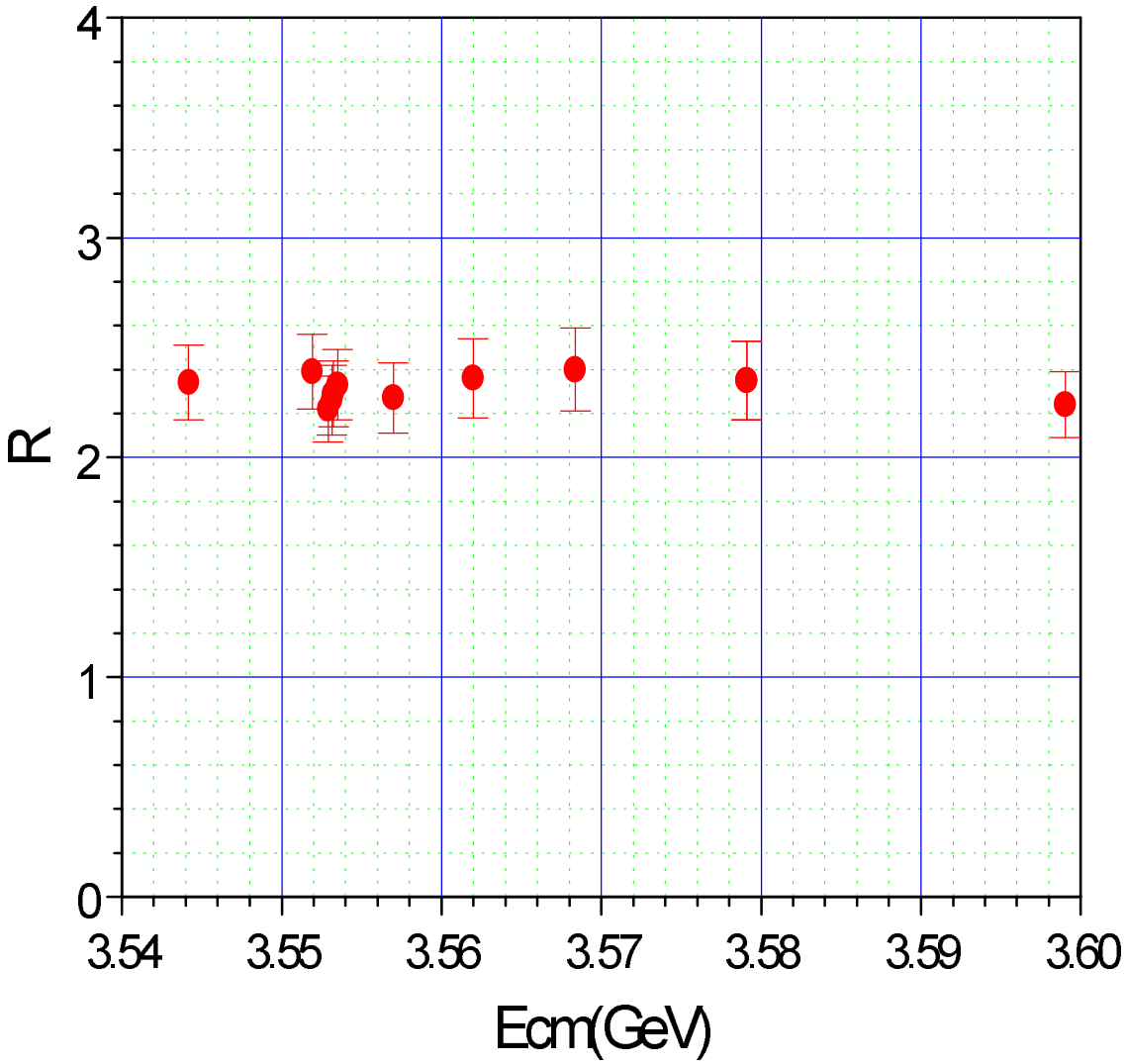




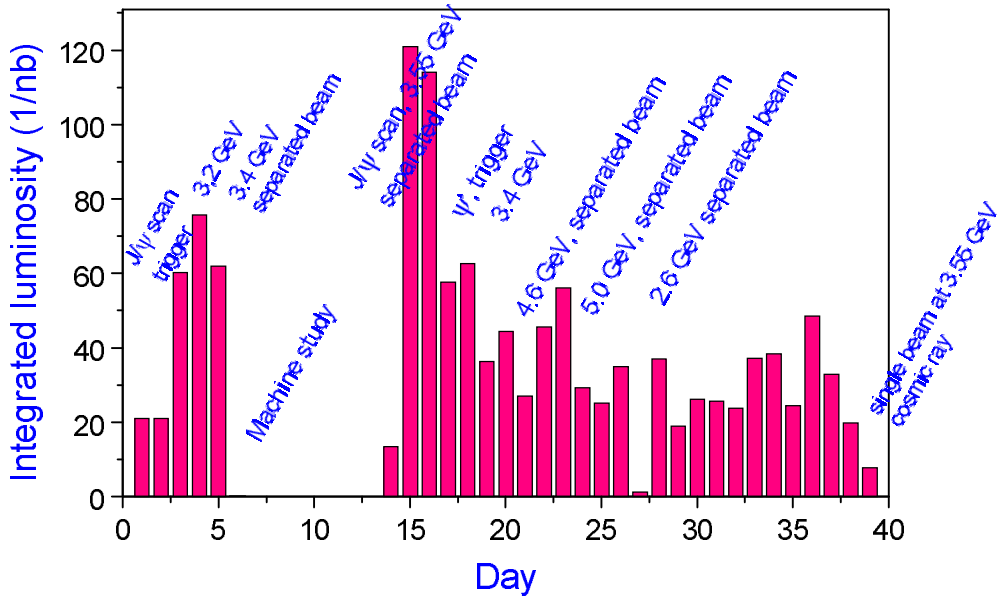


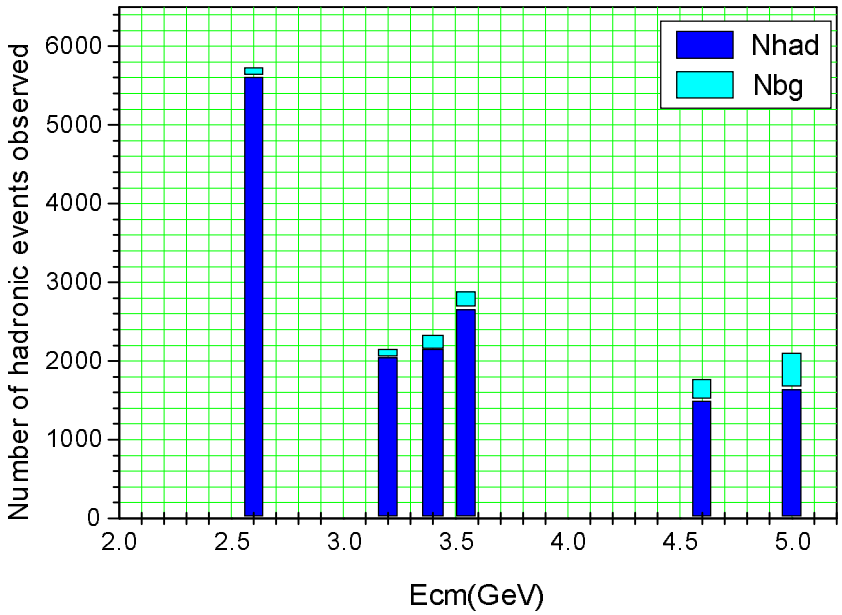
☞ Preliminary results

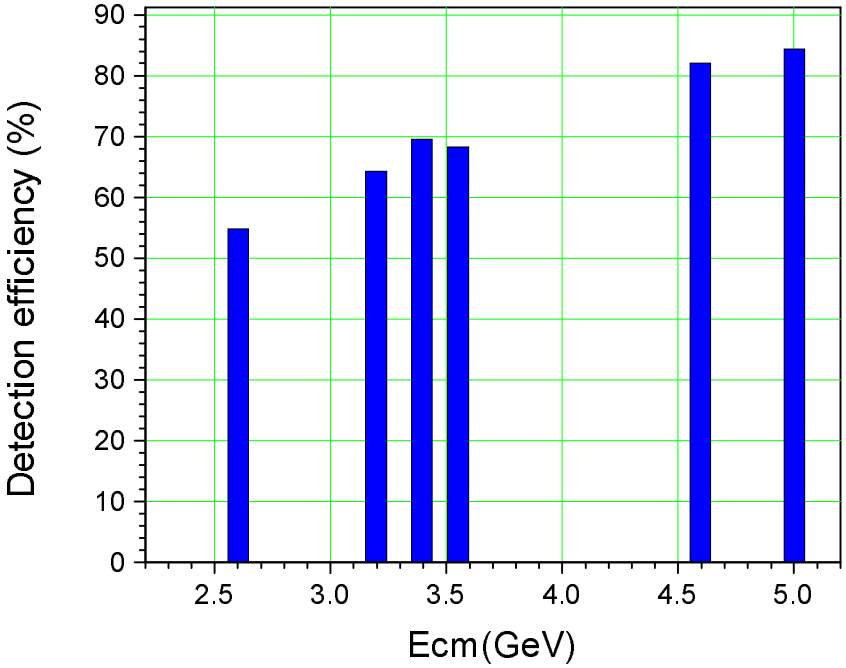
- **R values around 3.55 GeV (m_τ data)**

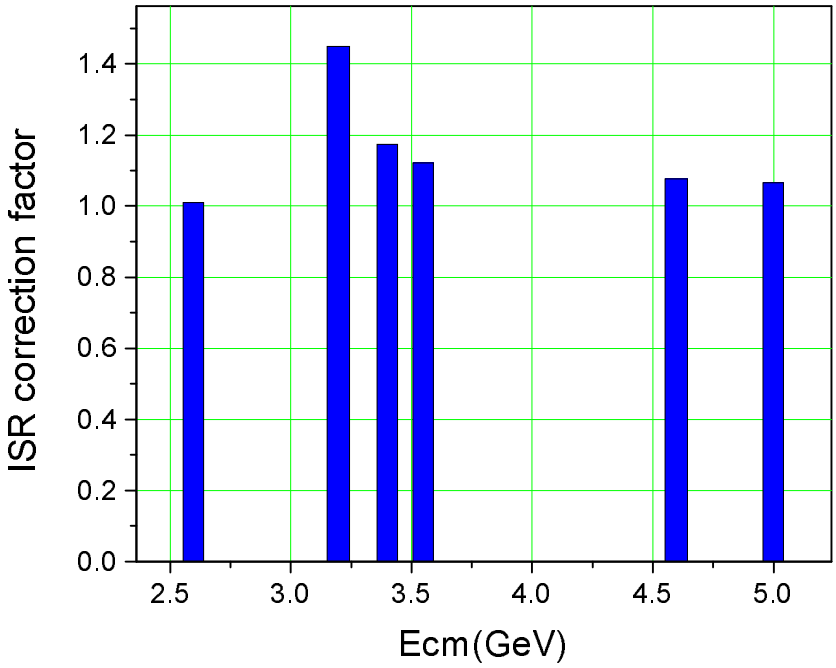


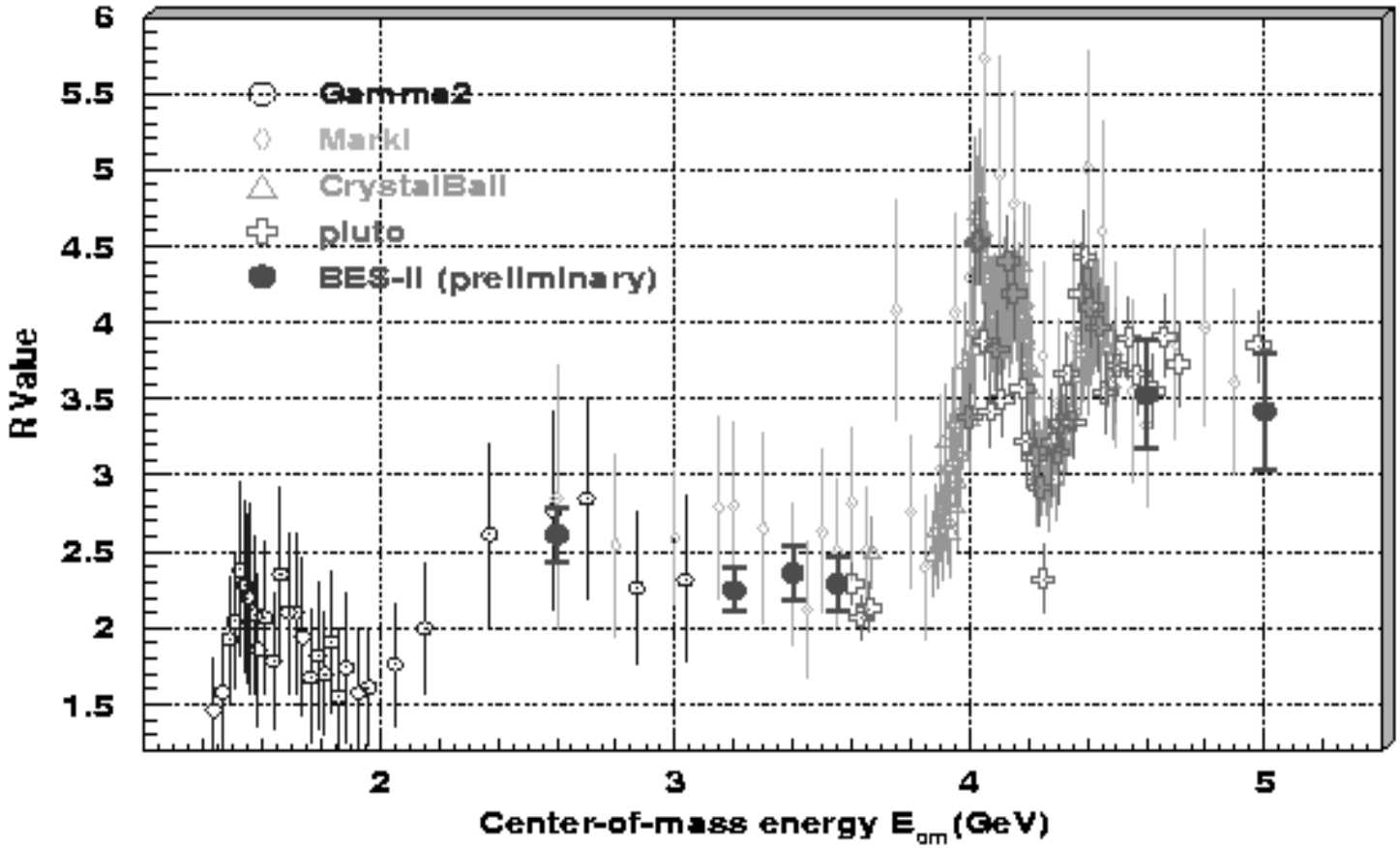
- **The first R scan**






Detection efficiency (%)
90
80
70
60
50
40
30
20
10
0
2.5
3.0
3.5
4.0
4.5
5.0
Ecm(GeV)

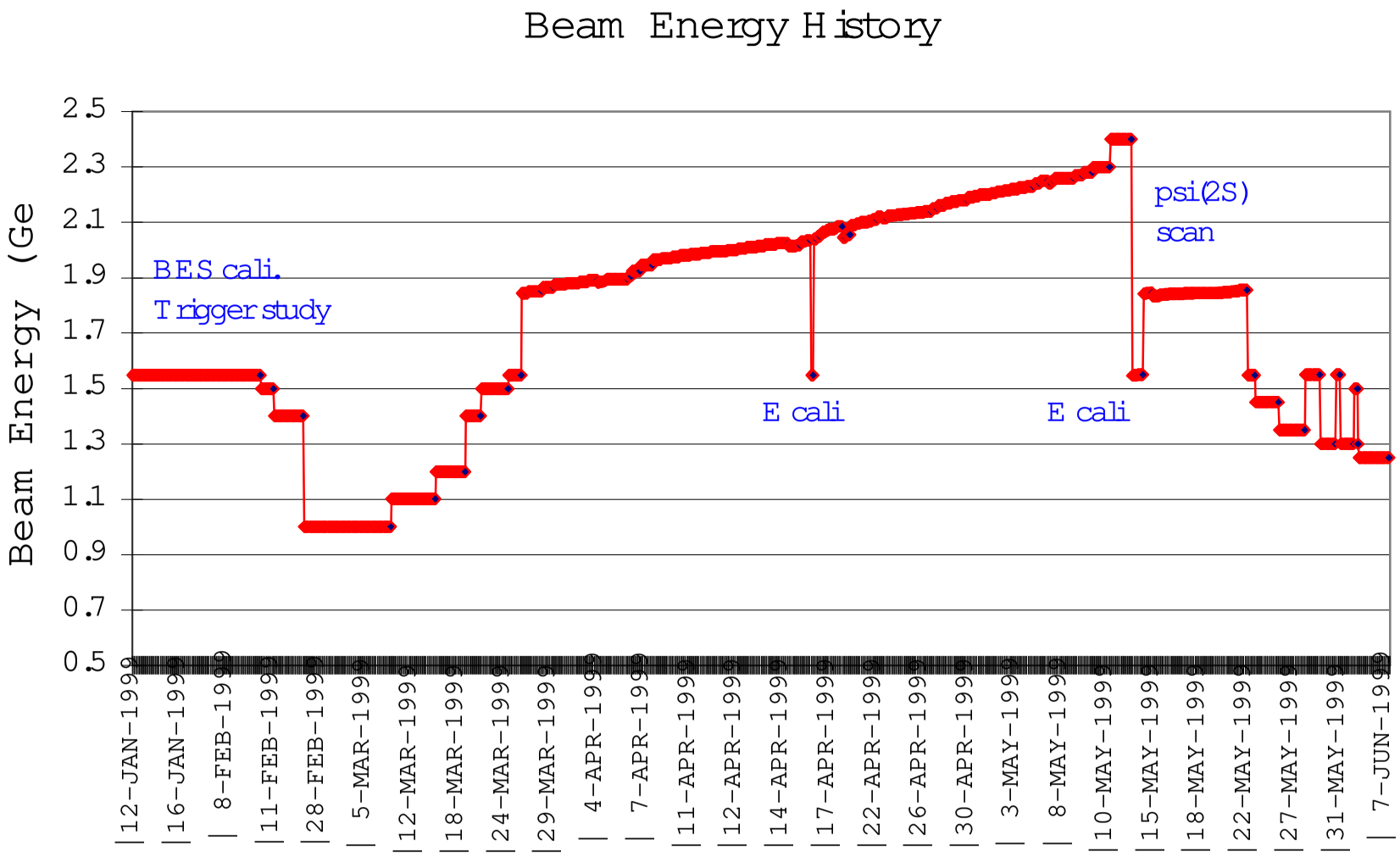

ISR correction factor
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
2.5
3.0
3.5
4.0
4.5
5.0
Ecm(GeV)


Gamma2
Mark1
CrystalBall
pluto
BES-II (preliminary)
R Value
Center-of-mass energy E_{cm} (GeV)
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
2
3
4
5

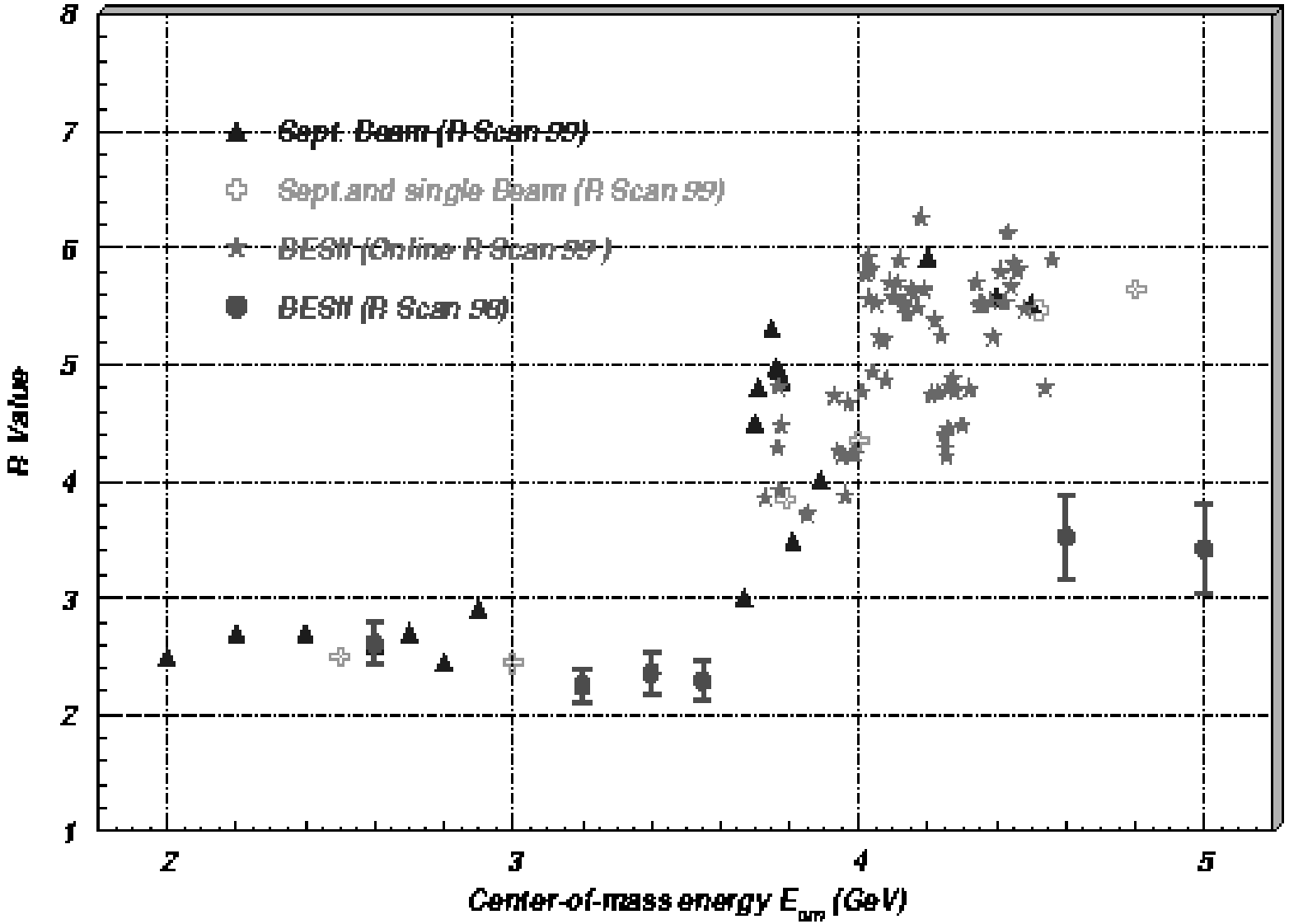
Results of the first R scan

E_{cm} (GeV)	N_{had}	N_{bg}	L (nb^{-1})	ε_{had} (%)	$1+\delta$	R	ΔR	
							Stat.	Syst.
2.6	5617	127	292.9	54.82	1.009	2.61	0.05(1.8%)	0.17(6.7%)
3.2	2051	100	109.3	64.30	1.447	2.26	0.07(3.2%)	0.13(5.6%)
3.4	2149	178	135.3	69.61	1.173	2.37	0.07(3.1%)	0.16(6.8%)
3.55	2672	216	200.2	68.40	1.125	2.30	0.07(2.7%)	0.16(6.9%)
4.6	1497	282	87.7	82.27	1.079	3.56	0.20(5.6%)	0.29(8.2%)
5.0	1648	463	102.3	84.53	1.068	3.45	0.32(9.4%)	0.29(8.4%)

- **Finer R scan (07/02/99 - 07/06/99)**



	E_{cm} (GeV)	Point	Special beam operation		Time spent (days)	Motivation & task
			single e^+, e^-	separated		
Pre-study	3.55	12	×	×		Establish a framework for the R meas. • N_{had} selection • ISR • Lund→ε_{had} • L meas.
Machine study	2.0-5.0	7	×	×	~30	Machine feasibility 2-5 GeV possible
Test run	2.6-5.0	6	1 pt (3.55)	6 pt	40	Understand: • trigger criteria • beam associated bg • L←largeangle Bhabha • conf. and a paper
Finer scan	2.0-4.8	85	6 pts	37 pt	105	• $\Delta R/R$(2-5 GeV) ~7 10%. • Understand the structure in 3.7-4.5 GeV


Sept. Beam (R Scan 99)
Sept.and single Beam (R Scan 99)
BESII (Online R Scan 99)
BESII (R Scan 98)
R Value
Center-of-mass energy E_{cm} (GeV)
1
2
3
4
5
6
7
8
2
3
4
5

☞ Summary

- **Reducing ΔR in the low energy region is important and urgent for the precision test of the SM**

- **R scan with BES at BEPC was carefully planned and were successful**

  Pre-study→first scan→finer scan

- **BES measurement will reduce ΔR/R from (15-20)% to (7-10)% in 2-5 GeV**