Off-Peak Physics

on behalf of the **P**eeking **o**ff-**P**eak group

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Perspectives on σ_{had} with 2 fb^{-1}

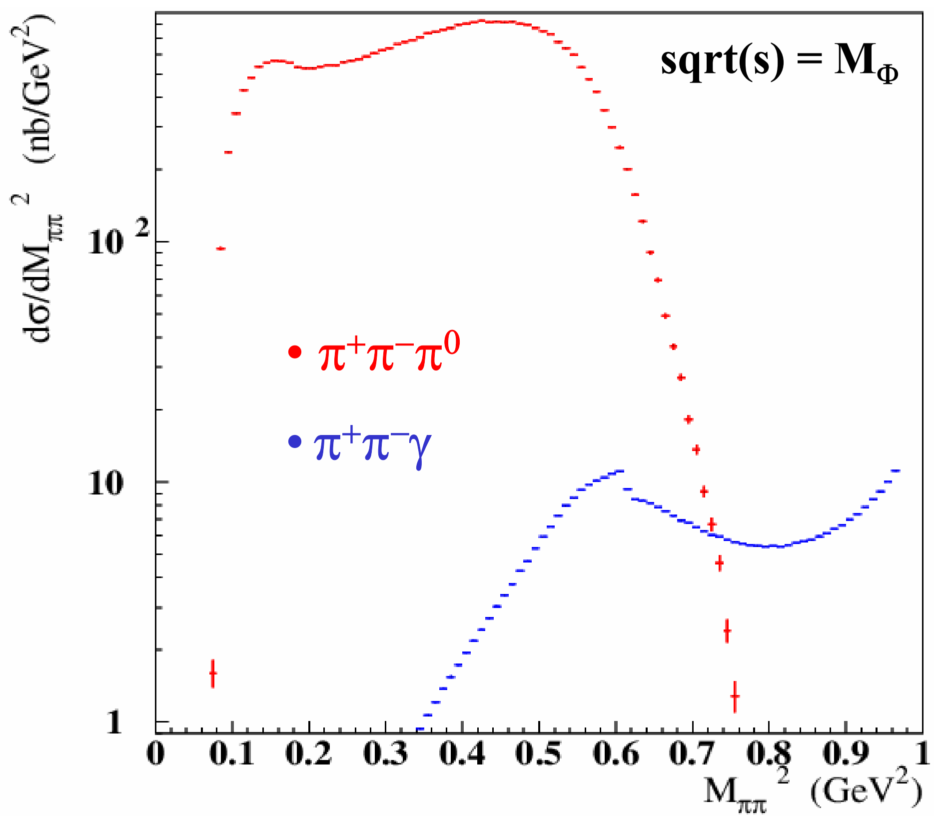
on behalf of the PPG group

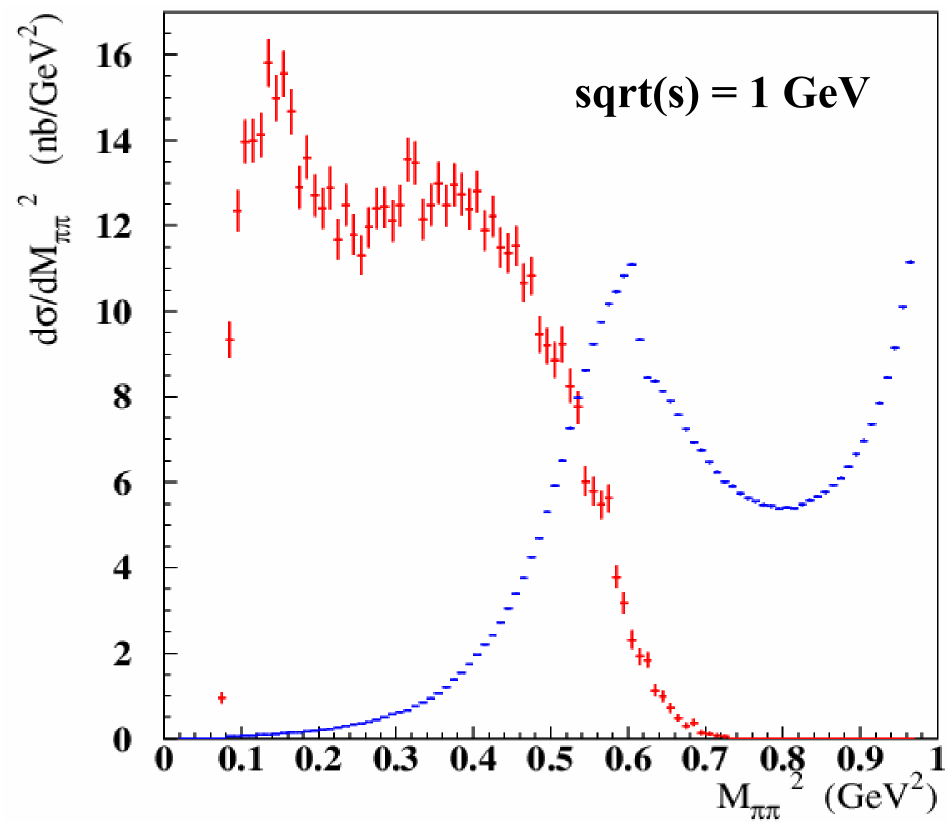
Off-peak physics: an outline

- motivations for taking data off-peak
- impact on a_μ
- other physics items

Why should we switch off the Φ?

in the large angle analysis, θ_π, $\theta_\Sigma \in$ **[50°,130°]**, the threshold is dominated by $\pi^+\pi^-\pi^0$





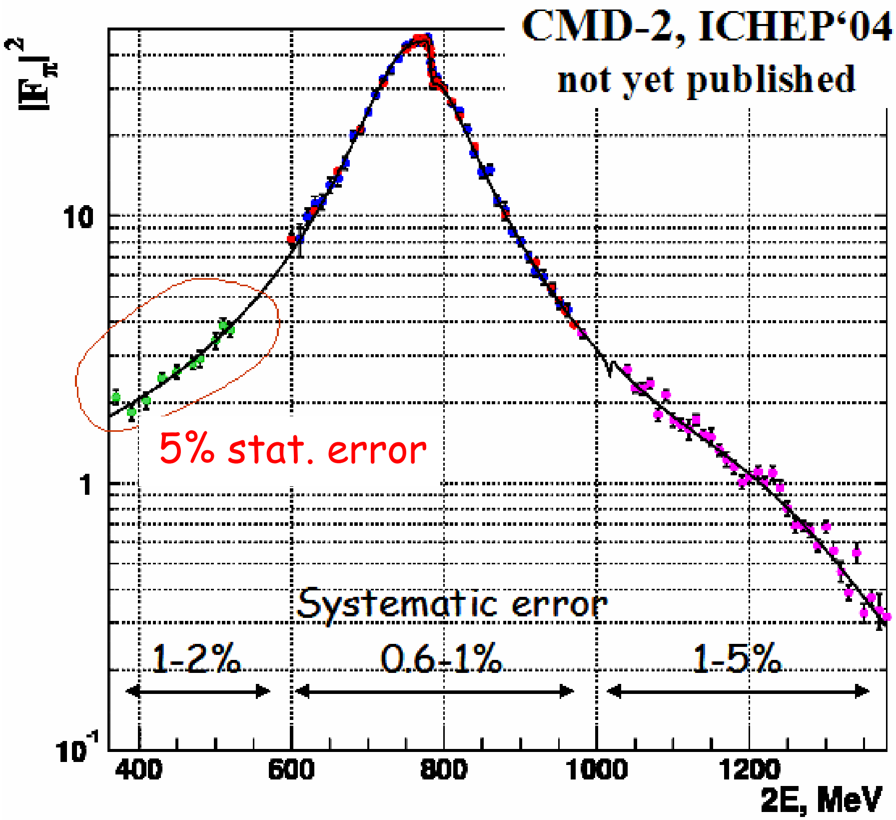
$\sigma_{\pi+\pi-\pi 0}$ = 329.8 nb (from C. Bini's analysis, after cuts)

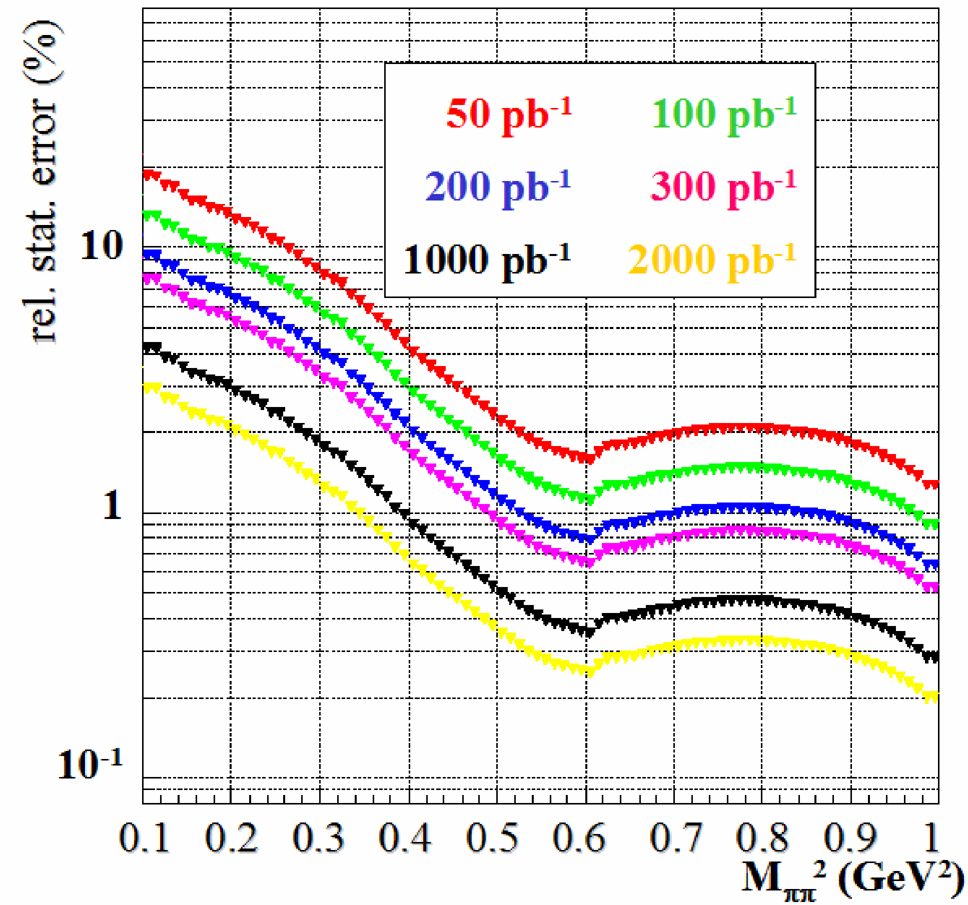
$\sigma_{\pi+\pi-\gamma}$ = 4.4 nb (from Phokhara3, after cuts)

$\sigma_{\pi+\pi-\pi 0}$ = 6 nb, sqrt(s)=1003.71 MeV

(from SND, PRD66 (2002) 032001, after cuts)

Statistical accuracy





- with ~ 200 pb^{-1} off peak results are comparable with CMD-2
- their bin width ~ **15 MeV**, ours is **0.01 GeV²** ⇔ **10-13 MeV** in $2E_{beam}$
- moreover the gap region is covered

What about a_μ ?

the threshold region is poorly covered by data,

1) that's why τ data entered the game in 1997

2) use of χPT expansion at the threshold

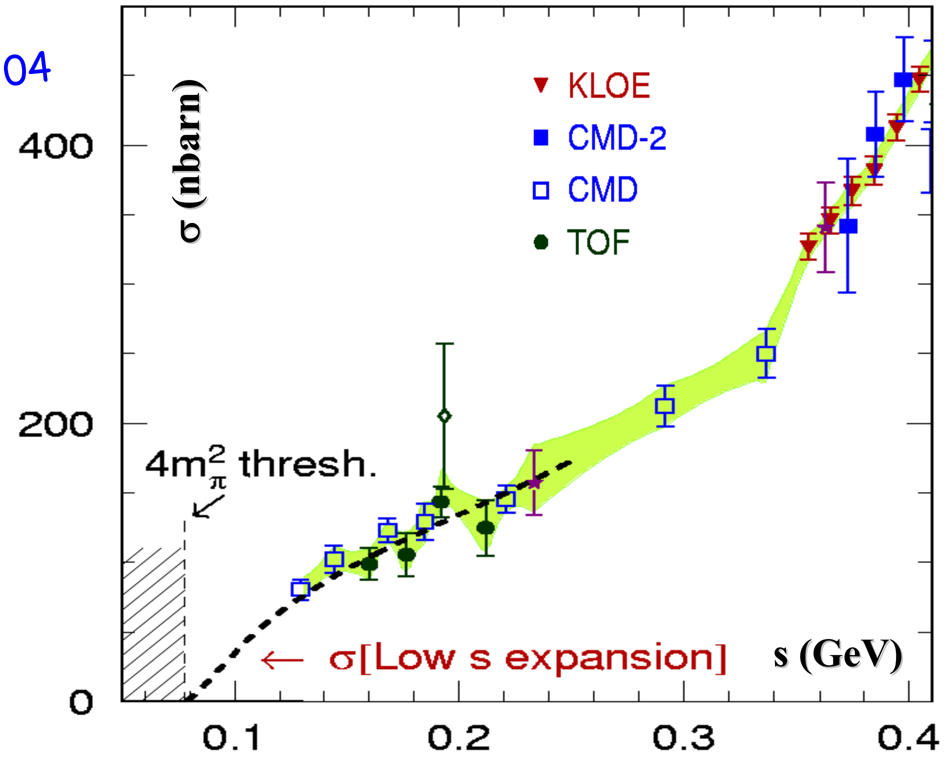
from A. Höcker @ ICHEP'04

$10^{10}\times a_\mu^{\pi\pi}$ [$2m_\pi$-1.8 GeV]

$448.3 \pm 4.1_{syst+stat} \pm 1.6_{rad}$

$10^{10}\times a_\mu^{\pi\pi}$ [$2m_\pi$-0.5 GeV]

$58.0 \pm 1.7_{fit\ to\ data} \pm 1.2_{rad}$

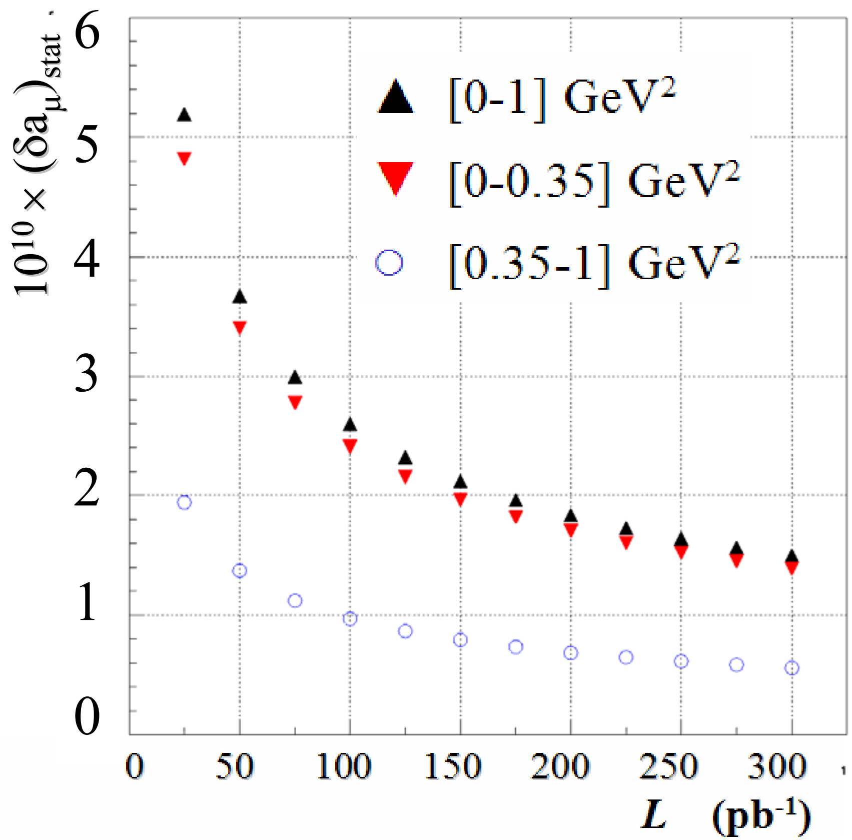


our publication did not cover

the region below 0.59 GeV

What about a_μ ?

- **stat. error is fully dominated by energy region < 0.35 GeV^2**
- **absolute stat. contribution to a_μ: ca. [1.5-2.5]$\times 10^{-10}$ (300-100 pb^{-1})**
- **$(\delta\sigma_{\pi\pi\gamma}/\sigma_{\pi\pi\gamma})_{syst} \sim 2\%$ gives ca. 2×10^{-10} (half of the total error on a_μ) from region below 0.35 GeV^2**



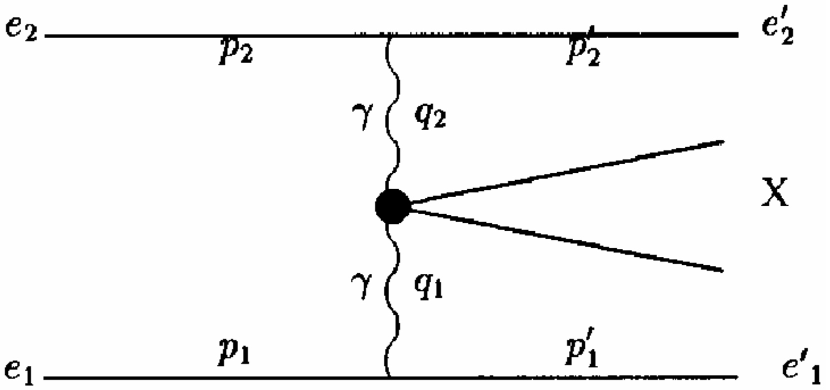
1) the measurement would give an error (**based on data directly**) on a_μ comparable to the analytical interpolation (in a region largely weighted by the dispersion integral)

2) another comparison with **existing (a few) data**

Feasibility studies for γγ fusion

remark:

if no requirement is applied on $e^{\pm}$ (in particular no tagging) $\gamma\gamma$ are quasi-real and the final state must have $J^P = 0^{\pm}, 2^{\pm}$...



only motivations we see:

1) determination of the η radiative width, $\Gamma(\eta \rightarrow \gamma\gamma)$

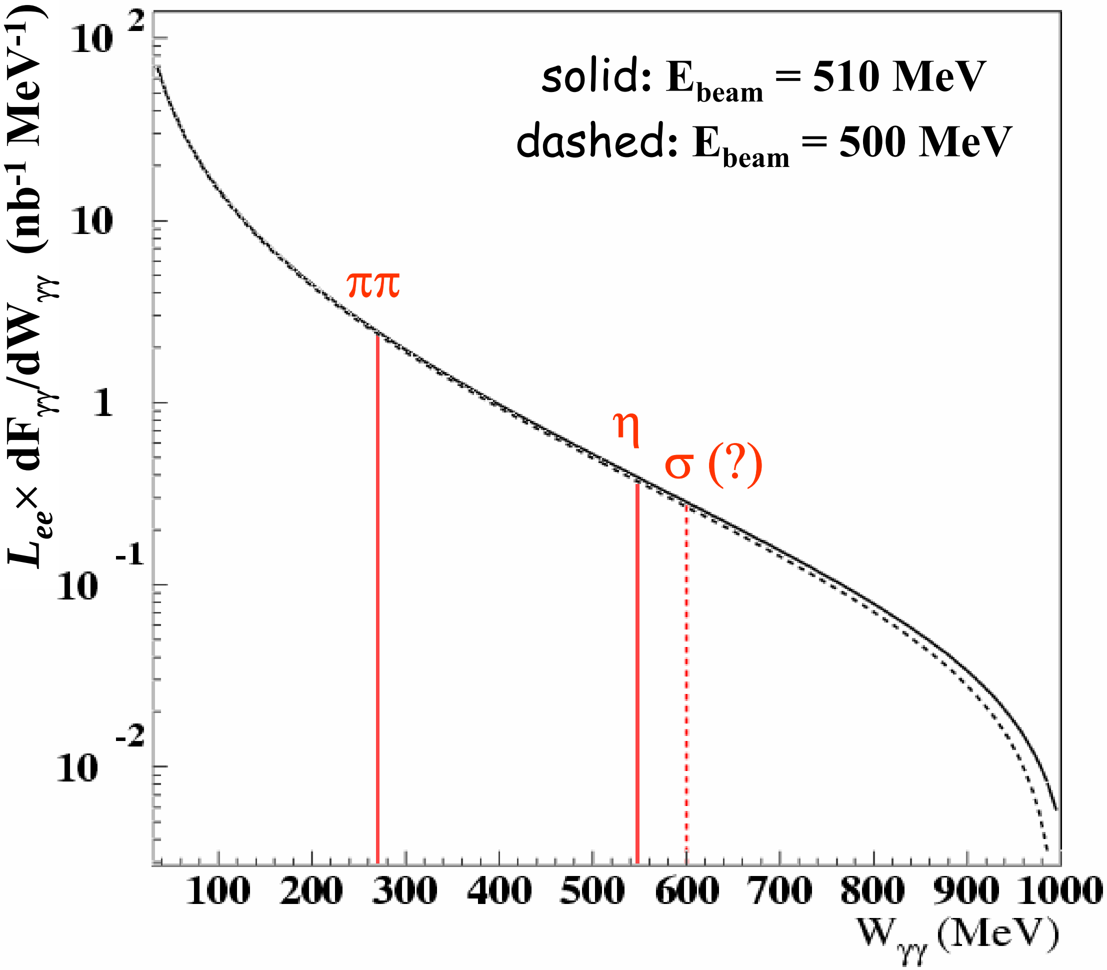
2) production (and discovery) of the scalar meson σ with the process $\gamma\gamma \rightarrow \sigma \rightarrow \pi\pi$

How many $\gamma\gamma$ collisions?

the $\gamma\gamma$ flux is defined as:
$$N_{e^+e^- \to e^+e^- hadrons} = L_{ee} \int \frac{dF_{\gamma\gamma}}{dW_{\gamma\gamma}} \sigma_{\gamma\gamma \to hadrons}(W_{\gamma\gamma})\, dW_{\gamma\gamma}$$

with $L_{ee} = 250$ pb^{-1}

vertical bars show threshold or masses



we need to know detection efficiency, of course, but:

1) no loss of statistical significance stepping from 1020 MeV to 1000 MeV,

2) no room for $\gamma\gamma \to f_0(980)$ effects,

3) let's see also the cross sections…

What about the η ?

the tiny $\Gamma(\eta \to \gamma\gamma)$ is extracted from

VALUE (keV)	EVTS	DOCUMENT ID		TECN	COMMENT
0.510±0.026 OUR FIT					
0.510±0.026 OUR AVERAGE					
0.51 ±0.12 ±0.05	36	BARU	90	MD1	$e^+e^- \to e^+e^-\eta$
0.490±0.010±0.048	2287	ROE	90	ASP	$e^+e^- \to e^+e^-\eta$
0.514±0.017±0.035	1295	WILLIAMS	88	CBAL	$e^+e^- \to e^+e^-\eta$
0.53 ±0.04 ±0.04		BARTEL	85E	JADE	$e^+e^- \to e^+e^-\eta$

integrating the $\gamma\gamma$ flux weighted by $\sigma(\gamma\gamma \to \eta)$:

$$\sigma_{\gamma\gamma\to\eta} \propto \Gamma_{\eta\to\gamma\gamma}\,\delta(W_{\gamma\gamma} - m_\eta)$$

$$\sigma_{e^+e^-\to e^+e^-\eta} = \frac{64\,\alpha_{em}^2}{m_\eta^3} \ln^2\frac{E_{beam}}{m_e} \ln\frac{2E_{beam}}{m_\eta}\,\Gamma_{\eta\to\gamma\gamma}$$

we expect $\sim 3\times10^4$ η events with $L_{ee} = 250\ \mathrm{pb}^{-1}$ (2 months @ $5\times10^{31}\ \mathrm{cm}^{-2}\,\mathrm{s}^{-1}$)
possible channels are $\eta \to \pi^+\pi^-\pi^0$, $\eta \to \gamma\gamma$

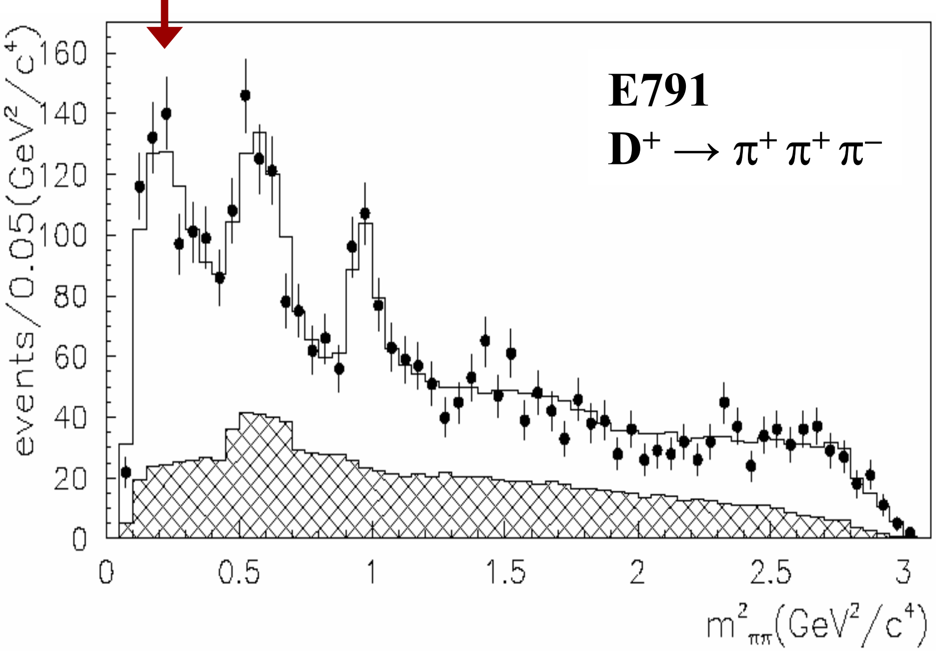
$\mathbf{BR}_{\eta\to\gamma\gamma} = (39.43 \pm 0.26)\ \%$ $\mathbf{BR}_{\eta\to\pi+\pi-\pi0} = (22.6 \pm 0.4)\ \%$

What about the σ ?

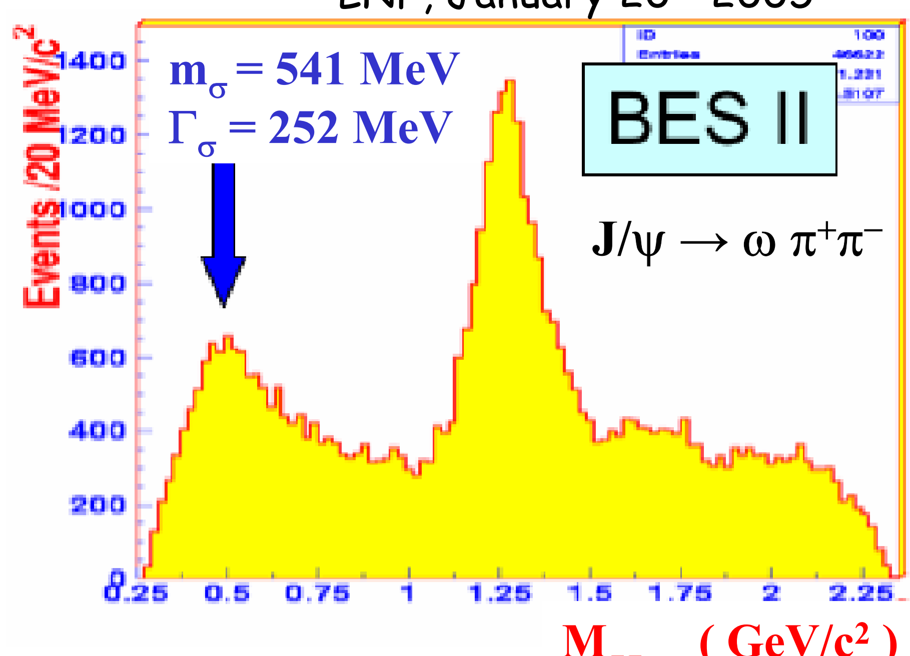
$\gamma\gamma \to \sigma \to \pi\pi$ would be the cleanest way, electromagnetic production, to say if it exists and what is its mass…

except for KLOE, fits of purely hadronic dalitz plots: model dependence/interference/rescattering??

$m_\sigma = 478$ MeV
$\Gamma_\sigma = 324$ MeV



presented by Prof. L Maiani, LNF, January 20th 2005



The σ looks challenging

multiplying the γγ flux by the cross section $\gamma\gamma \to \sigma \to \pi\pi$:

$$\sigma = 8\pi \frac{\Gamma_{\sigma\to\gamma\gamma}\Gamma_\sigma BR(\sigma\to\pi\pi)}{\left(W_{\gamma\gamma}^2 - M_\sigma^2\right)^2 + M_\sigma^2\Gamma_\sigma^2}$$

$$\Gamma_{\sigma\to\gamma\gamma} = 3.8\,\text{keV}$$

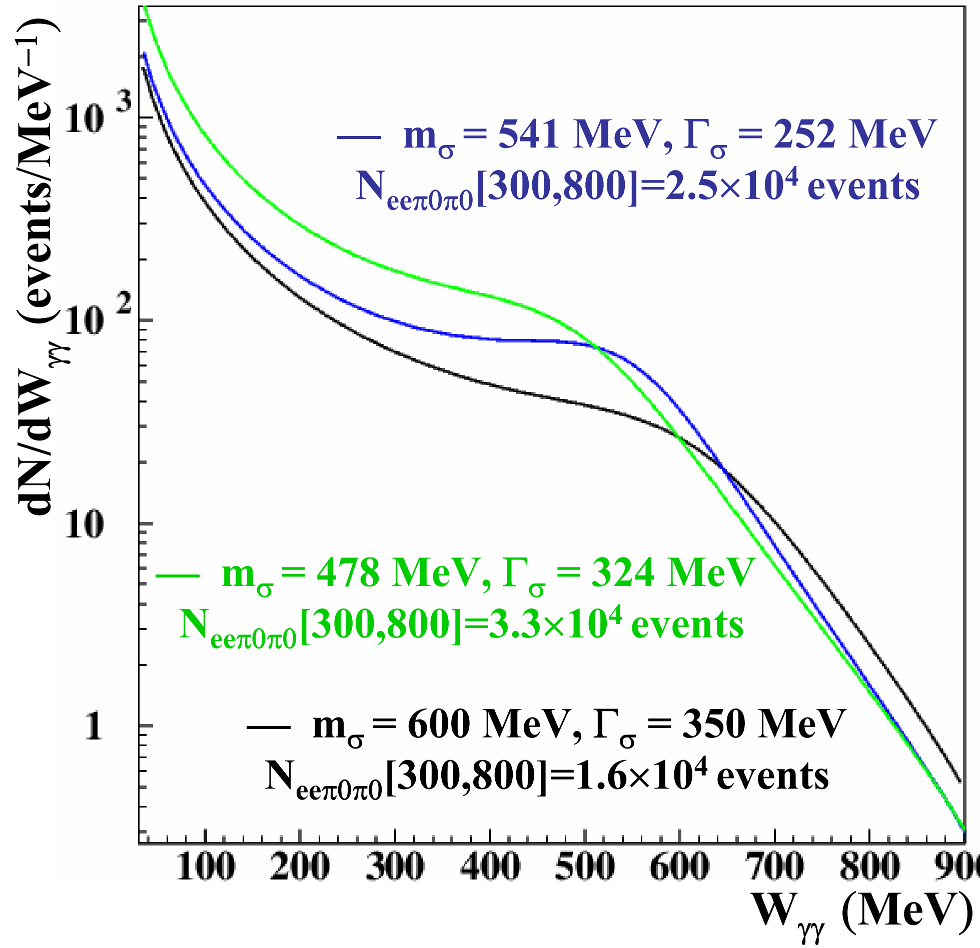
M. Boglione and M. R. Pennington, Eur.Phys.J.C9:11-29,1999

1) in the channel $\pi^+\pi^-$ the signal is overwhelmed by ISR and FSR
2) in the neutral case, background (not interfering) channels are:

$$e^+e^- \to \omega\,\pi^0 \to \pi^0\,\gamma\,\pi^0$$

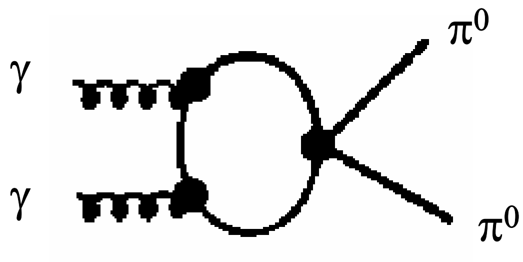
$$e^+e^- \to \omega\,\gamma_{isr} \to \pi^0\,\gamma\gamma_{isr}$$

$e^+e^- \to e^+e^-\sigma \to e^+e^-\pi^0\pi^0$, event yield with 250 pb^{-1}:



Some kinematics (I)

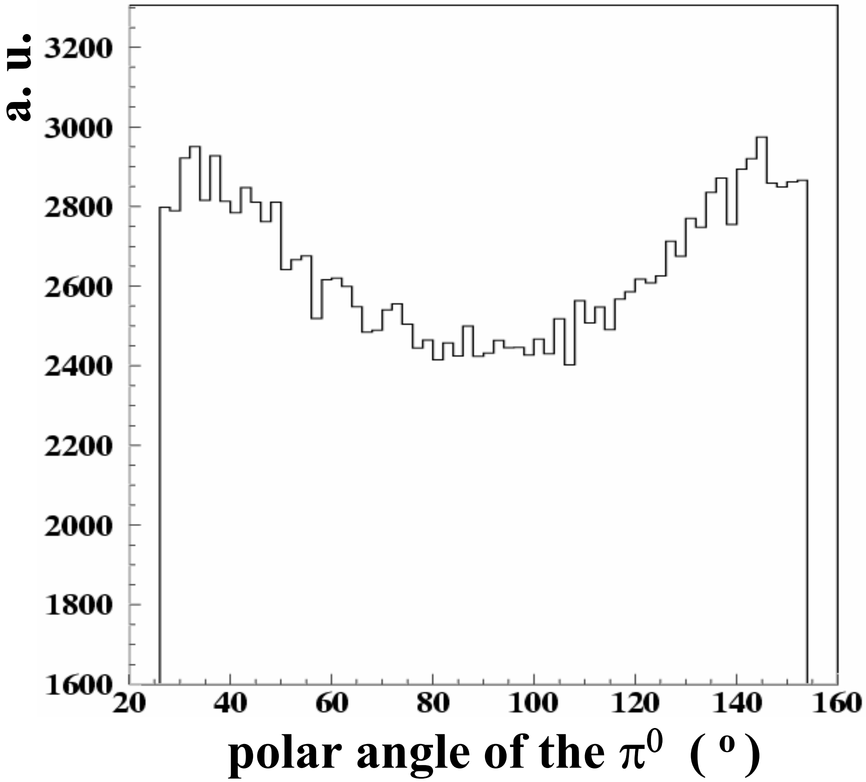
1. the Anulli-Courau code has been modified inserting an amplitude in χPT
2. the process $\gamma\gamma \rightarrow \pi^0 \pi^0$ is not possible at tree level
3. the amplitude at 1 loop in χPT has been implemented, no σ at the moment
4. absolute normalization still to be checked (please rely on the shape, only)
5. sqrt(s) = 1 GeV, $|\cos\theta| < 0.9$ for both pions

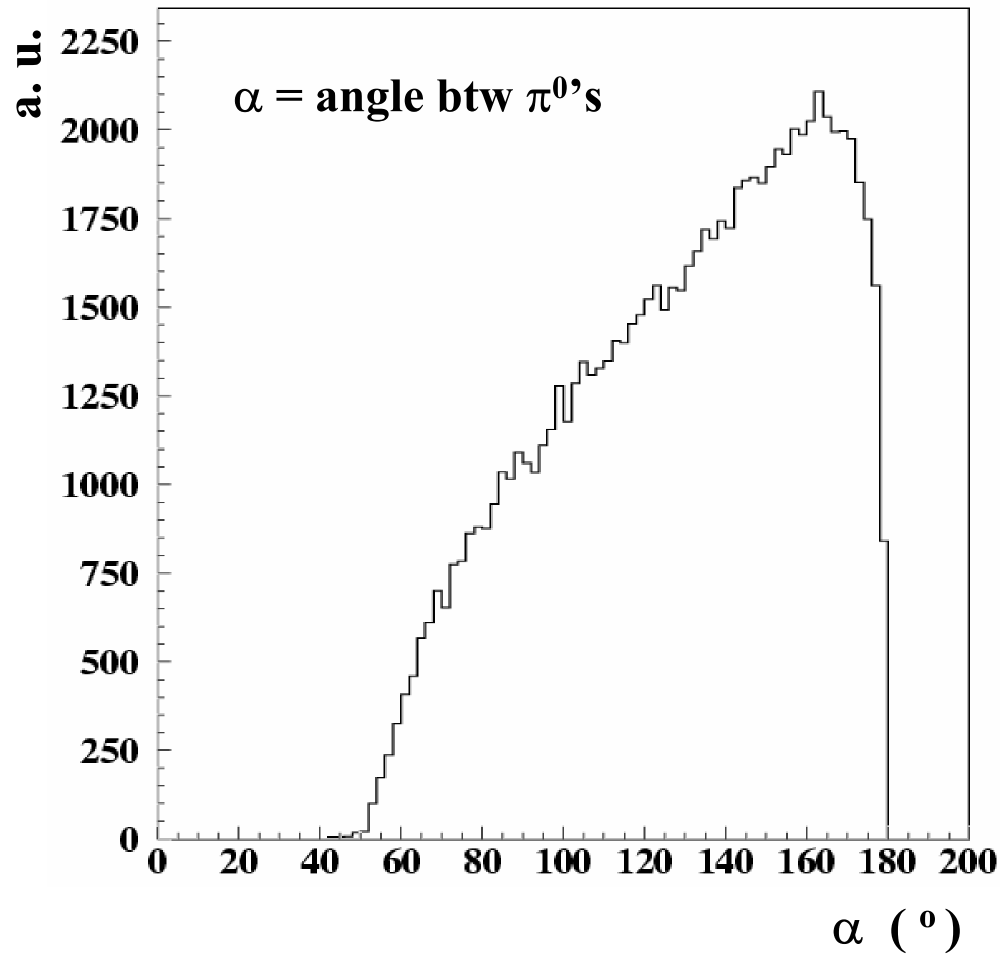


a systematic comparison with $\omega\pi^0 \rightarrow \pi^0\pi^0\gamma$ is mandatory, however…

Some kinematics (II)

working hypothesis: aside from longitudinal $e^{\pm}$ momenta the kinematics is similar to that of 2 body reactions





1. either a structure is observed, ⇒ "Direct observation of the σ with KLOE"
2. or, after scanning $m_{\pi 0 \pi 0} \leq 700$ MeV, ⇒ "Exclusion of the σ with KLOE, at a ...% CL"

Off peak physics: conclusions

- significant contribution with $\sim$ **200 pb^{-1}** in

  a cleaner environment for $\sigma_{\pi\pi}$

- unique opportunity for settling the σ (existence

  with which mass)

Perspectives on σ_{had}: an outline

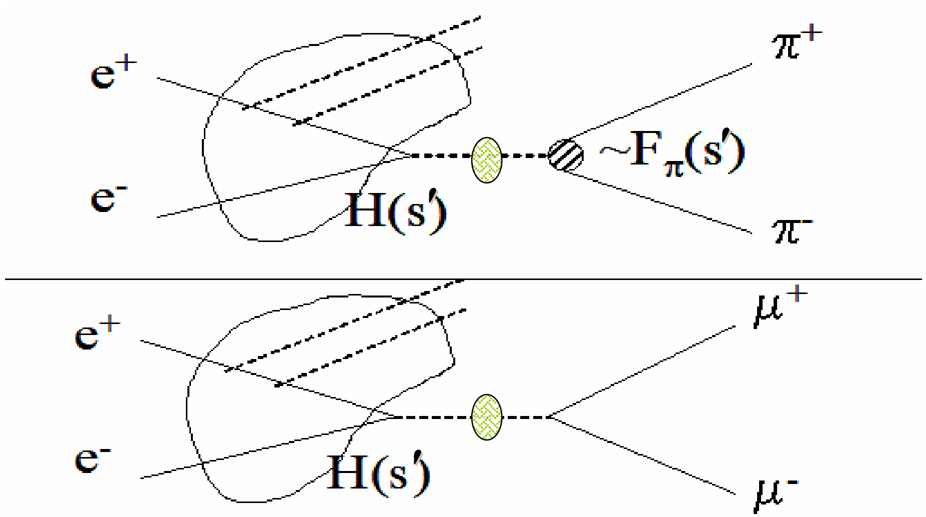
- statistical considerations with 1 fb^{-1}
- benefits from the reprocessing
- preliminary studies: DC trigger

Let's normalize to μμγ

in the limit of neglecting FSR effects: $\sigma_{\pi\pi}^{Born} \approx d\sigma_{\pi\pi\gamma}^{obs} / d\sigma_{\mu\mu\gamma}^{obs} \times \sigma_{\mu\mu}^{Born}$

as suggested by Paolo Franzini (KLOE Memo nr. 248) many systematic effects cancel out (theory) or reduce to small corrections (tracking, vertexing and DC trigger)

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



different from the normalization with Bhabha, statistics is an issue, due to the small μμγ cross section in some bins

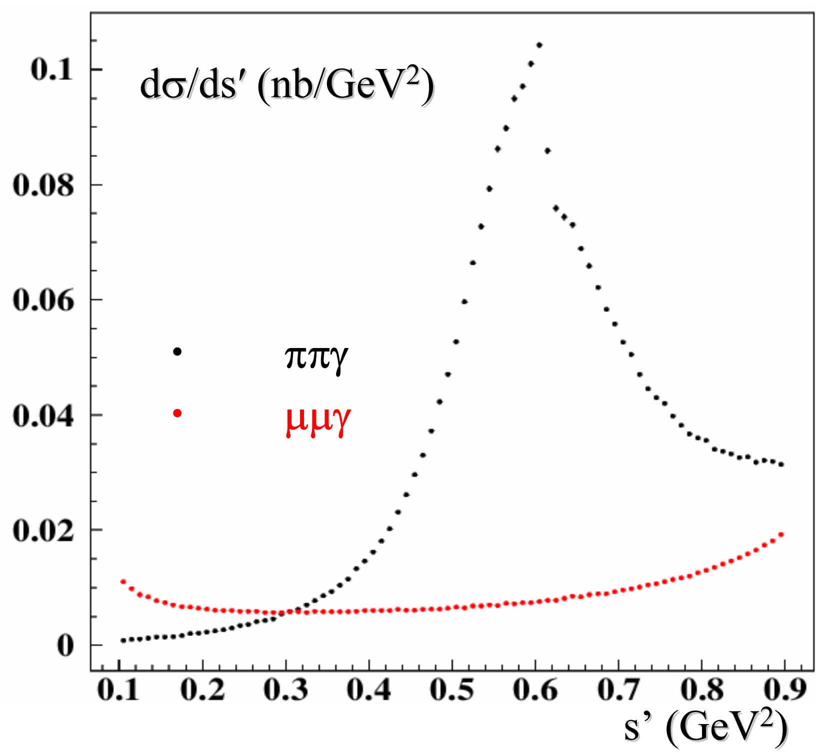
Statistics at large angle

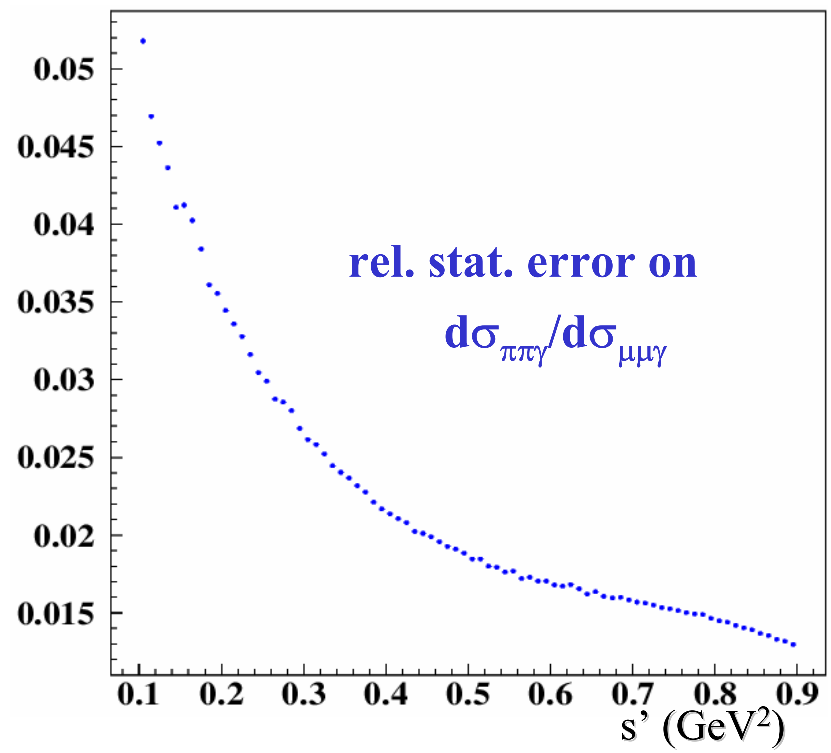
only ISR at the NLO for both processes

$50^o < \theta_\pi, \theta_\gamma < 130^o$, $E_\gamma > 50$ MeV

$L = 1$ fb^{-1}, $\varepsilon = 50\%$ flat in s′, in both channels

statistics is competitive with CMD-2, the challenge is to keep systematic errors really small through the ratio (see below)





evaluated with Phokhara4, J. Kühn et al. (2004)

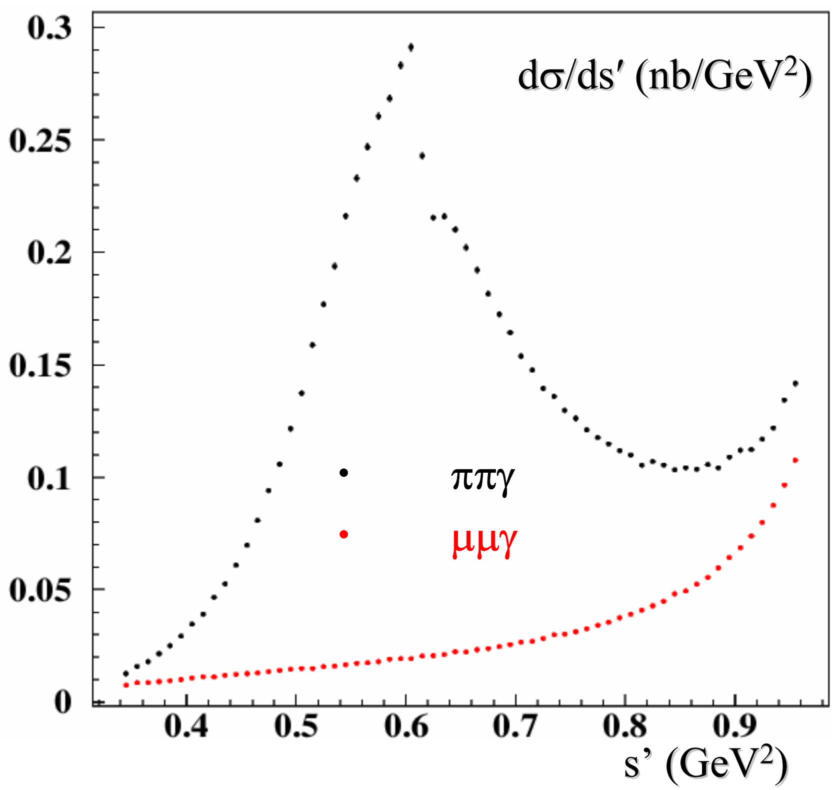
Statistics at small angle

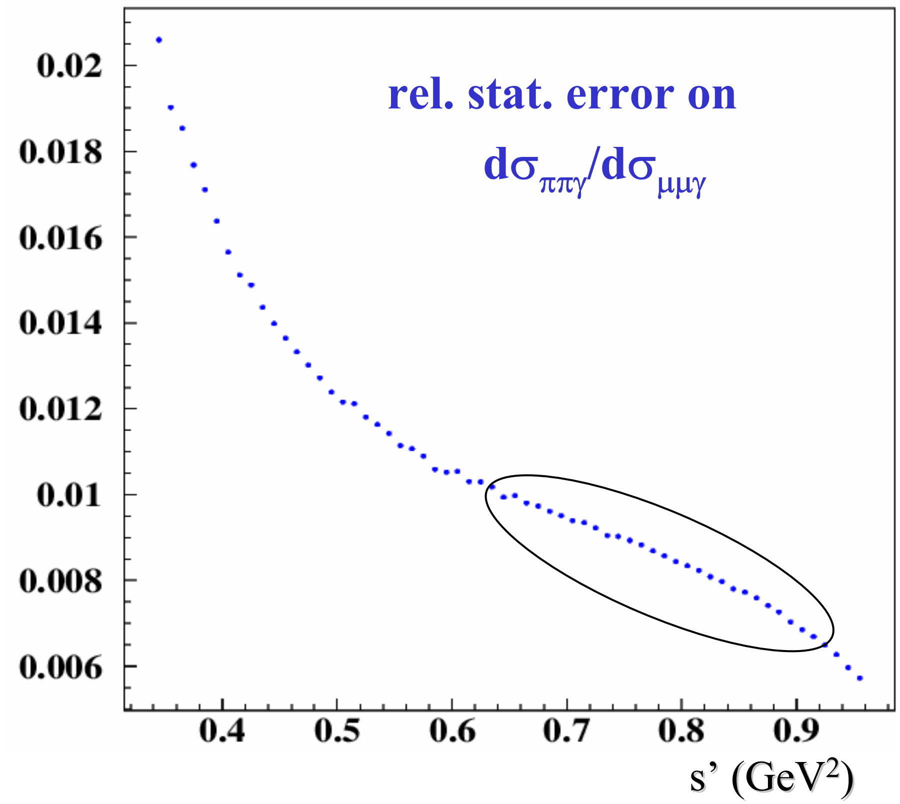
only ISR at the NLO for both processes

$\theta_{\pi\pi} < 15^o$, $50^o < \theta_{\pi} < 130^o$, $p_{miss} > 10$ MeV

$L = 1$ fb^{-1}, $\varepsilon = 50\%$ flat in s', in both channels

in the small angle region, we can give a remarkable cross check in the region puzzled by τ data*

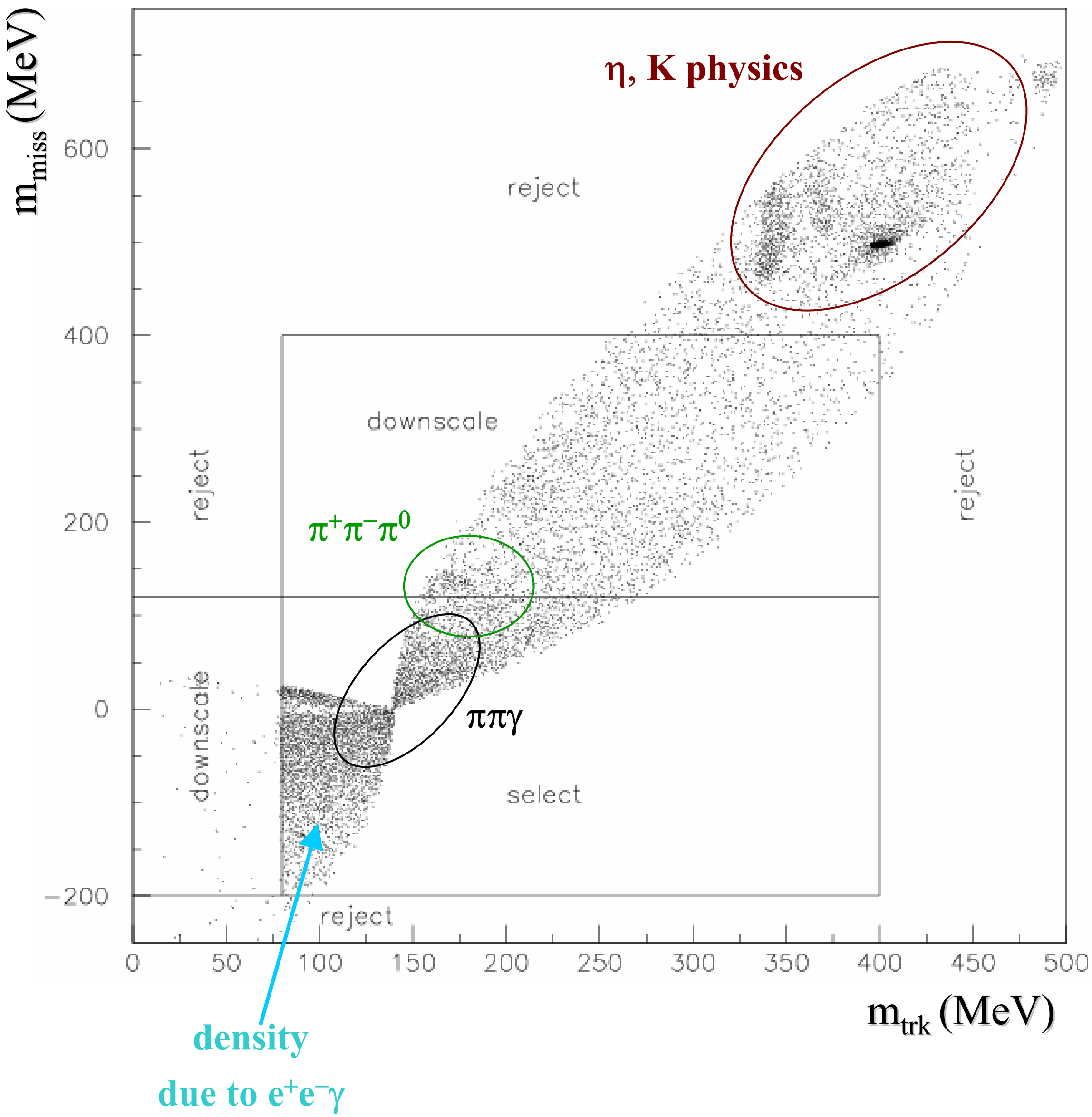




* K. Maltman, hep-ph/0504201: "sum rule tests favor the reliability of τ data…"

New tagging algorithm

1. the requirement of 1 and only 1 vertex has been dropped
2. at least two tracks (of opposite charge), with PCA in the cylinder $|z| < 15$ **cm**, $\rho < 8$ **cm**
3. for $\mu\mu\gamma$ purpose, trackmass window has been enlarged, $\mathbf{m_{trk}} > 80$ **MeV** instead of 90 **MeV**
4. the anti-coincidence with the RPI stream has been dropped, a downscale for events with $\mathbf{m_{miss}} \in [120,400]$ **MeV** is applied



Benefits in systematics: a critical overview

Acceptance	0.3 %
Trigger	0.3 %
Reconstruction Filter	0.6 %
Tracking	0.3 %
Vertex	0.3 %
Particle ID	0.1 %
Trackmass	0.2 %
Background subtraction	0.3 %
Unfolding	0.2 %
Total exp systematics	0.9 %

disabled cosmic veto, DC trigger efficiencies should cancel in the ratio

new FILFO criteria should get rid of the dependence on the mach. backgr. (only working in 2004-05, not in 2002)

tracking and vertex efficiencies should cancel in the ratio, the new vertex algorithm should decrease systematics (only in 2005, neither present in 2002, nor in 2004)

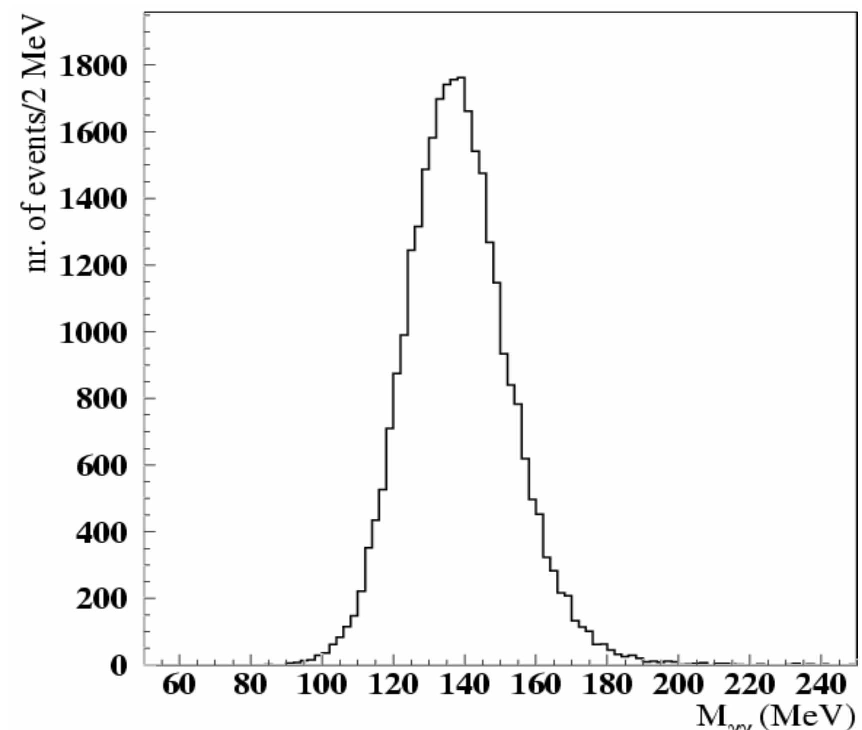
the new PPGTAG criteria do not exclude to use data (RPI stream) to evaluate the $\pi^+\pi^-\pi^0$ content (only in 2005, neither present in 2002, nor in 2004)

A look at the DC trigger in 2002: $\pi^+\pi^-\pi^0$

- an estimator of DC trigger efficiency is provided by the ratio N_{BOTH} / N_{EMC}
- this quantity has been studied on a sample of $\pi^+\pi^-\pi^0$ to avoid the bias present in $\pi\pi\gamma$ events with the cluster associated to the track firing the EMC trigger

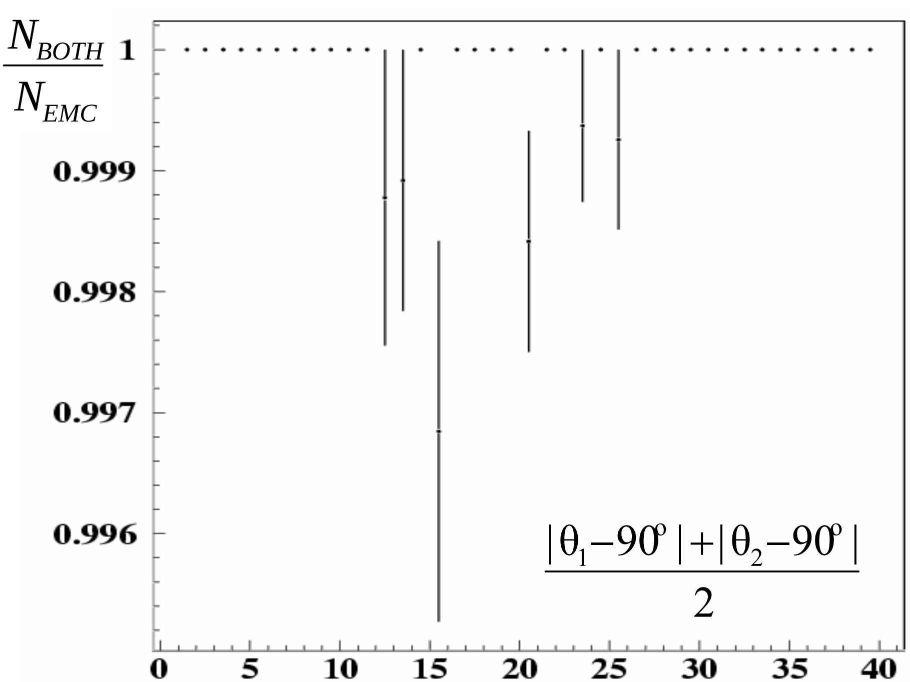
$$N_{EMC} = \varepsilon^{trg}_{EMC} N_{TOT}$$
$$N_{DC} = \varepsilon^{trg}_{DC} N_{TOT}$$
$$N_{BOTH} = \varepsilon^{trg}_{EMC} \varepsilon^{trg}_{DC} C_T N_{TOT}$$

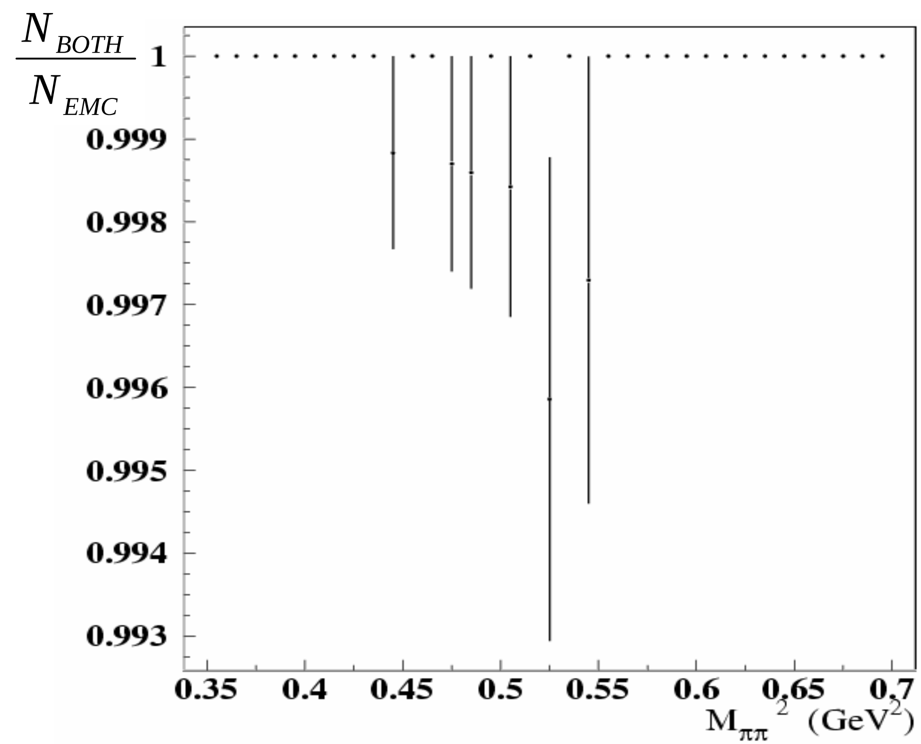
1. 2002 $\pi^+\pi^-\pi^0$ sample: **runs 26566-592, 26617-644, 26658-673**
2. only events with 2 photons, each with $E_\gamma > 100$ **MeV**
3. if α = angle btw the photons, $\alpha > 15^o$, to be sure that 2 sectors are fired
4. $50^o < \theta_\pi < 130^o$, for both tracks



A look at the DC trigger in 2002: $\pi^+\pi^-\pi^0$

- this estimate shows high efficiency
- no dependence on the polar angle of the track has been observed
- since $\mu\mu\gamma$ and $\pi\pi\gamma$ differ in θ, if no θ dependence of the DC trigger efficiency is found $\Rightarrow$ no particular reason for differences in ε_{DC}^{trg}





next steps:

1. data samples for both $\mu\mu\gamma$ and $\pi\pi\gamma$
2. a detailed look at the EMC trigger sectors in the event, to minimize the bias of clusters associated to tracks

Perspectives on σ_{had}: conclusions

- the large angle analysis by the ratio has a clear goal: explore the threshold region with a high level of accuracy, we need at least 1 fb^{-1} to be statistically competitive (e. g. made out of 2002+2005)
- the ratio at small angle provides an independent check of the published result: FSR under control, bin by bin comparison with CMD-2: for that, 2002 sample is sufficient and ready

data sets to date:

2002: lots of data quality studies performed, we need to reprocess them
2004: new FILFO implementation, but it suffers fake dead wires problem, they need to be re-reconstructed
2005: new FILFO and new PPGTAG

- in any case: reprocessing of the whole 2002 data set is advocated