Measurement of the luminosity

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Φ Decays February 3rd 2005

- Motivations: the error on $\sigma_{\pi\pi(\gamma)}$
- Selection criteria of VLAB events
- Comparisons among MC codes
- Acceptance
- Clustering
- Background
- Cosmic veto
- Dependence on $s^{1/2}$

Luminosity	0.6 %
Vacuum Polarization	0.2 %
FSR resummation	0.3 %
Radiation function ($H(s_\pi)$)	0.5 %
Total theory systematics	0.9 %

Large Angle Bhabha filter

$$\int \mathcal{L}\,dt = \frac{N_{obs} - N_{bkg}}{\sigma_{eff}}$$

luminosity is given by Bhabha events divided for a σ evaluated folding theory (QED rad. corrs.) with the detector simulation

Data

↓

TRIGGER

↓

EmC Reconstruction

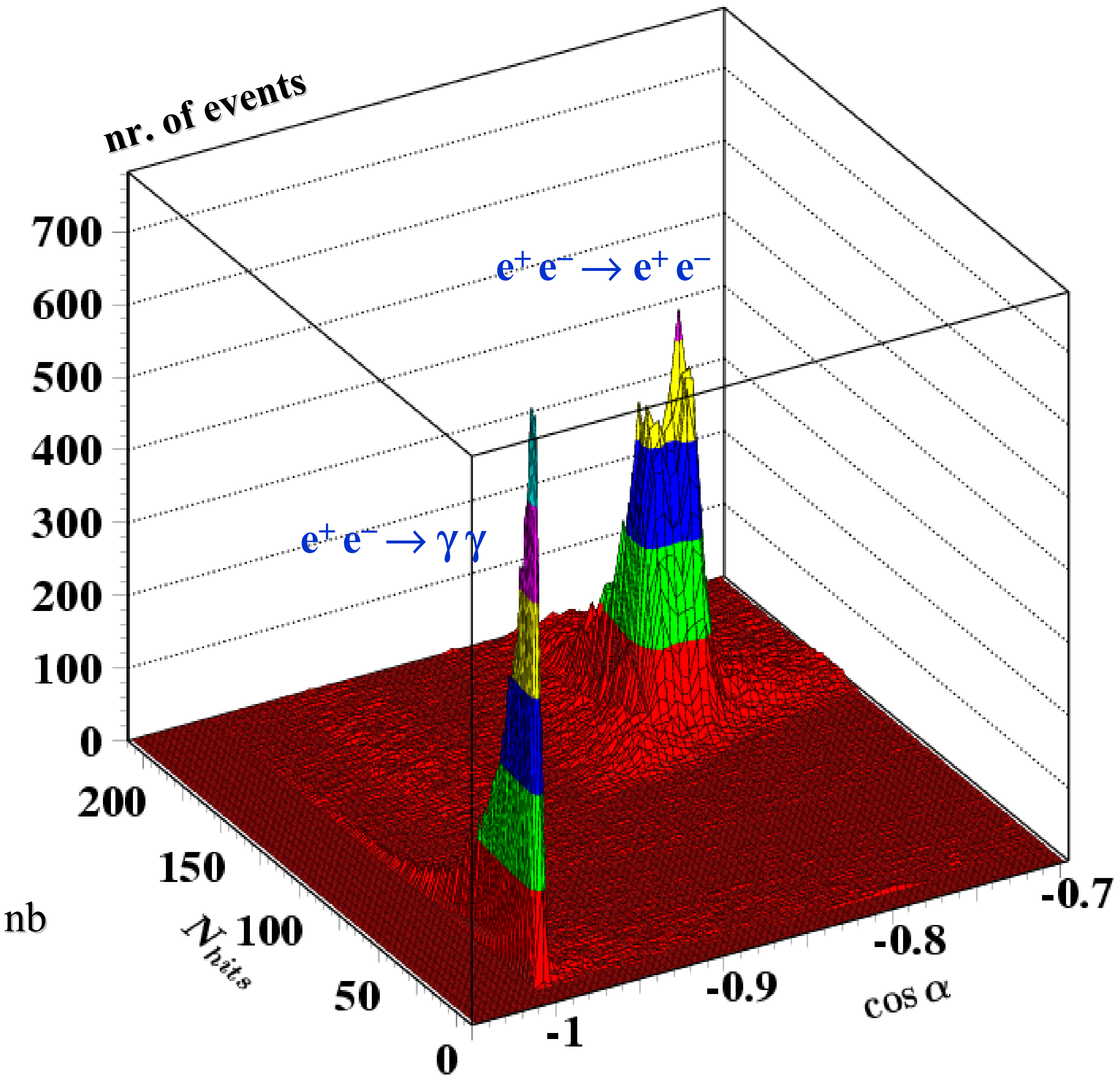
↓

FILFO

GGL: $\gamma\gamma$ $\sigma_{eff} \approx 120$ nb

LAB: e^+e^- $\sigma_{eff} \approx 800$ nb

α = angle btw the 2 most energetic clusters

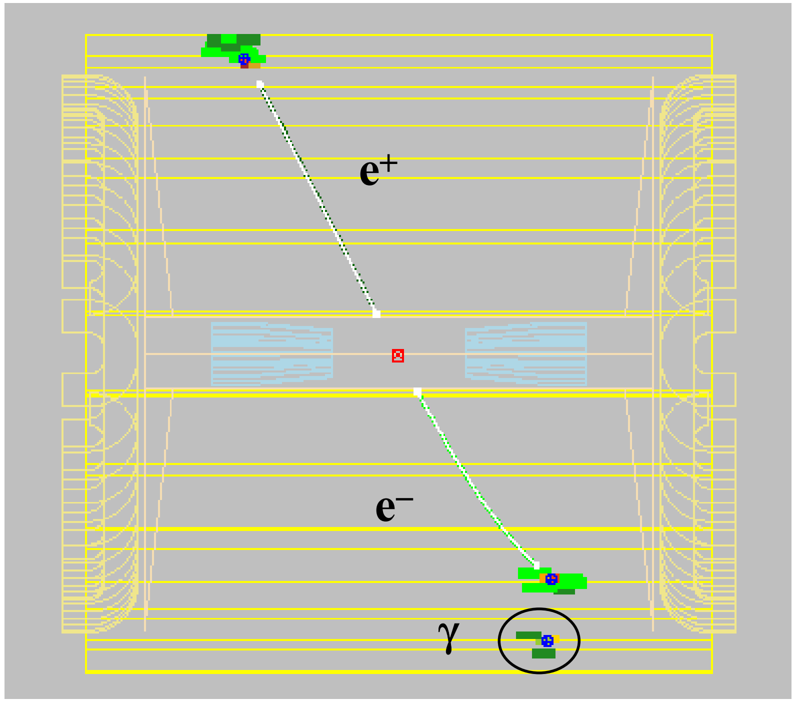


Very Large Angle Bhabha requirements

LAB filter: mainly EMC cuts, except for $N_{hits} > 50$

2 clusters with:

1) $300\ \text{MeV} < E < 800\ \text{MeV}$
2) $45^{o} < \theta_{1,2} < 135^{o}$
3) $\zeta = |\theta_1 + \theta_2 - 180^{o}| < 10^{o}$
4) $\cos\alpha > -0.975$



VLAB selection (after LAB): using DC to clean the sample

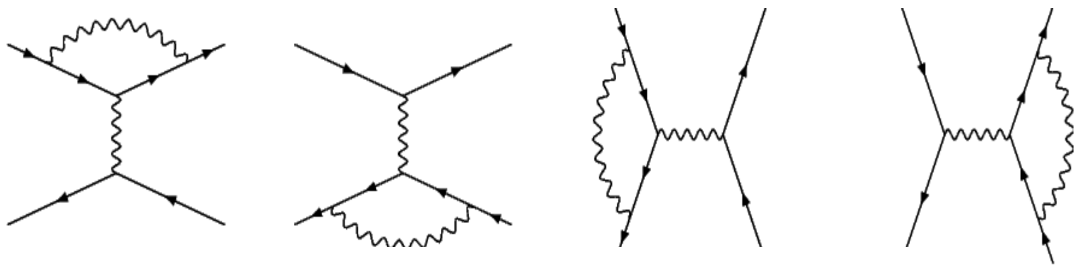
2 tracks with:

1) $\rho < 7.5$ cm, $|z| < 15$ cm
2) $p > 400$ MeV
3) opposite curvature

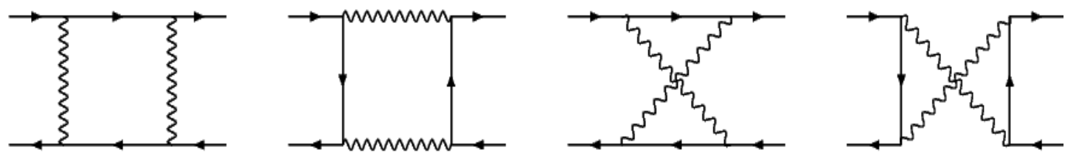
and the EMC cuts are tightened:

4) $55^{o} < \theta_{1,2} < 125^{o}$
5) $\zeta < 9^{o}$

The effective cross section: comparisons



a set of 1 loop diagrams



BHAGENF:

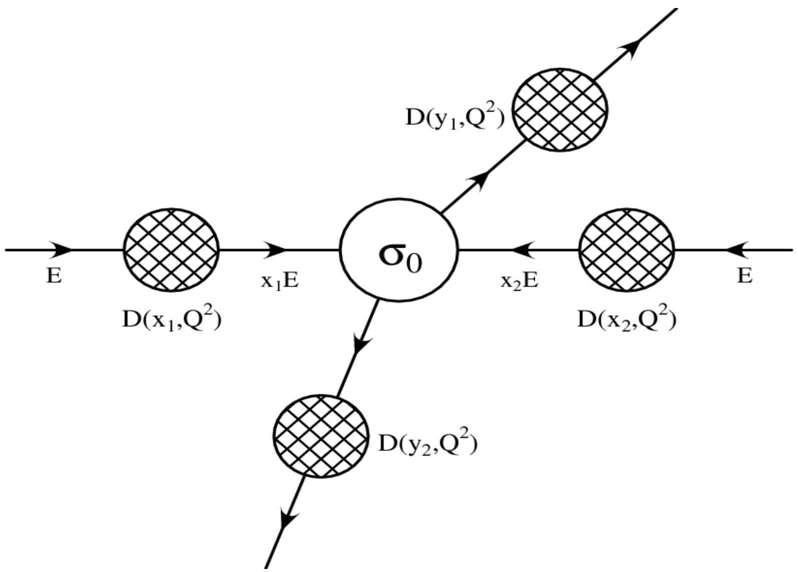
1) complete 1 loop calculations

2) infrared and hard γ corrections

3) the ϕ exchange diagram

BHAGENF: σ_{eff} = (430.7 ± 0.3_{stat}) nb

both groups of authors claim 0.5%



BABAYAGA:

1) multiphoton emission parameterized by structure functions $D(x,Q^2)$, folding the Born cross section σ_0, each $e^{\pm}$ can emit up to 4 photons

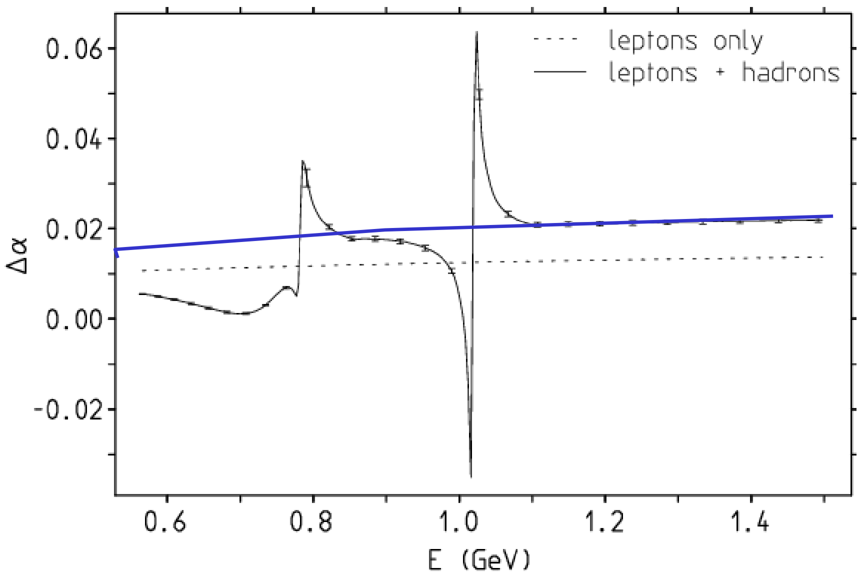
2) the ϕ exchange diagram

BABAYAGA: σ_{eff} = (431.0 ± 0.3_{stat}) nb

The effective cross section: comparisons

1) only comparing pure QED corrections (ϕ exchange and vacuum polarization are switched off) from "stand alone" evaluations:

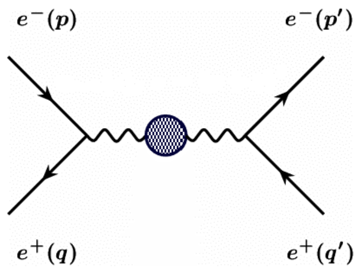
BHAGENF	$(460.8 \pm 0.1_{stat})$ nb	
		0.3 %
BABAYAGA	$(459.4 \pm 0.1_{stat})$ nb	
		0.7 %
BHWIDE	$(456.2 \pm 0.1_{stat})$ nb	
		0.1 %
MCGPJ	$(455.3 \pm 0.1_{stat})$ nb	



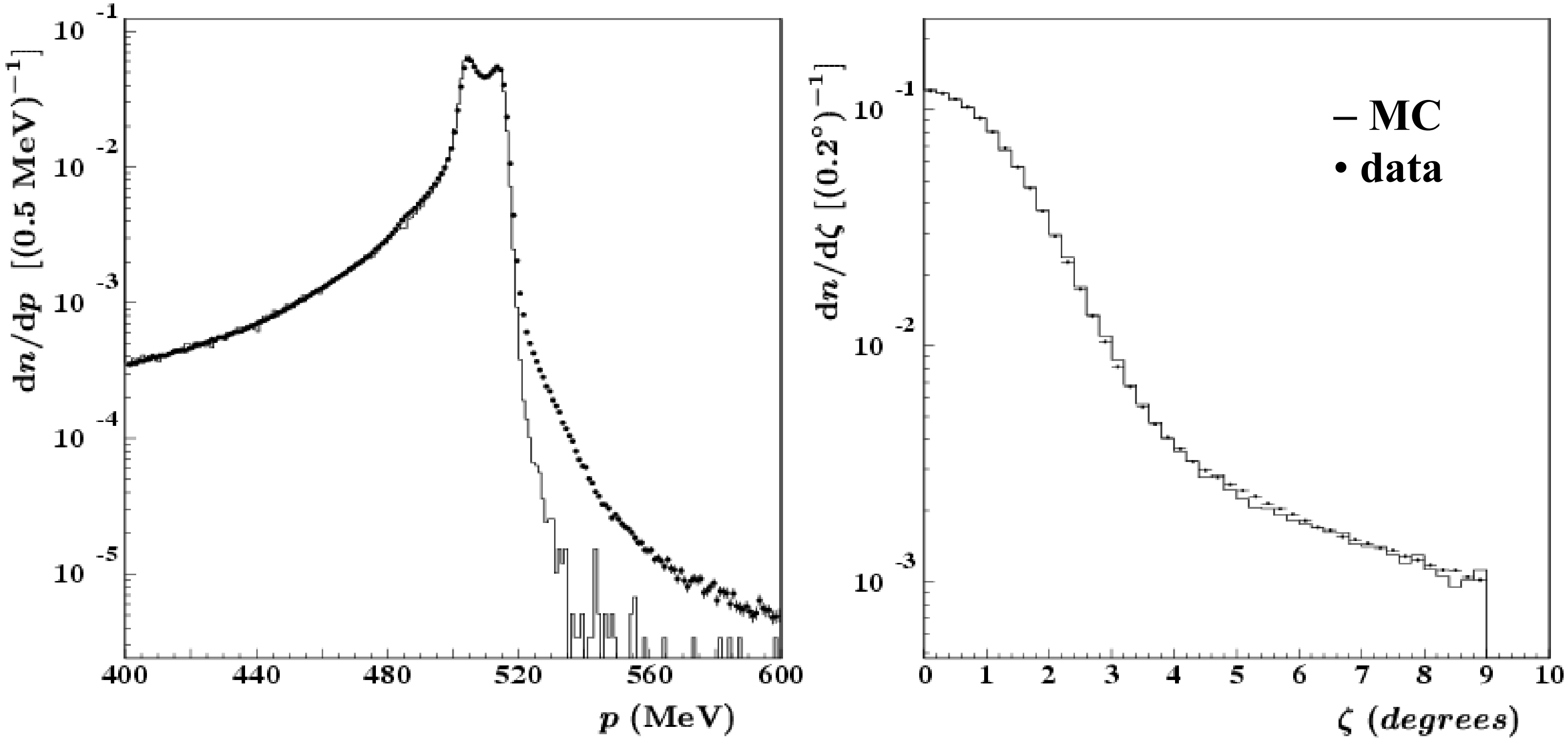
2) the correct running of $\alpha_{em}(s)$ is completely equivalent to the explicit ϕ exchange diagram:

$$\sigma \text{ (wrong } \Delta\alpha_{had}(s) \text{ with } \phi) = 471.97 \pm 0.11 \text{ nb}$$

$$\sigma \text{ (correct } \Delta\alpha_{had}(s) \text{ no } \phi) = 471.63 \pm 0.11 \text{ nb}$$

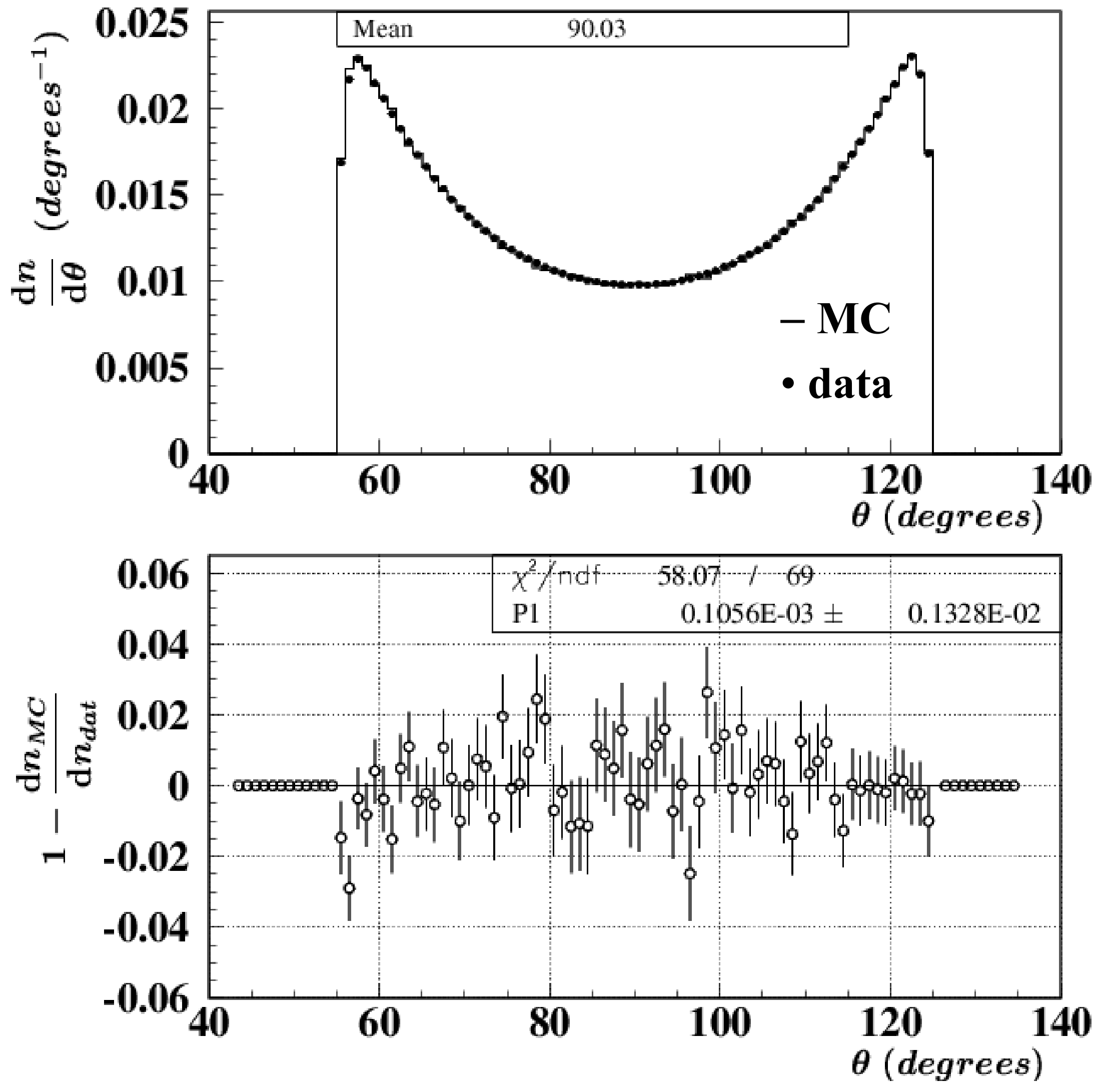


Momentum and ζ comparisons



- ✓ the agreement near p ~ 400 MeV is very good, a difference at large p tail is negligible
- ✓ perfect agreement in the acollinearity distributions

Polar angle studies



✓ global agreement is very good

but the cut occurs in a steep region of the distributions

⇒ estimate of border mismatches

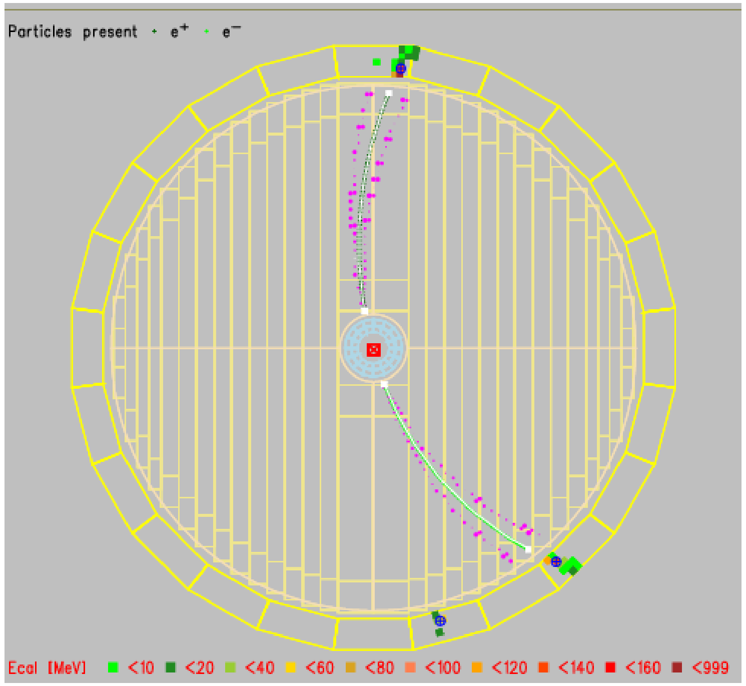
✓ after normalizing MC to make it coincide with data in the region $65^o < \theta < 115^o$, we estimate as a systematic error:

$$\frac{N^{dat}_{[55:65]+[115:125]} - N^{MC}_{[55:65]+[115:125]}}{N^{dat}_{TOT}} \sim 0.2\%$$

Clustering efficiency: the problem

definition of the control sample:

1) **1 vtx in |r| < 5 cm with exactly 2 tracks**
2) **ρ_{LH} > 180 cm for both**
3) **1017.5 MeV < M_{e+e-} < 1021.5 MeV**
4) **m_{trk} < 90 MeV**



among these events we look for 2 clusters with:

1) **$|\rho_{LH} - \rho_{clu}|$ < 40 cm for both**
2) **$|t_{clu1} - t_{clu2}|$ < 4 ns**
3) **E_{clu} > 300 MeV for both**

$$\varepsilon^{data}_{clust} = (99.58 \pm 0.11)\%$$

$$\varepsilon^{MC}_{clust} = (99.866 \pm 0.015)\%$$

a difference of 0.3% btw data and MC

A possible explanation

a failure in the clustering procedure,
due to wrong time information:
a parent Bhabha cluster is splitted in
≥ 2 fragments, none
surviving the cut at 300 MeV

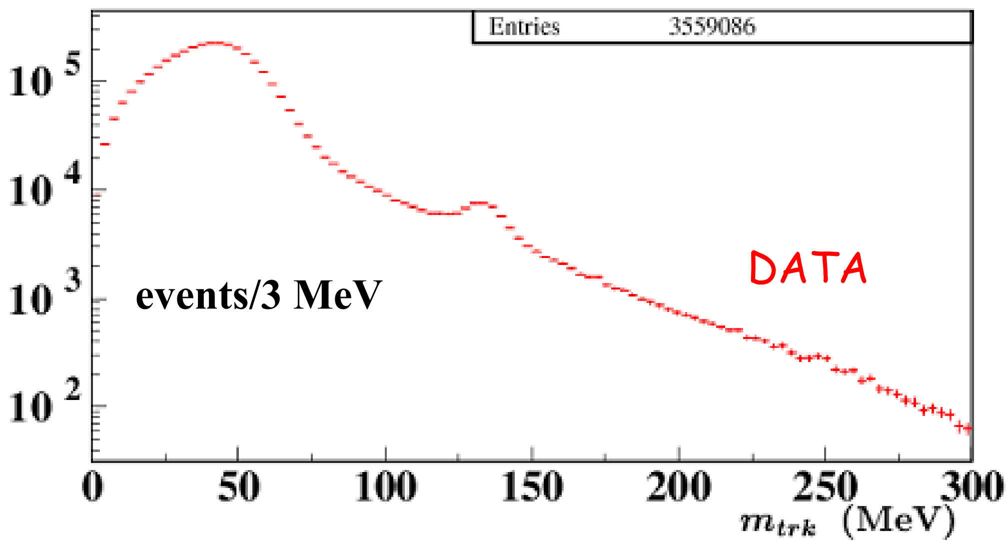
run number	VLAB events	rejected events
19400	22494	38
20477	26601	43
21849	46073	56
21851	43582	42
22222	51352	66
23100	48489	94

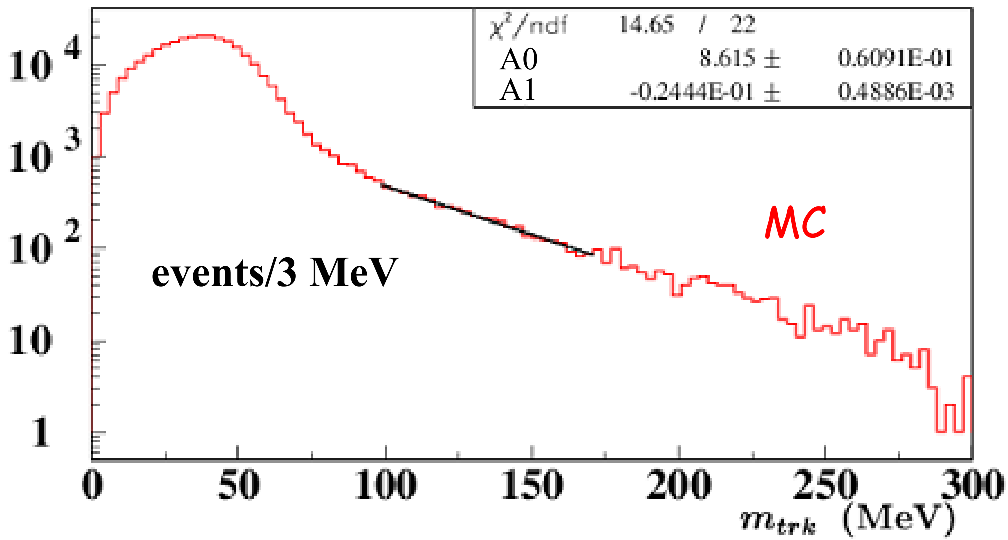
the effect is stable in time: a
correction of 0.15%, leads to a
relative difference data-MC of 0.1%

e.g. take 3 rejected events because
only 1 cluster has Ecl > 300 MeV

Ecl(MeV)	xcl(cm)	ycl(cm)	Tcl(ns)
272,3355	-208,5630	27,70736	8,378289
200,4780	-201,9149	23,74580	12,92257
252,3740	-207,5544	24,65547	8,316304
294,2352	-201,9149	23,74580	14,73577
261,4266	-208,1679	21,56501	8,280864
266,2234	-201,9149	23,74580	13,99564

Background estimate (I)

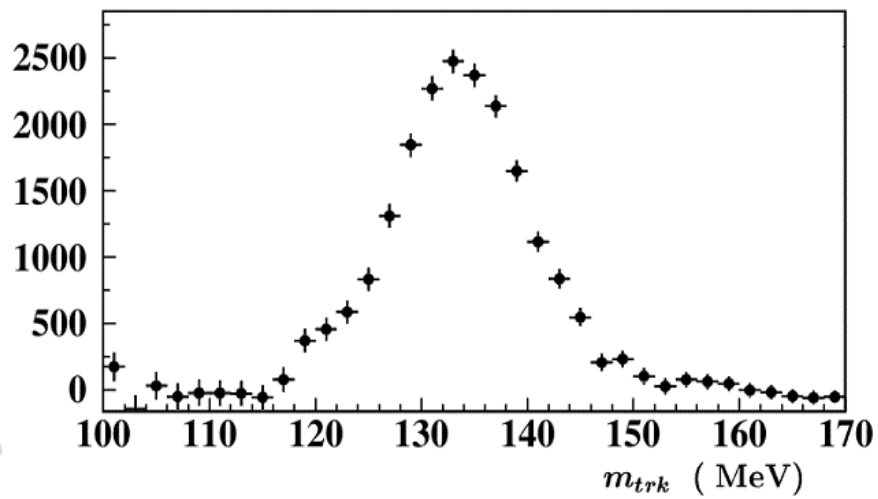




other than Bhabha, there are events with $m_{trk} \sim 136$ MeV, $e^+e^- \to \pi^+\pi^-$

around $m_{trk} \sim [100,170]$ MeV the exponential is subtracted from data

$$\frac{N_{bkg}}{N_{TOT}} = (0.541 \pm 0.004)\%$$

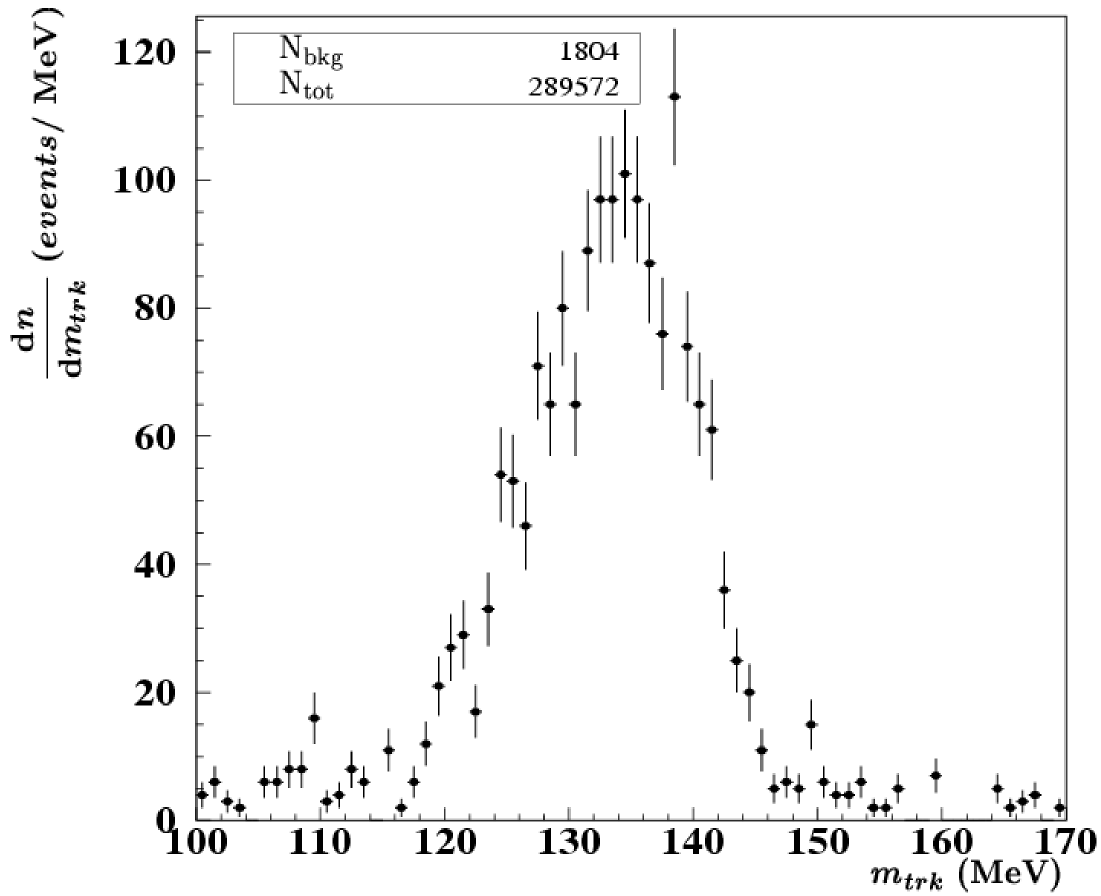


Background estimate (II)

a second method consists in using the particle discriminator e/π, requiring that at least one track to be identified as a pion in the range m_{trk} > 100 MeV

$$\frac{N_{bkg}}{N_{TOT}} = (0.623 \pm 0.015)\%$$

a weighted average of background content of 0.55% and a systematic error of 0.10% are estimated



Correction for the loss of vetoed events

in rejecting cosmic events, only 1/5 of events with **E > 30 MeV** in the outer plane of the calorimeter are acquired (2001 conditions), after filtering a run with SELCOS and running the VLAB selection, a fraction of events survives

this fraction is really stable in different runs: ~ 0.1%

the correction to be applied because of VLAB events lost at the trigger level is 4*0.1%

run number	VLAB events	lost events
19400	22494	100
20477	26601	104
21849	46073	208
22222	51352	212
23000	45483	160

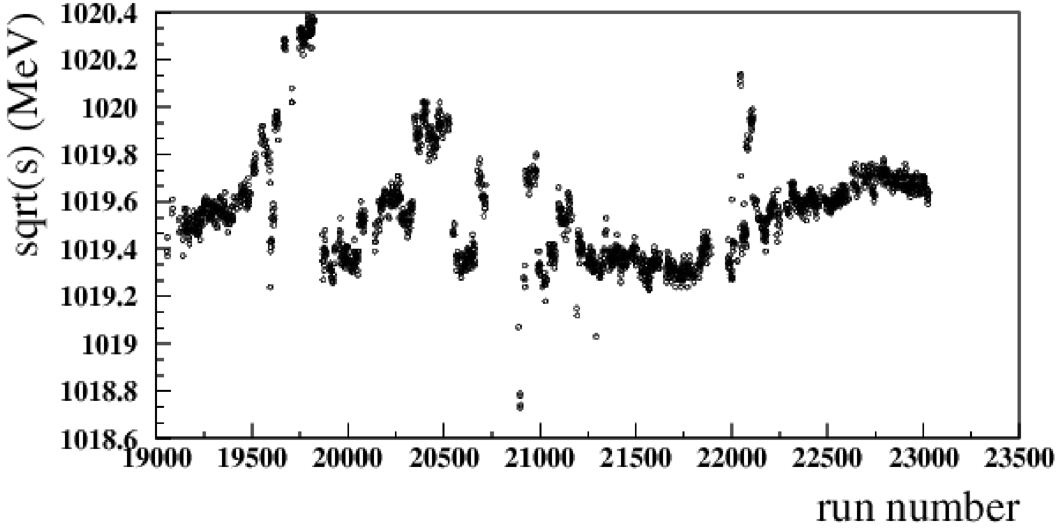
Dependence on sqrt(s) run by run

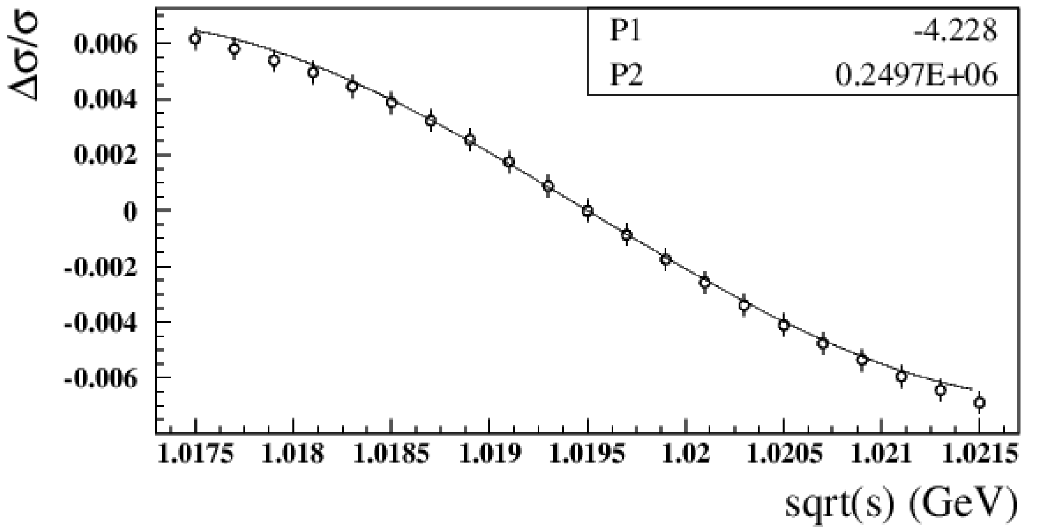
since the cross section is evaluated at the nominal value of $s^{1/2}$ = **1019.5 MeV** some checks are performed to see how much *L* changes according to the measured $s^{1/2} = M_{e+e-}$

$$\Delta L / L = -\Delta\sigma/\sigma$$

is parameterized as a function of $s^{1/2}$, from Monte Carlo:

$$\frac{\Delta\sigma}{\sigma} = -4.228 \cdot (x - 1.0195) + 2.497 \times 10^{5} \cdot (x - 1.0195)^{3}$$





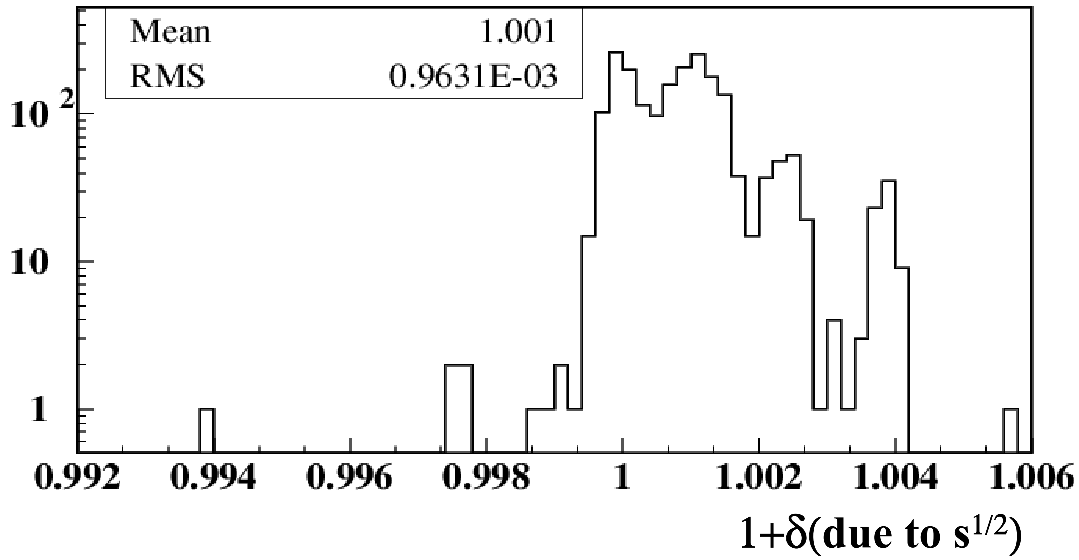
List of corrections and systematics

putting all together:

0.5 % (theory) ⊕

0.3 % (experiment) =

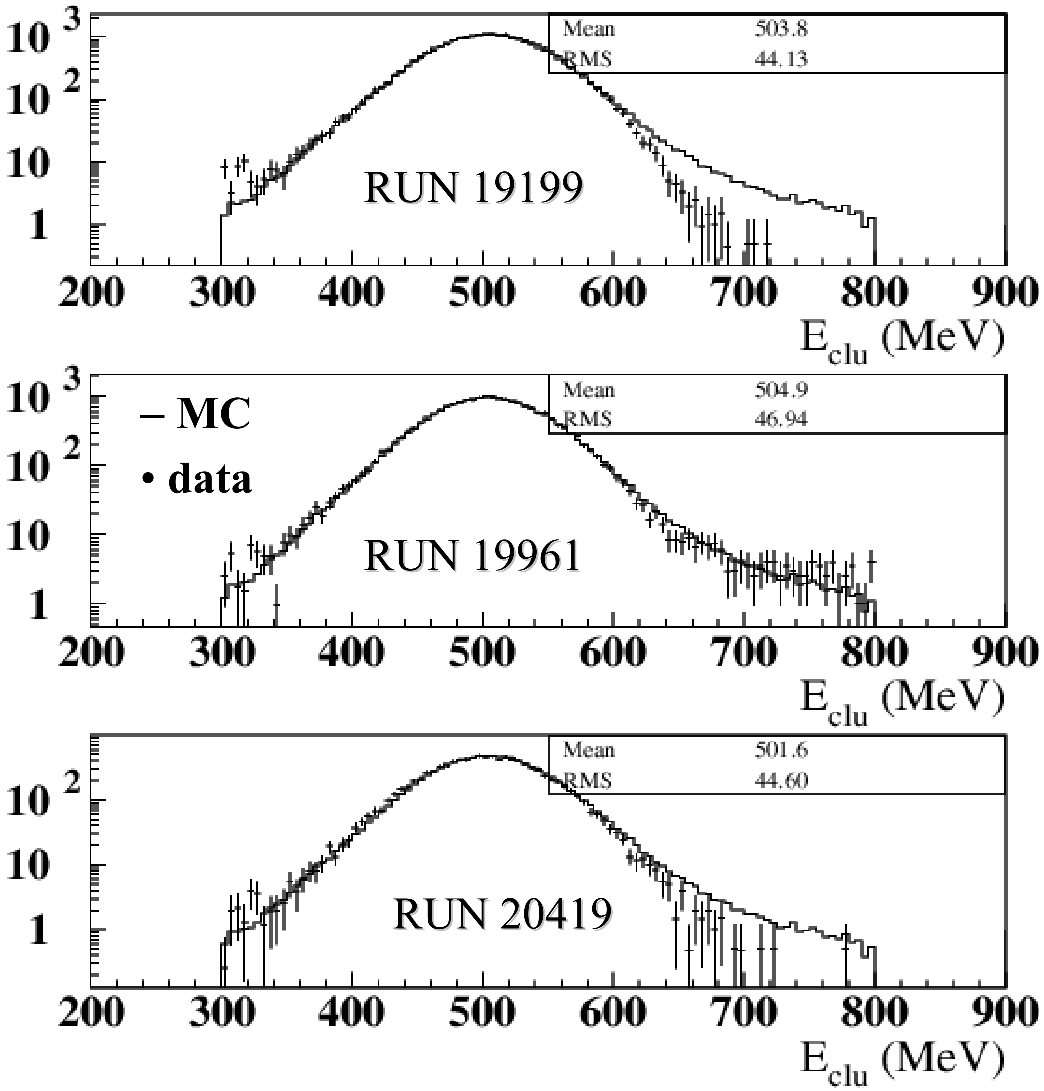
0.6 % (total error)



	correction (%)	systematic error (%)
acceptance	+0.18	0.2
tracking	–	< 0.1
clustering	+0.15	0.1
background	−0.55	0.1
cosmic veto	+0.41	< 0.1
dependence on $\sqrt{s}$	+0.1	0.1

$L = (141.0 \pm 0.8)\ \mathrm{pb}^{-1}$

Energy calibration studies



in looking at the 1st plot I thought about a correction to compensate the mismatch at high E_{clu} values, but then there comes the 2nd plot…, something to refine in a run by run approach

Conclusions and outlook

- in the measurement of the luminosity, the major source of uncertainty is from theory
- the Pavia theory group has worked at an improved version of Babayaga
- EURIDICE is a great opprtunity in triggering theorists to improve their calculations

to do (short term):

- release a paper (a KLOE Note) with the details of the measurement
- understand BHWIDE and Novosibirsk generators (not that trivial)

to do (long term):

- analysis of the 2002 runs
- measurement of $\mathcal{L}$ with $\gamma\gamma$, theorists claim 1% precision, but if we show them how clever are our measurements, we can motivate them to do better…