New R values in 2-5 GeV from the BES

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The BES Collaboration

China

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Shanghai Jiaotong University
Zhe Jiang University
Hua Zhong Normal University
Wu Han University
Henan Normal University
Hunan University

US

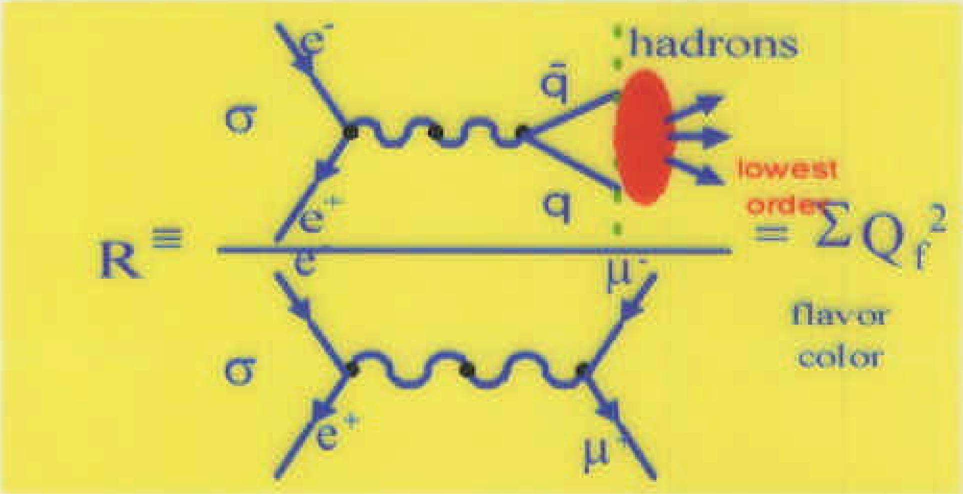
University of Hawaii
Colorado State University
Stanford Liner Accelerator Center
University of Texas at Dallas

South Korea

Korea University
Seoul National University
Chonbuk National University

I Motivation

R: one of the most fundamental quantities in particle physics



Experimentally,

$$R = \frac{1}{\sigma_{\mu+\mu-}} \cdot \frac{N_{had} - N_{bg}}{L \cdot \varepsilon_{had} \cdot (1+\delta)}$$

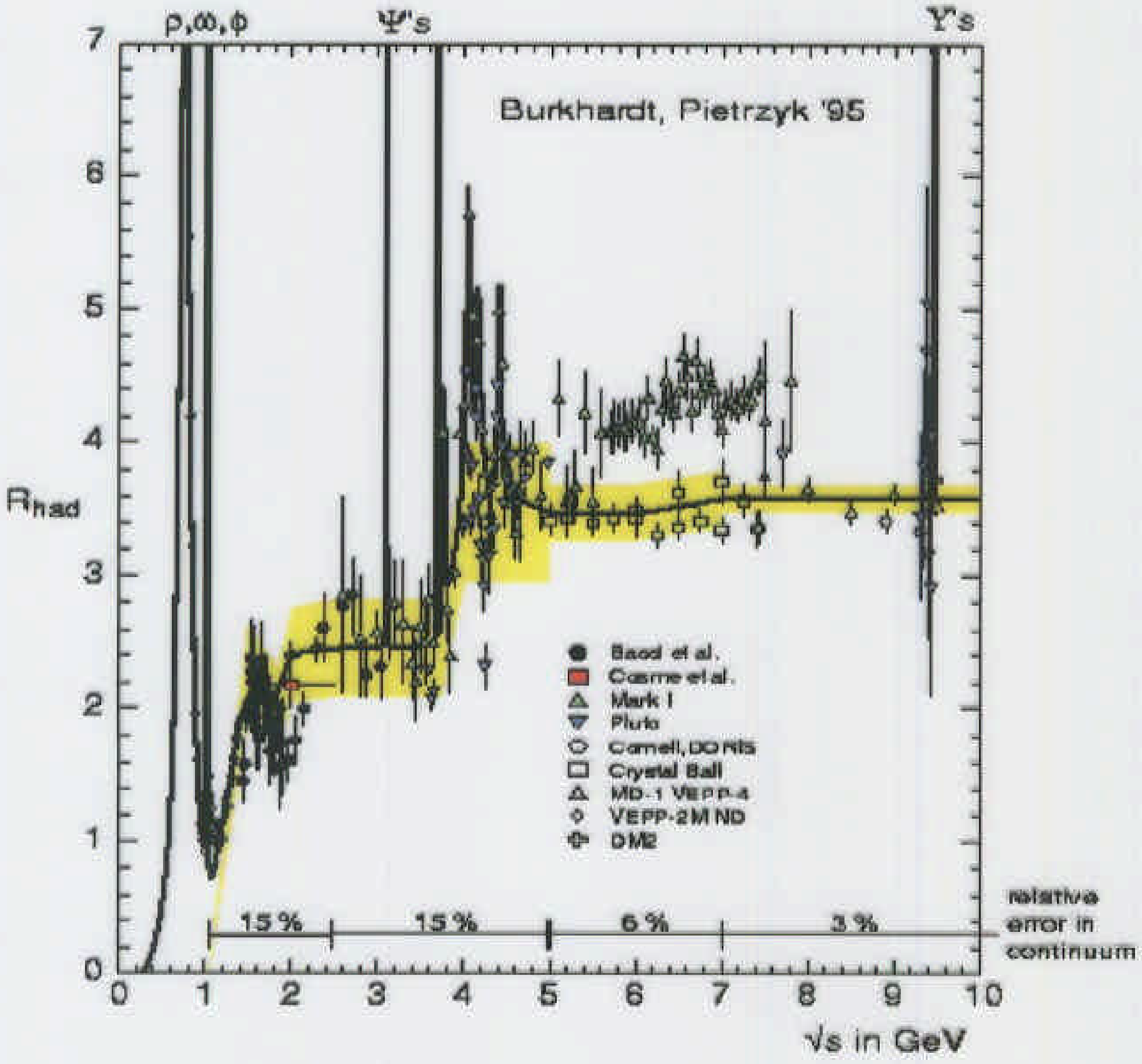
N_{had}: observed hadronic events

N_{bg}: background events

L: integrated luminosity

ε_{had}: detection efficiency for N_{had}

δ: radiative correction



- ΔR/R~15% below 5 GeV
- Unclear & complex structure in 3.7-5 GeV

Why are R-values in low energy e^+e^- of interest?

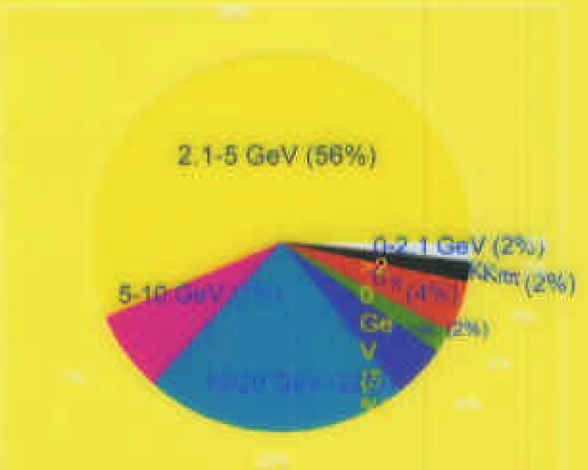
- Reducing the uncertainty of $\alpha(M_Z^2) \rightarrow$ essential for precision tests of the SM

$$\alpha \equiv \alpha_0 / (1 - \Delta\alpha)$$

$$\Delta\alpha(s) = \Delta\alpha(s)_{lep} + \Delta\alpha(s)_{had}$$

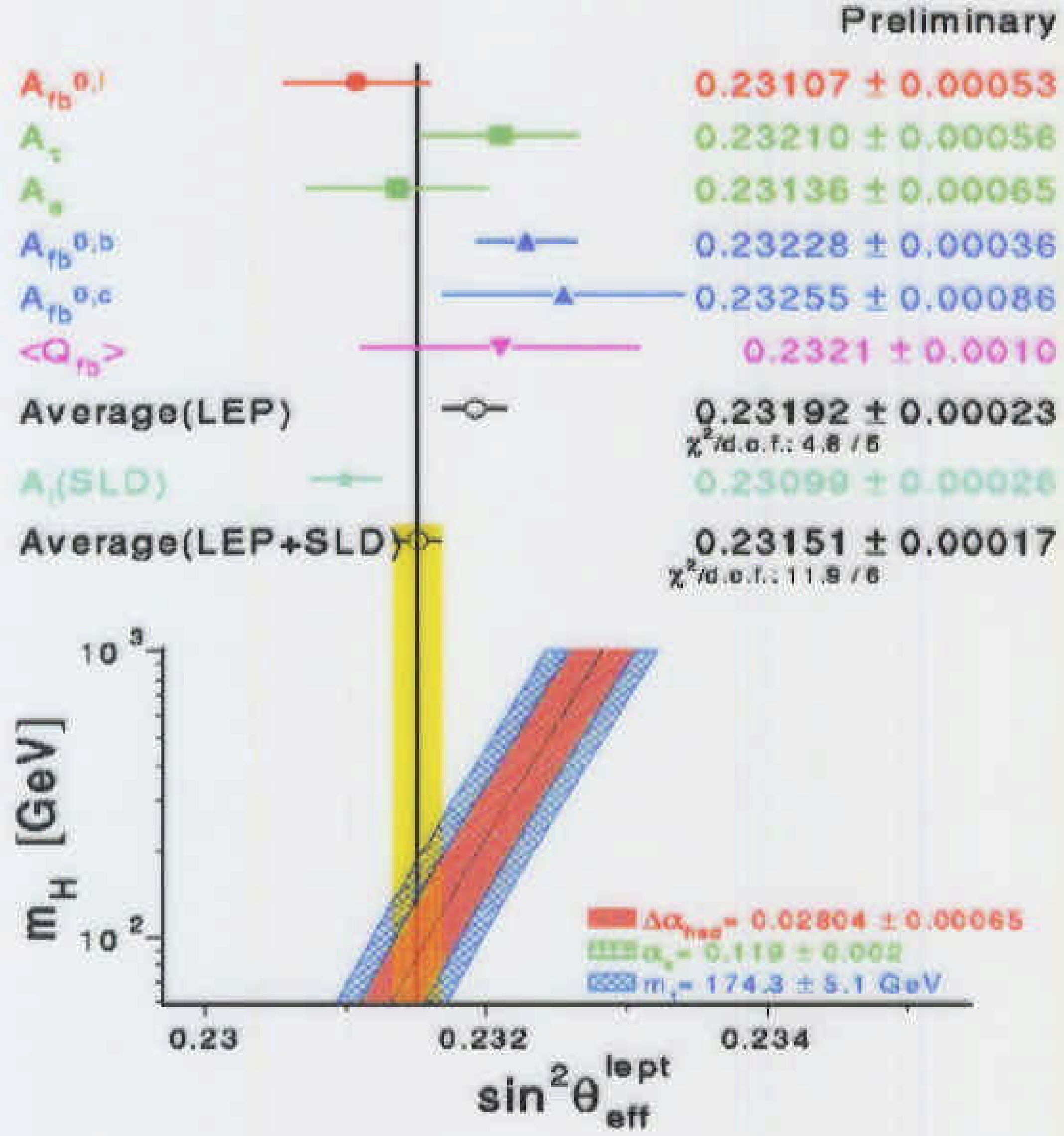
	calculated	measured
at M_Z^2	0.03142	0.0280±0.0009

$$\Delta\alpha_{had}(M_Z^2) = -\frac{\alpha(0) M_Z^2}{3\pi} \mathrm{Re} \int_{4m_\pi^2}^{\infty} ds \frac{R(s)}{s(s - M_Z^2) - i\varepsilon}$$



Relative contribution to the uncertainty of $\Delta\alpha(M_Z^2)$

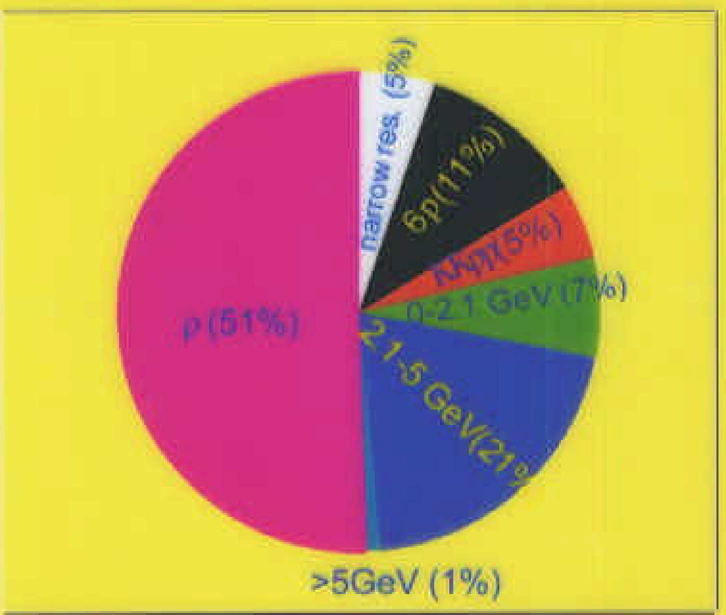
The E.W. data from high energy are now so precise that the radiative correction gives rise to the precision tests of the E.W. theory
In particular, the indirectly determination of m_H depends critically on the precision of $\alpha(M_Z^2)$



- Hunting for new physics from $a_\mu \equiv (g-2)/2$
  → Interpretation of E821 at BNL

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

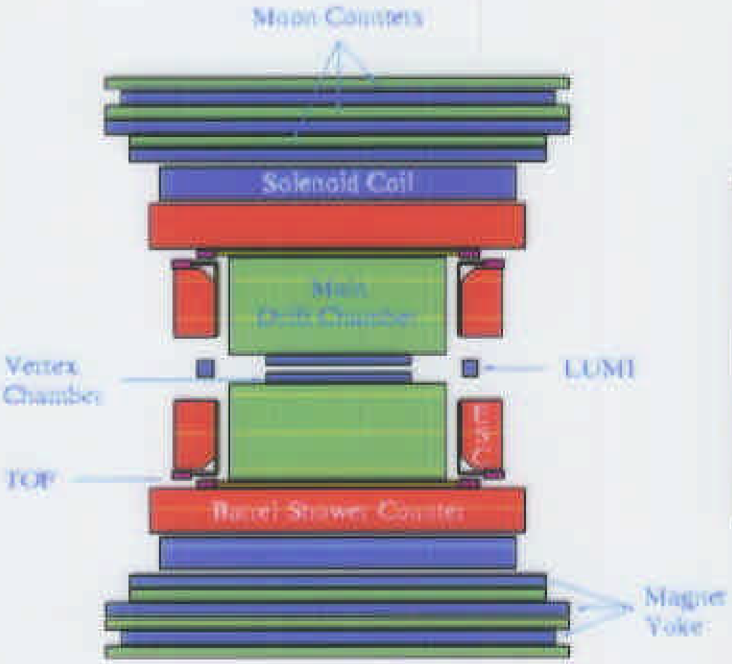
$$a_\mu^{had} = \frac{\alpha^2(0)}{3\pi^2} \int_{4m_\pi^2}^{\infty} ds \frac{K(s)}{s^2} R(s)$$



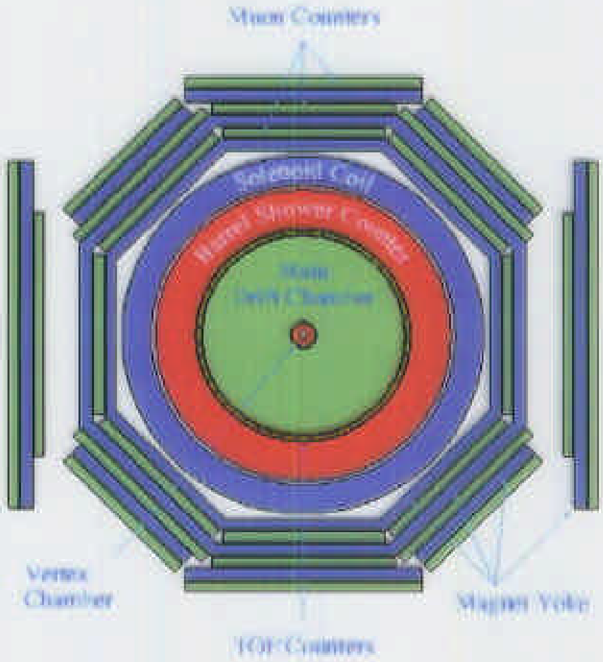
Relative contribution to the uncertainty of g-2

II R Scan and Data Analysis

BESII detector



Side view of the BES detector



End view of the BES detector

VC:	$\sigma_{xy} = 100\ \mu m$
MDC:	$\sigma_{xy} = 200\ \mu m$, $\sigma_{dE/dx} = 8.4\ \%$
	$\Delta p/p = 1.78\sqrt{(1+p^2)}\ \%$
BTOF:	$\sigma_T = 180$ ps
BSC:	$\Delta E/\sqrt{E} = 22\ \%$, $\sigma_z = 2.3$ cm
μ counter:	$\sigma_z = 5.5$ cm

BES R Scan

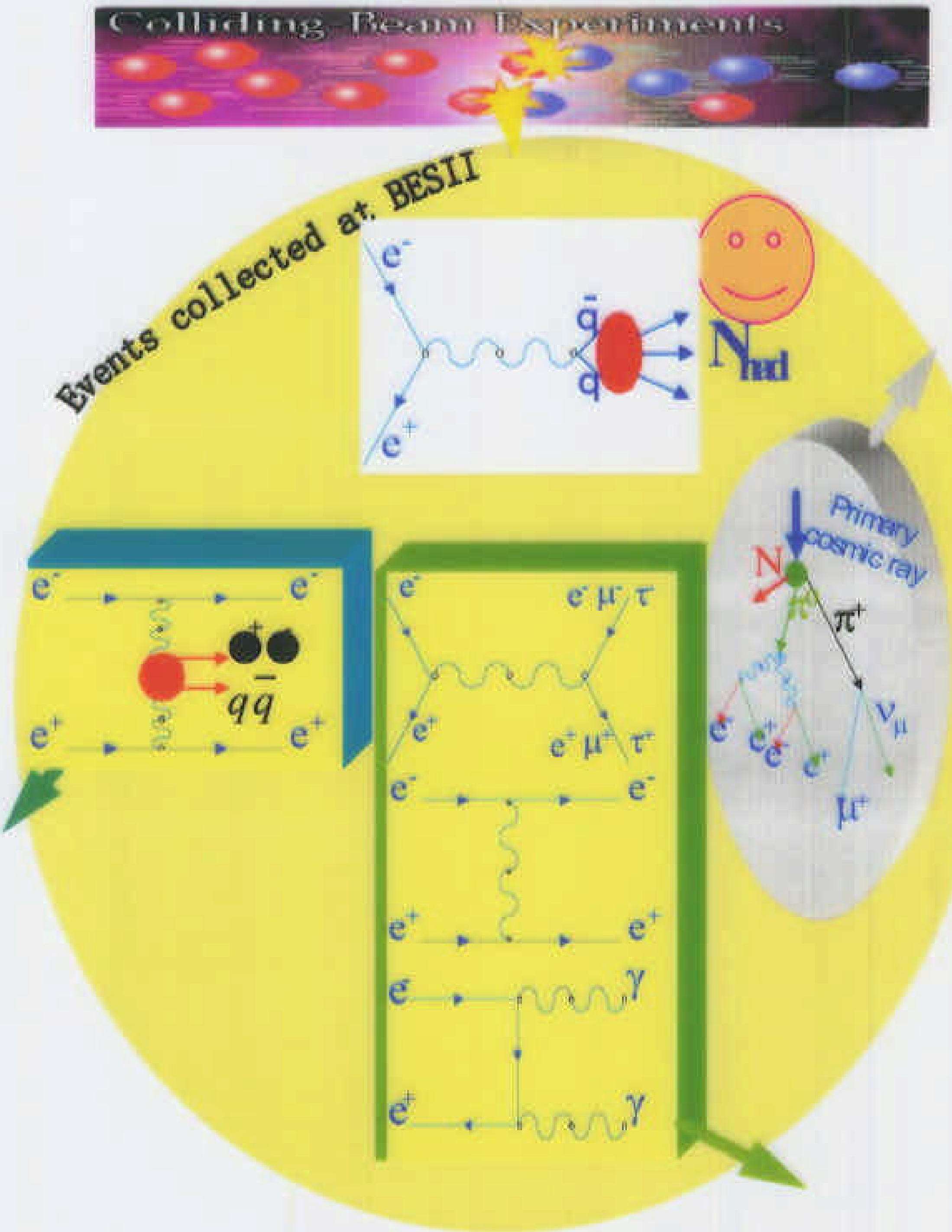
March-May, 1998:

- 6 energy points
  at 2.6, 3.2, 3.4, 3.55, 4.6, 5.0 GeV

Feb.- June, 1999:

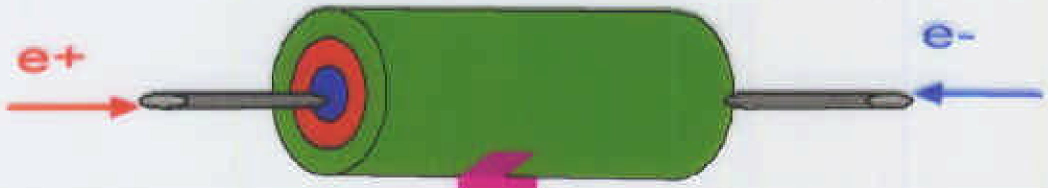
- 85 energy points at 2.0-4.8 GeV
  + 24 energy points separated beam operation

Events Recorded by BESII



Hadronic Events Selection

Select $N_{had}(e^+e^- \to \gamma \to hadrons)$ from all other possible contamination mechanisms.



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:

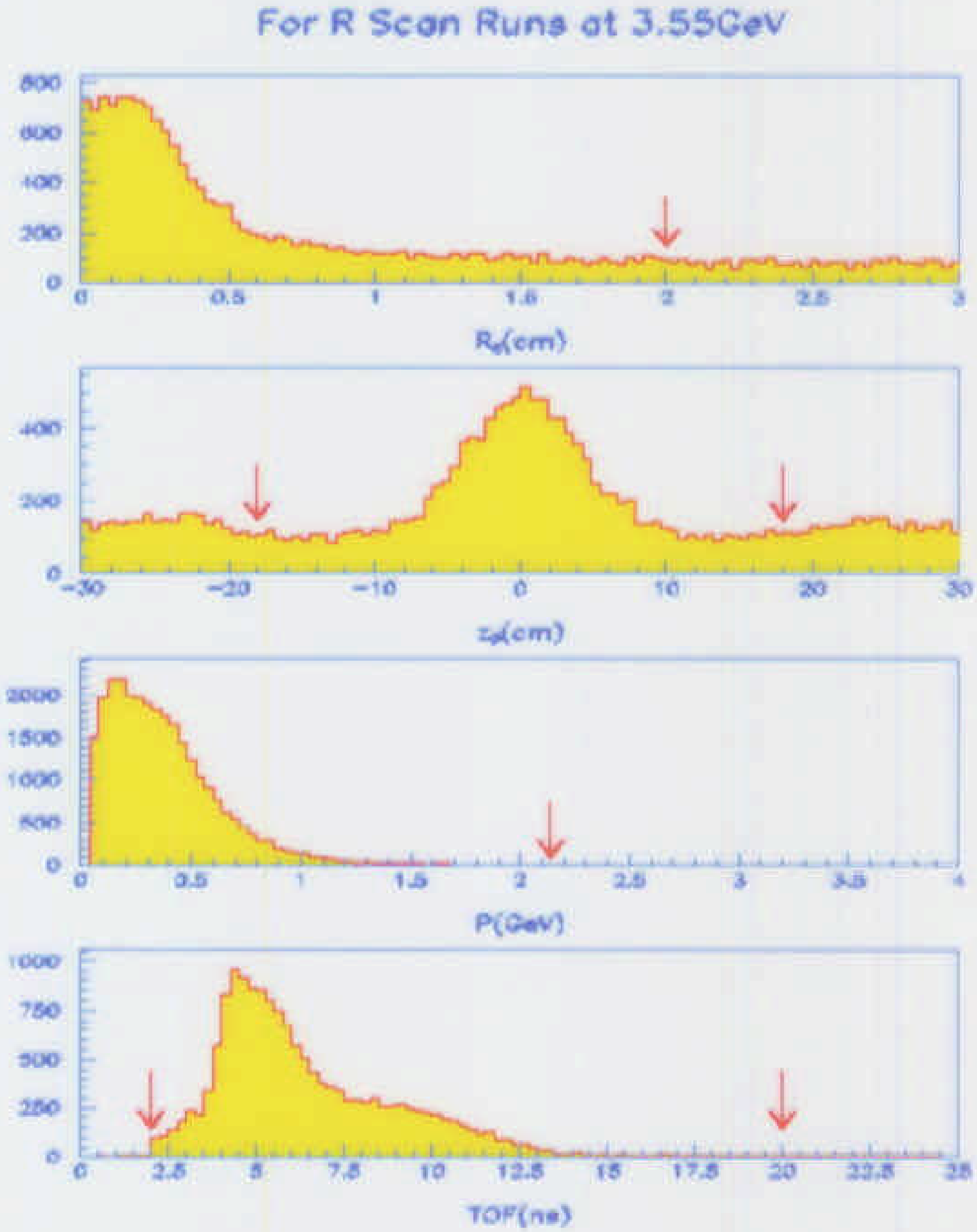
t	$2 < t < t_p + 5\sigma_{TOF}$
	$\lvert\cos\theta\rvert < 0.84$
r	$r_0 < 2.0$ cm, $\lvert z_0\rvert < 18$ cm for MFIT=2
	N_{hit} (dE/dx) ≥ 16 for MFIT=-19
p, E	$p < 0.6\ E_{beam} + 5\ \sigma_p$, $E < 0.6\ E_{beam}$

Select good hadronic events:

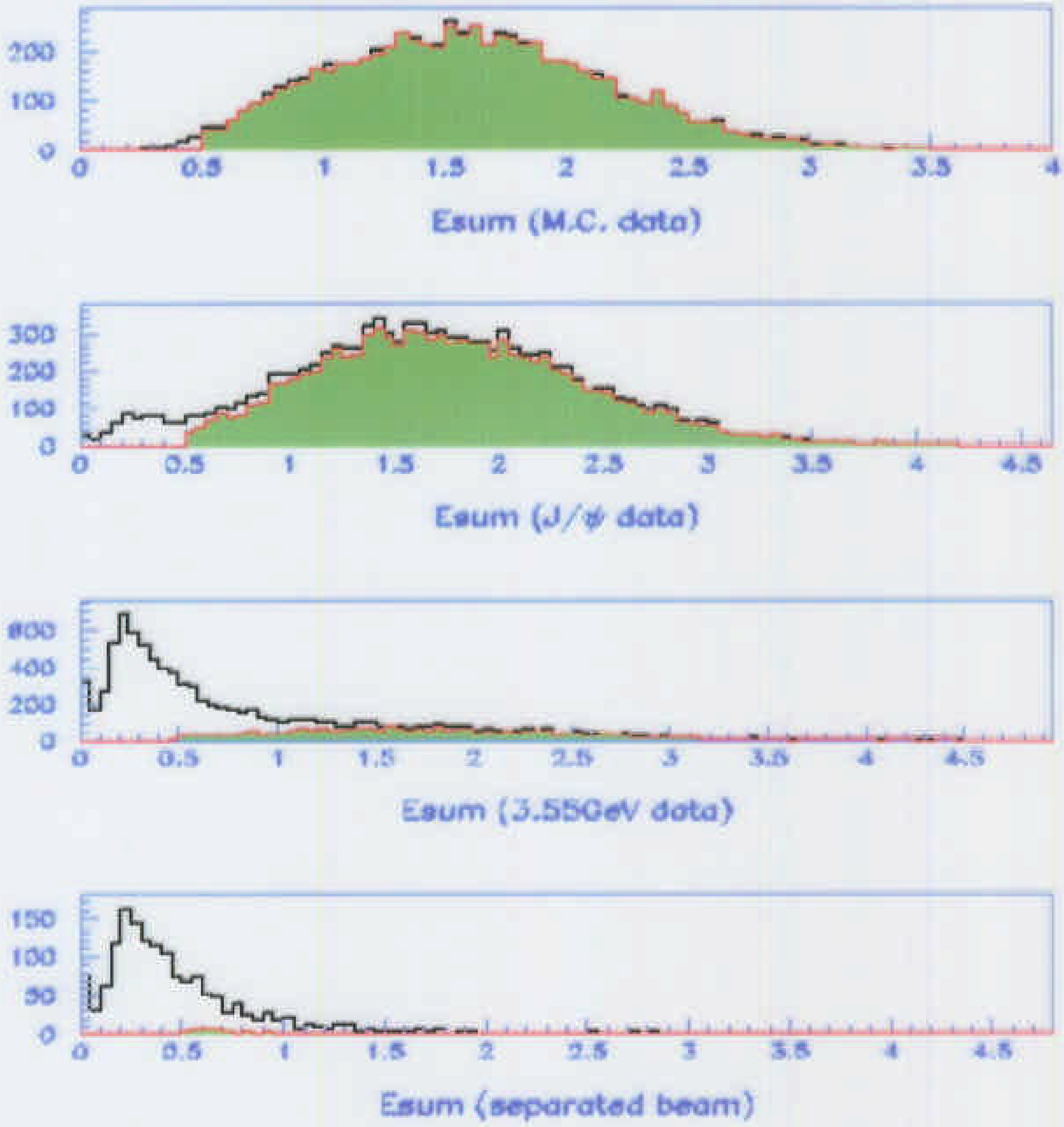
- $\geq$ 2-prong with $\geq$ 1 good track (MFIT=2)
- $\Sigma\ E > 0.28\ E_{beam}$
- Not back-to-back + $\geq$ 2 isolated γ's

N_{had}

Some Cuts for Selecting N_{had}



The observed hadronic events (green parts) for different data



Background Subtraction

Background sources:

1 Cosmic ray

2 Lepton pair production

3 Two-photon processes

4 Beam associated ← most serious

1-3 subtracted by event selection and MC

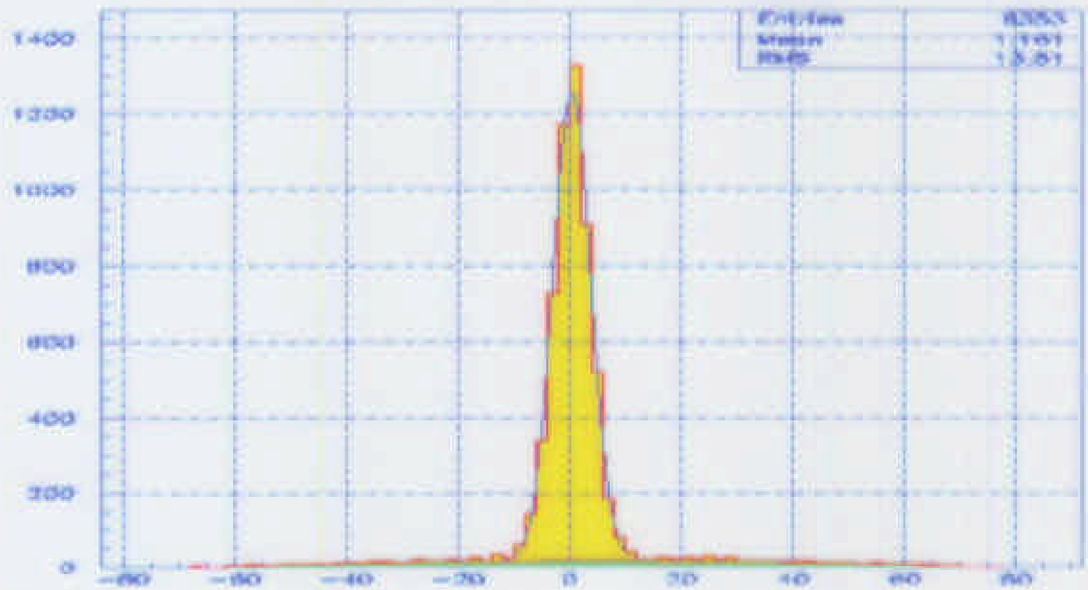
4 subtracted by

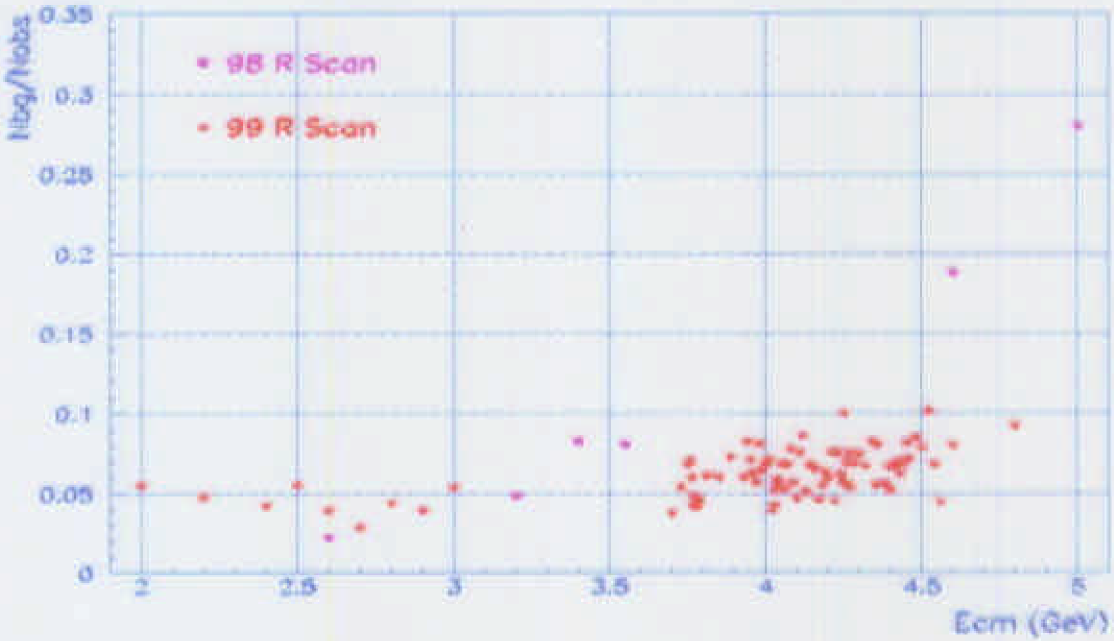
a fit the event vertex distribution

b separated beam and single beam operation data

$$N_{bg} = f \times N_{sep} \qquad f = \frac{\int_{colliding} dt \cdot P(t) \cdot [I_{e^+}(t) + I_{e^-}(t)]}{\int_{separate-beam} dt \cdot P(t) \cdot [I_{e^+}(t) + I_{e^-}(t)]}$$

Both a and b are consistent

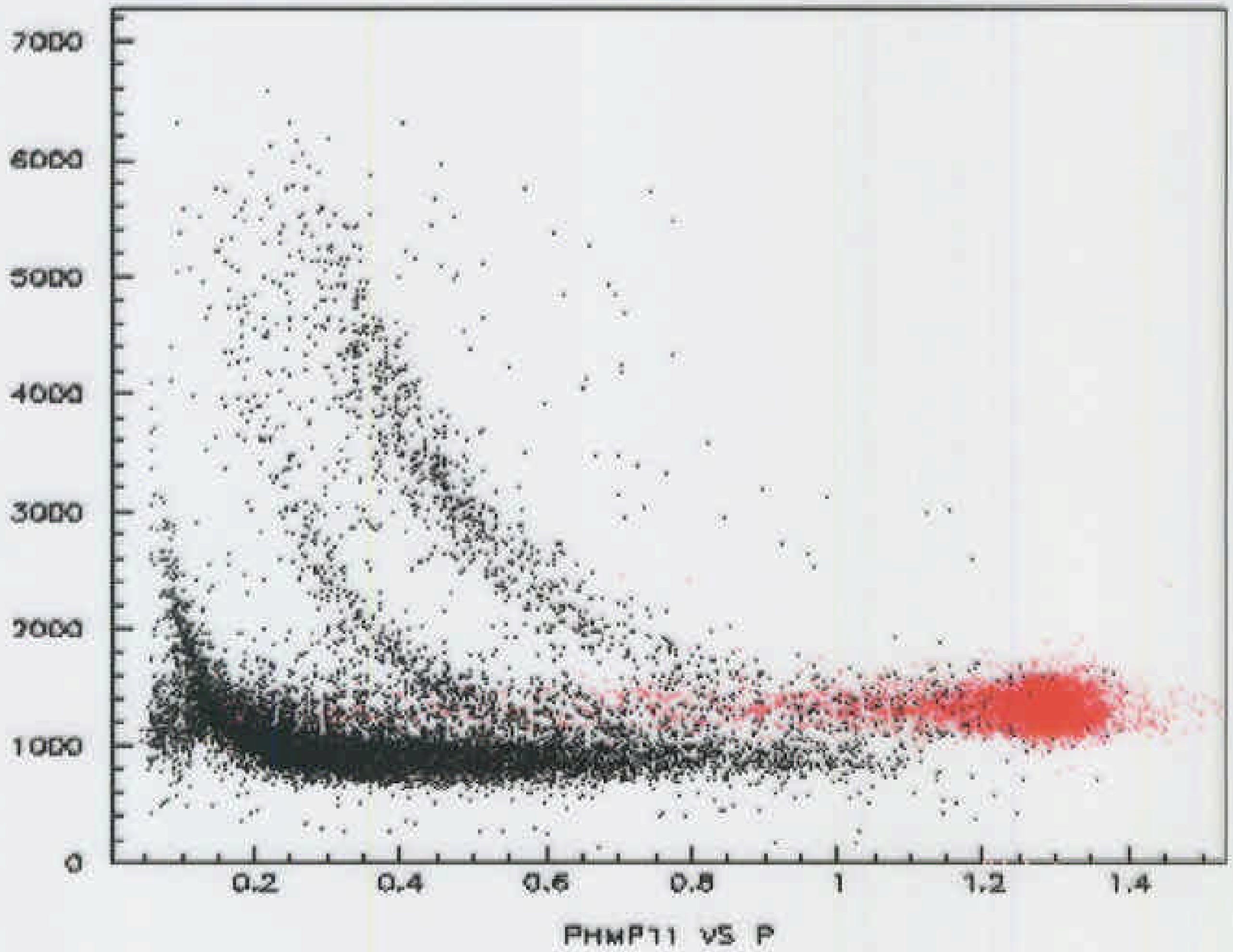

1400
1200
1000
800
600
400
200
0
-80
-60
-40
-20
0
20
40
60
80


Nbg/Nobs
98 R Scan
99 R Scan
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
2
2.5
3
3.5
4
4.5
5
Ecm (GeV)

Luminosity Measurement

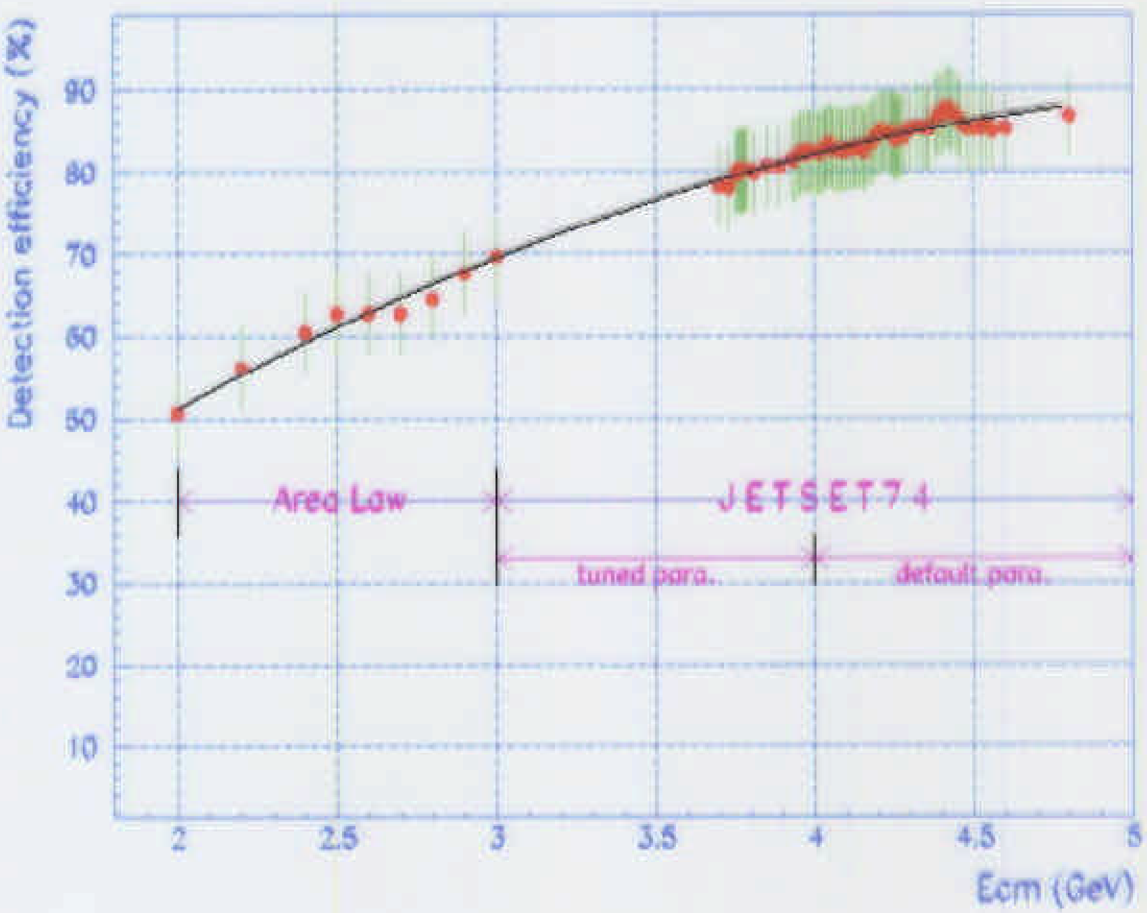
Rely on large-angle Bhabha

- $e^+e^- \rightarrow e^+ e^- (\gamma)$
- $e^+e^- \rightarrow \gamma\gamma$ (cross check)

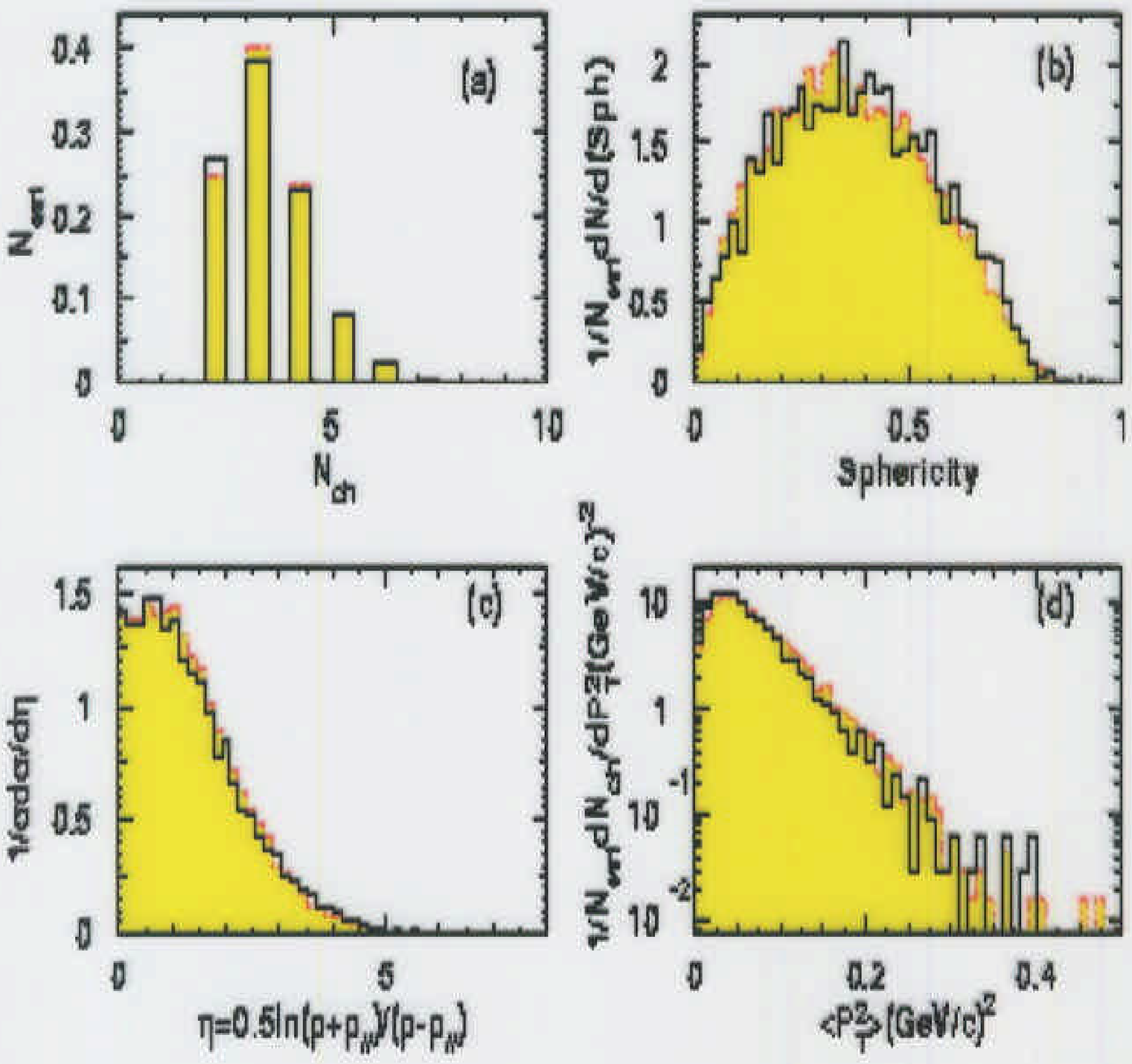


Detection Efficiency for the Hadronic Events

- Rely on hadronic events generator $\leftarrow$ model dependent
- LUARLW is developed to improve JETSET for low energy region



Some Hadronic Event Shapes



Radiative Correction

ISR: remove high order effects from

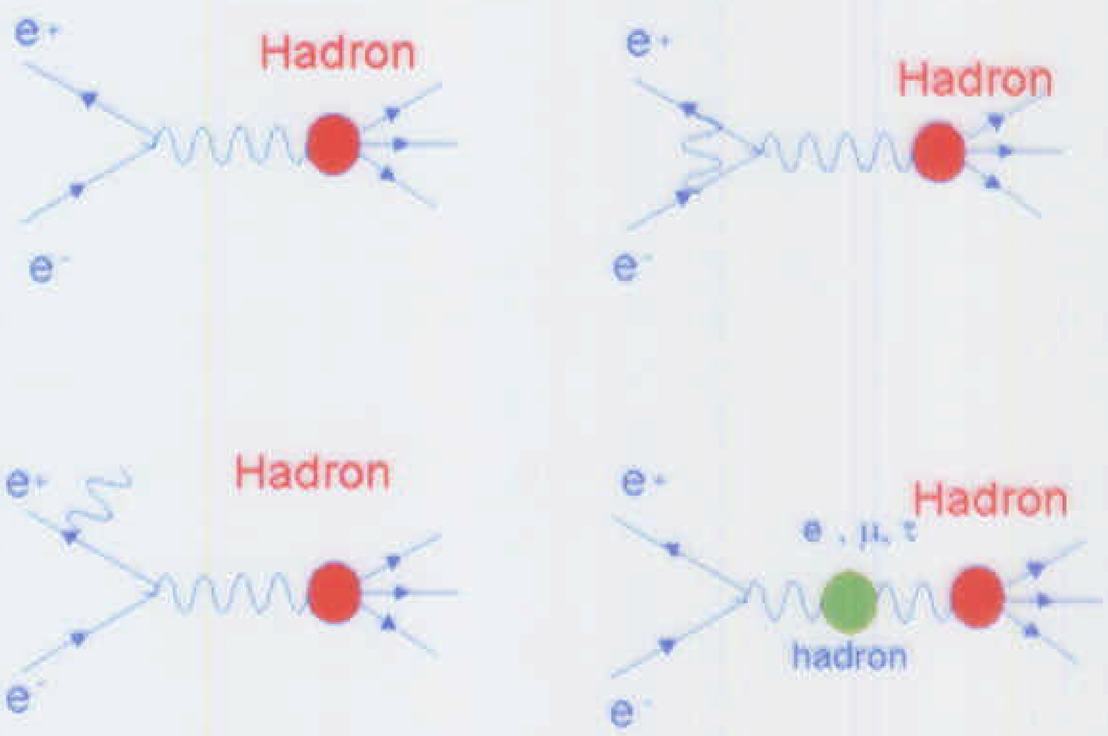
leading order [$O(\alpha^2)$, diagram (a)] σ_{had}^{obs}

↓

$$\sigma_{had}^{obs} = \sigma_{had}^{0} \cdot \bar{\varepsilon}_{had} \cdot (1+\delta)$$

↑

δ_{vert}, δ_{vac}^{l} (l=e, μ, τ), δ_{vac}^{had} and δ_{γ}



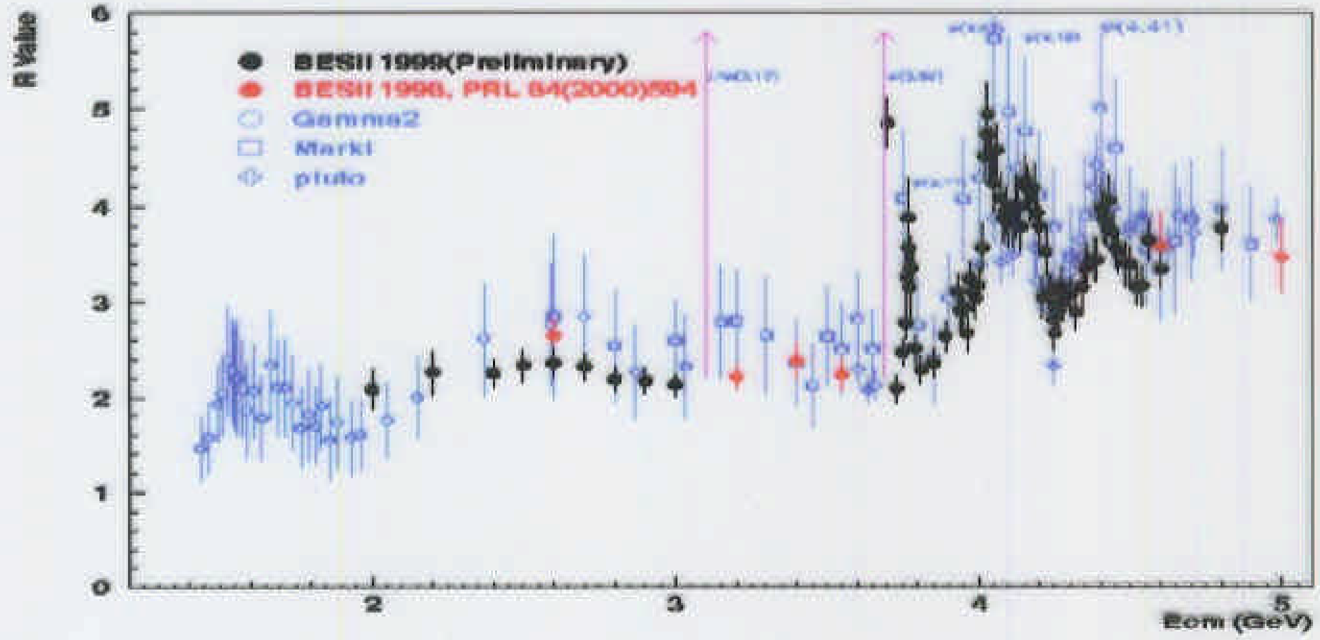
Four schemes are used to calculate ISR. They are consistent within 1%. In the continuum region.

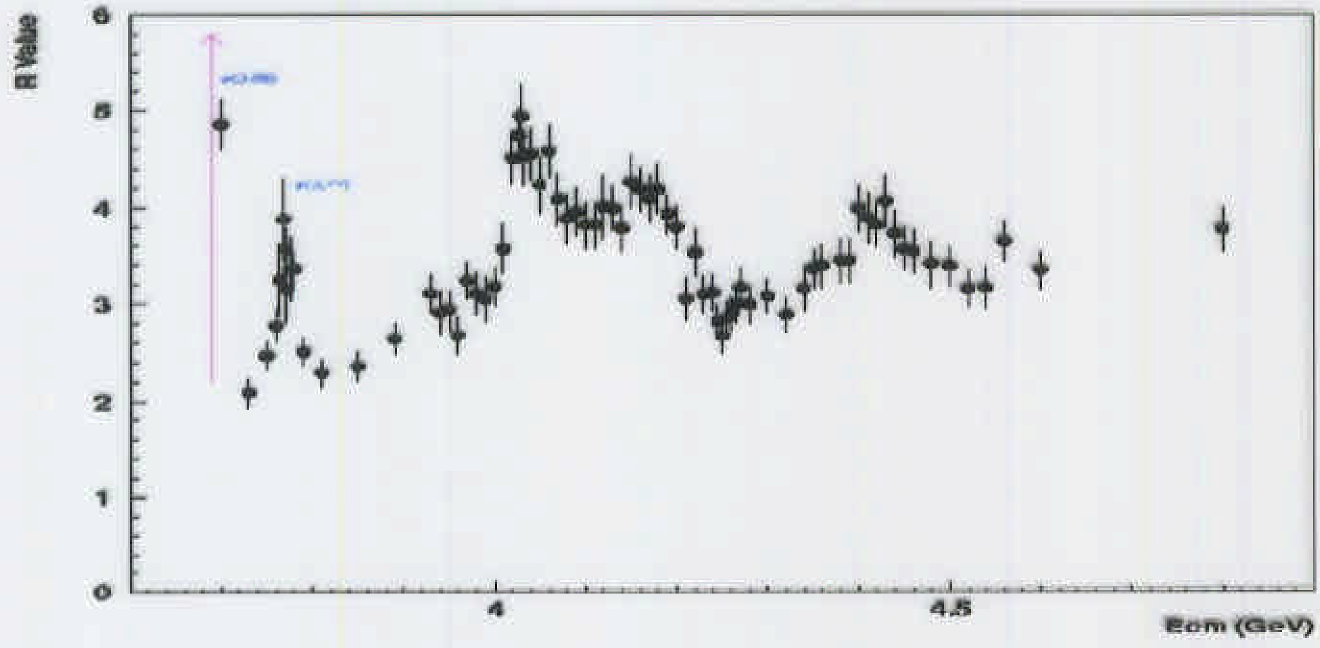
III Preliminary Results

Error Sources (at 3.0 GeV)

Source	Error contribution (%)
N_{had}	3.3
L	2.3
$1+\delta$	1.3
ε_{had}	3.0
Stat.	2.5
Total	**5.5**

R Values in 2-5 GeV





IV Summary

- BES measured R in 2-5 GeV with typical uncertainties of ~7%
  (a factor of 2-3 improvement)
- Further significant improvements in the 2-5 GeV energy region would require a τ-charm factory