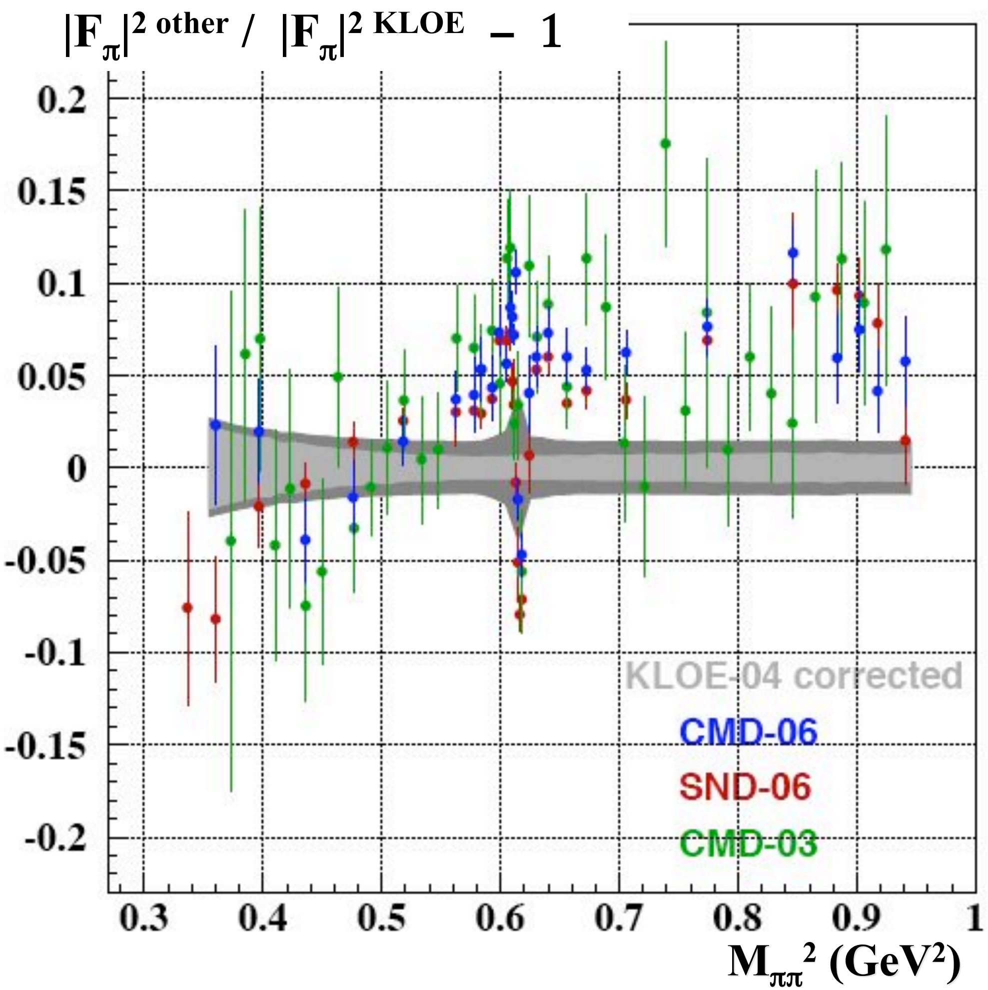
$\sigma_{\pi\pi(\gamma)}$ small angle analyses

F. Nguyen for the PPG group

- ✓ Brief reminder
- ✓ Progress in the $\pi\pi\gamma/\mu\mu\gamma$ analysis
- ✓ Refinements of the absolute $\pi\pi\gamma$ analysis: vertex+unfolding
- ✓ Discussion and results

State of the art among published spectra*

* updated trigger correction and theoretical σ_{Bhabha} [Nucl. Phys. B758 (2006) 227], decrease $|F_\pi|^2$ of 0.7%



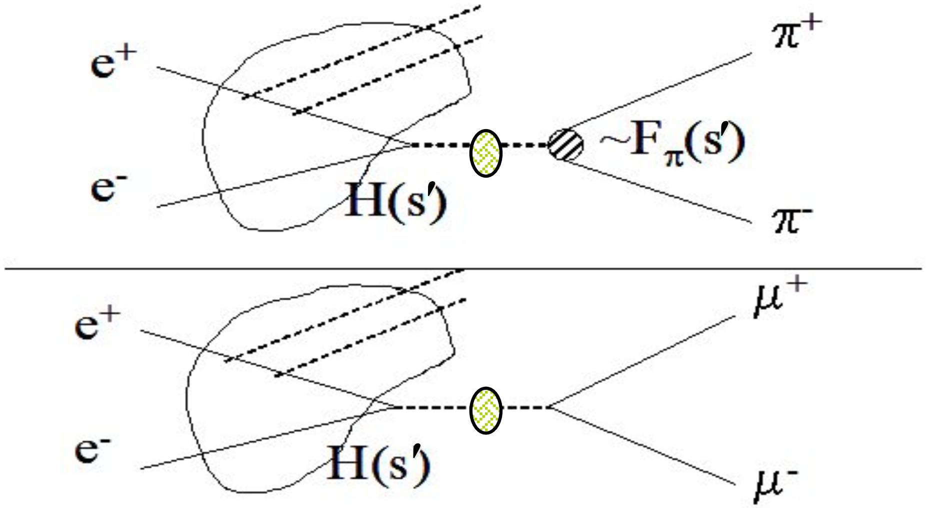
1) slope with respect to VEPP-2M scan experiments
2) momentum scale analyzed in detail (P. Beltrame@Capri)
3) other effects peculiar to the Radiative Return method (radiation function, vacuum polarization, etc…) ?

Experimental answer:

analysis of $\pi\pi\gamma/\mu\mu\gamma$

Why the ratio of ππγ over μμγ events?

$$\sigma_{\pi\pi}^{Born}(s') \approx \frac{d\sigma_{\pi\pi\gamma}^{obs} / ds'}{d\sigma_{\mu\mu\gamma}^{obs} / ds'} \sigma_{\mu\mu}^{Born}(s') \longrightarrow F_\pi$$



important effects cancel out

~~Luminosity~~
~~Radiator H~~
~~Vacuum polarization~~

also from experimental side...

or, in alternative, a measurement of the $d\sigma_{\mu\mu\gamma}/dM_{\mu\mu}$ cross section gives

radiator H function × vacuum polarization

(provided that luminosity is correct)

How to extract F_π from the ratio

$$\sigma_{\pi\pi}^{Born}(s') \approx \frac{d\sigma_{\pi\pi\gamma}^{obs} / ds'}{d\sigma_{\mu\mu\gamma}^{obs} / ds'} \sigma_{\mu\mu}^{Born}(s')$$

exact only in the absence of FSR

$$\left|F_\pi(s')\right|^2 \cdot \left(1+\eta(s')\right) = \frac{4\left(1+2m_\mu^2/s'\right)\beta_\mu}{\beta_\pi^3} \cdot \frac{\left(d\sigma_{\pi\pi\gamma}/ds'\right)^{ISR+FSR}}{\left(d\sigma_{\mu\mu\gamma}/ds'\right)^{ISR}}$$

FSR (Schwinger)

from measured cross sections

measurement of FSR inclusive $d\sigma_{\pi\pi\gamma}/ds'$ and ISR exclusive $d\sigma_{\mu\mu\gamma}/ds'$ gives $|F_\pi|^2 \cdot (1+\eta_{FSR})$ [i.e. the „bare“ pion form factor].

- $|F_\pi|^2 \cdot (1+\eta_{FSR})$ is the quantity to be put in the a_μ^{had} dispersion integral (η_{FSR} for pointlike pions ~ 0.8%)
- corrections needed to extract $d\sigma_{\mu\mu\gamma}/ds'$ are pure QED and can be reliably obtained from PHOKHARA (rel. difference with KKMC ~ 0.3%)

Selections of $\pi\pi\gamma$ and $\mu\mu\gamma$ events

a) 1 and only 1 vertex ($|z| < 7$ cm) connected to 2 and only 2 tracks from IP

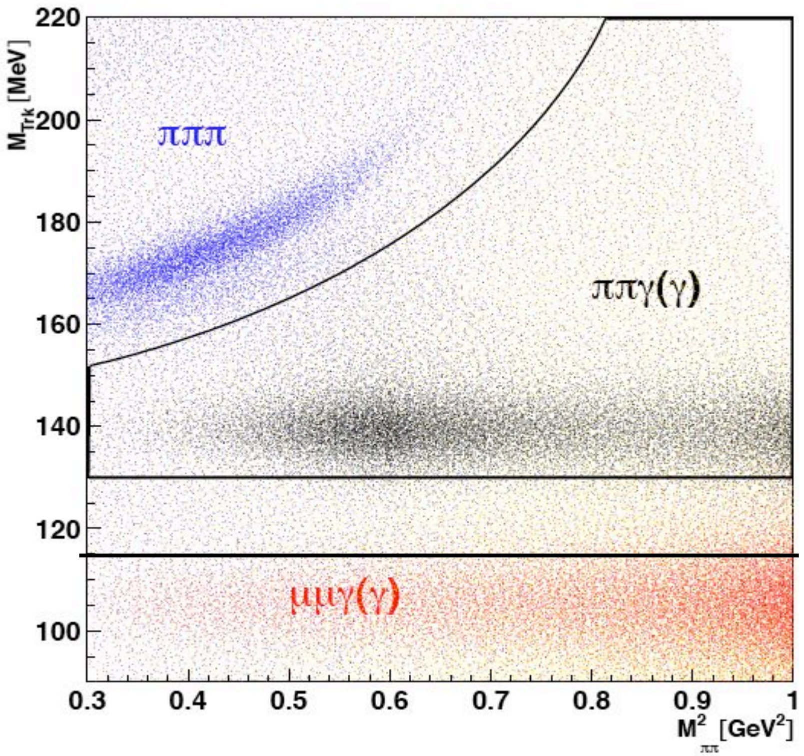
b) each track with $50^{o} < \theta_{track} < 130^{o}$

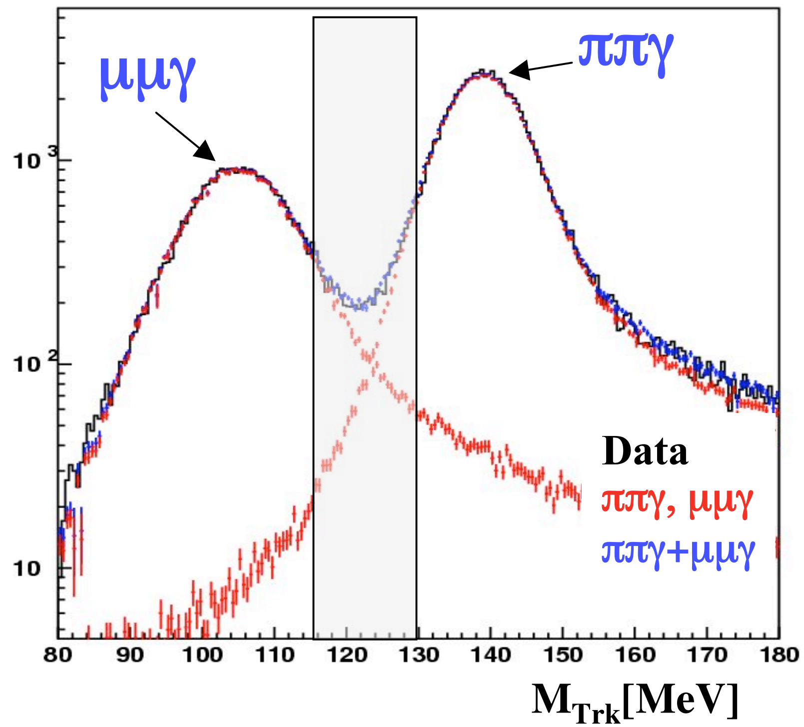
c) small angle γ ($\theta_{\pi\pi} < 15^{o}$)

d) at least one track with $\log L_{\pi}/L_{e} > 0$

for $\mu\mu\gamma$: **new**

at least one track with $\mathrm{MLP} > 0.7$





M_{Trk} = mass under the hypothesis of 2 tracks of equal mass and 1 photon

Federico Nguyen
10-12-2007

Discrimination μ/π using neural networks

Multi Layer Perceptrons is a type of Neural Network widely used, interfaced with PAW/HBOOK, also used in kaon analyses

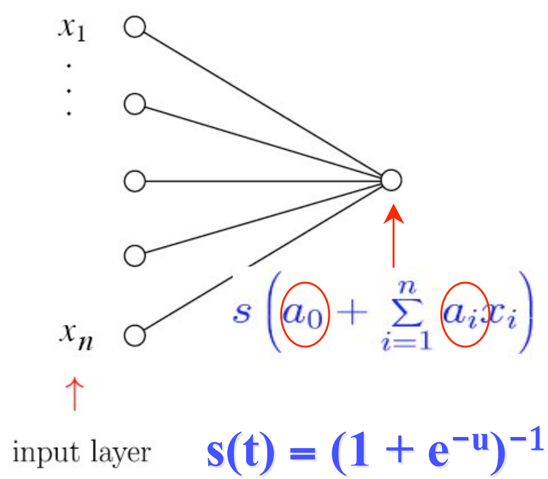
Input quantities are processed through successive layers; at the input layer ⇔ neurons = variables of the problem, in between layers = hidden layers, where variables are free to "interact" → output response

$$\Delta T = T_{clu} - \frac{L_{trk}\sqrt{p_{trk}^2 + m_\mu^2}}{c p_{trk}}$$

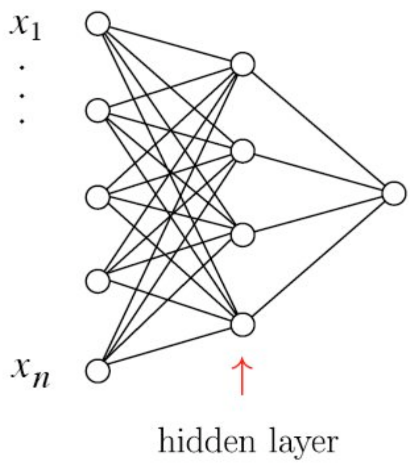
$$|\vec{r}_{clu} - \vec{r}_{ext}|$$

$$\frac{E_{clu}}{\sqrt{p_{trk}^2 + m_\mu^2}}$$

Single Layer

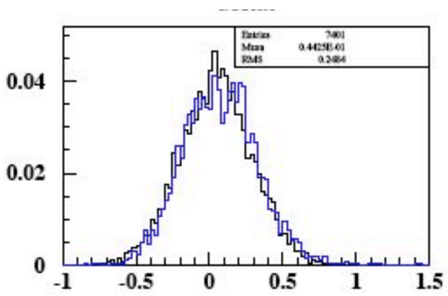


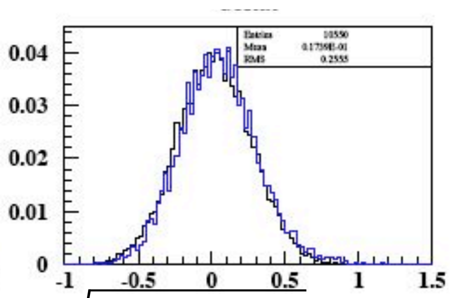
Multi Layer



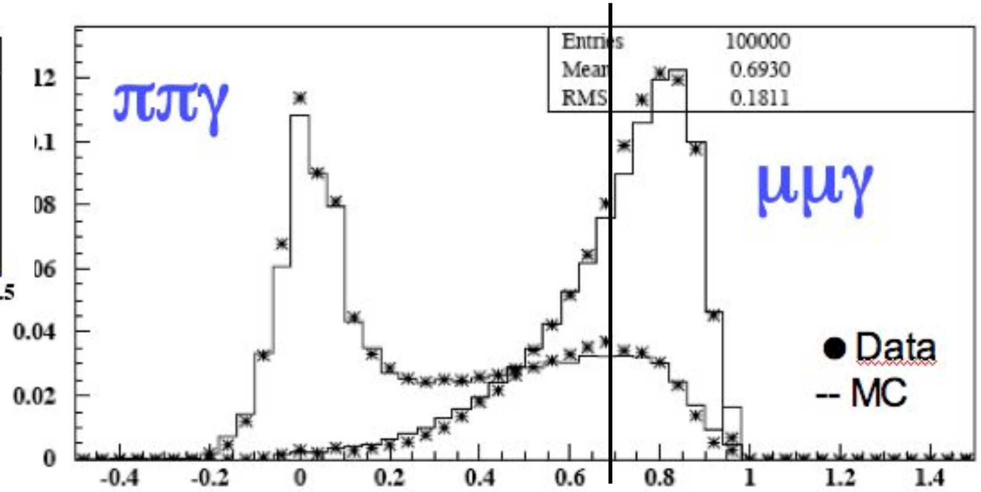
Federico Nguyen
10-12-2007

Training and performance of the MLP



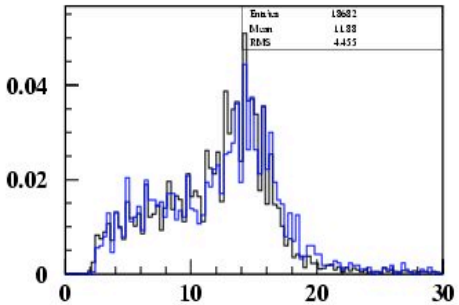


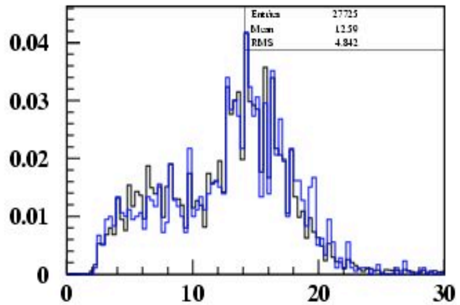
$$\Delta T(ns) = T_{clu} - \frac{L_{trk}\sqrt{p_{trk}^2 + m_\mu^2}}{c p_{trk}}$$



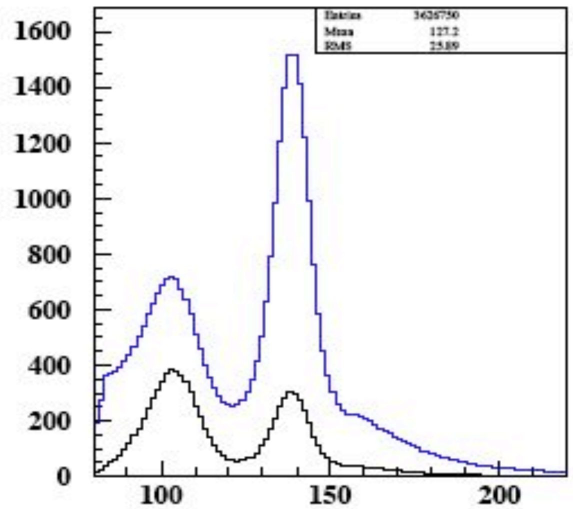
MLP

$300<p<350$ $350<p<400$





$$|\vec{r}_{clu} - \vec{r}_{ext}|\,(cm)$$



M_{Trk}[MeV]

MLP function developed with the specific aim of single track π/μ discrimination for our analysis, documentation will be written

Vertex corrections for $\pi\pi\gamma$: tighter m_{trk} cuts

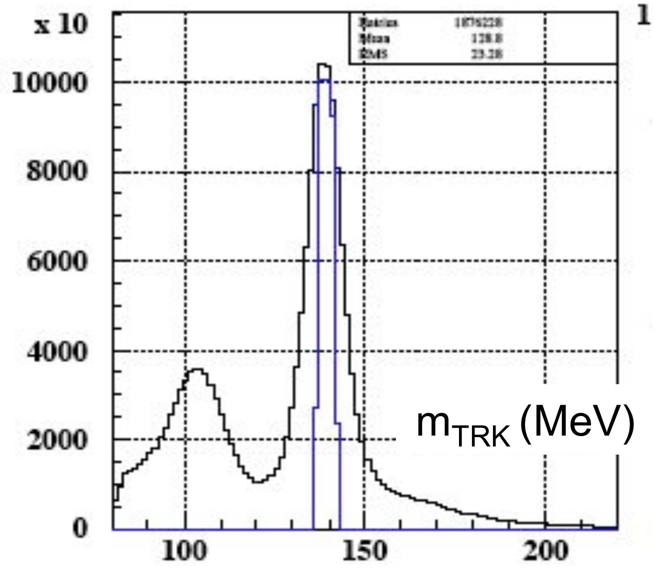
$$\varepsilon_{VTX} = \frac{\#\ \text{of events with a good vtx}}{\#\ \text{evts with a good pair of trks}}$$

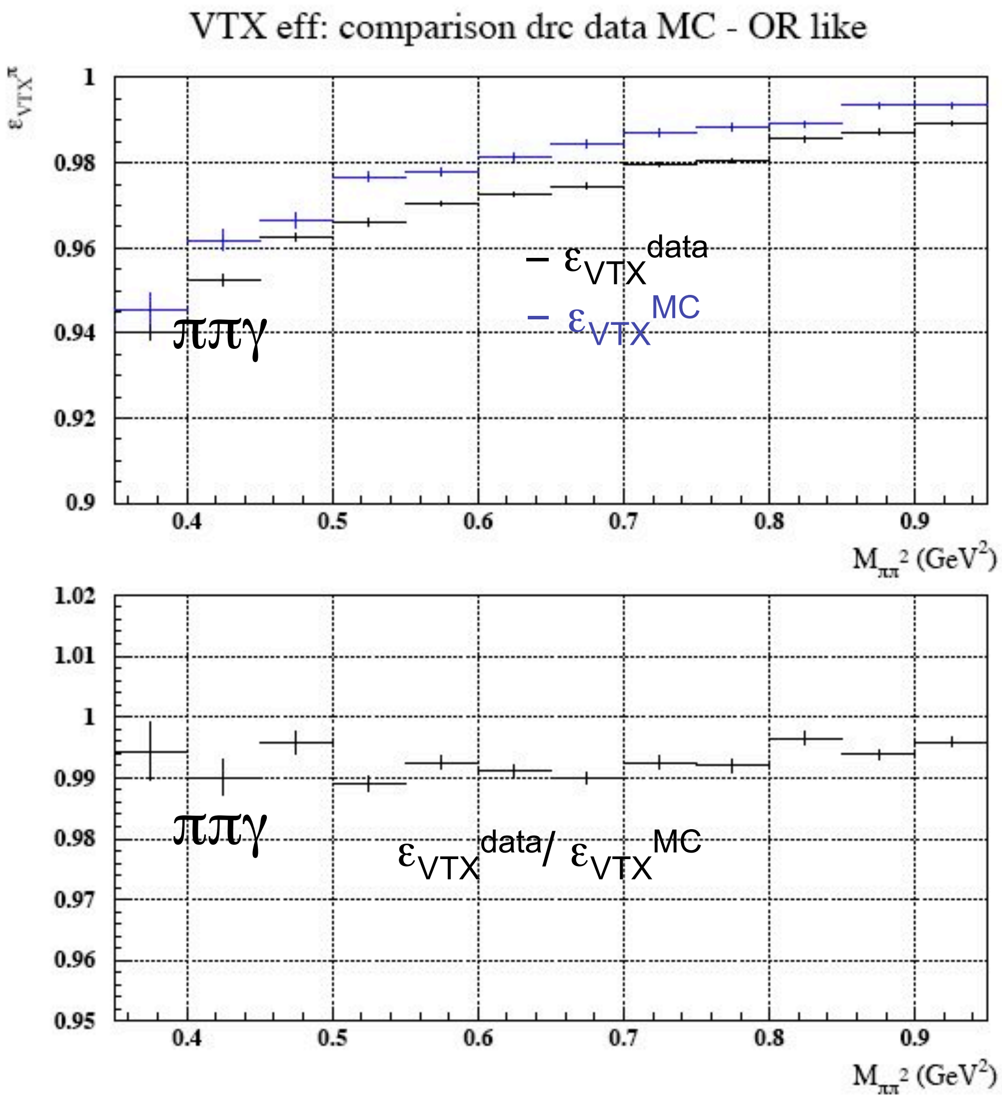
both tracks should satisfy usual selection, in particular:

$$\rho_{F.H.} < 50cm; \rho_{PCA} < 8cm; |z_{PCA}| < 7cm$$

with:

137 MeV$<m_{TRK}<$142 MeV





Vertex corrections for ππγ/μμγ : tighter m_{trk} cuts

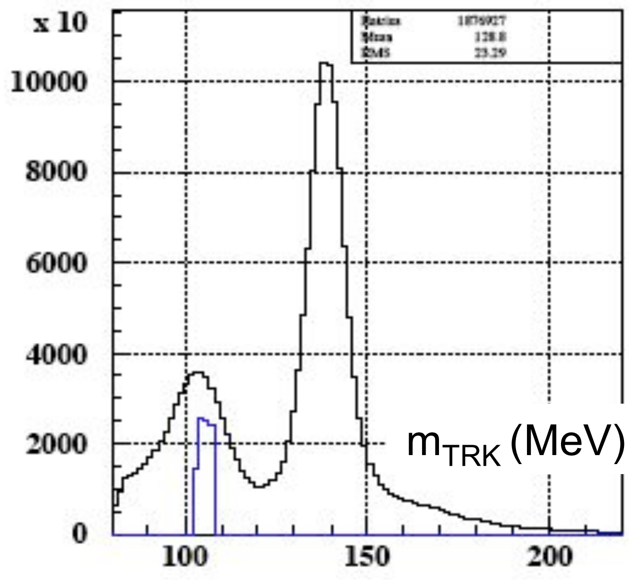
$$\varepsilon_{VTX} = \frac{\text{\# of events with a good vtx}}{\text{\# evts with a good pair of trks}}$$

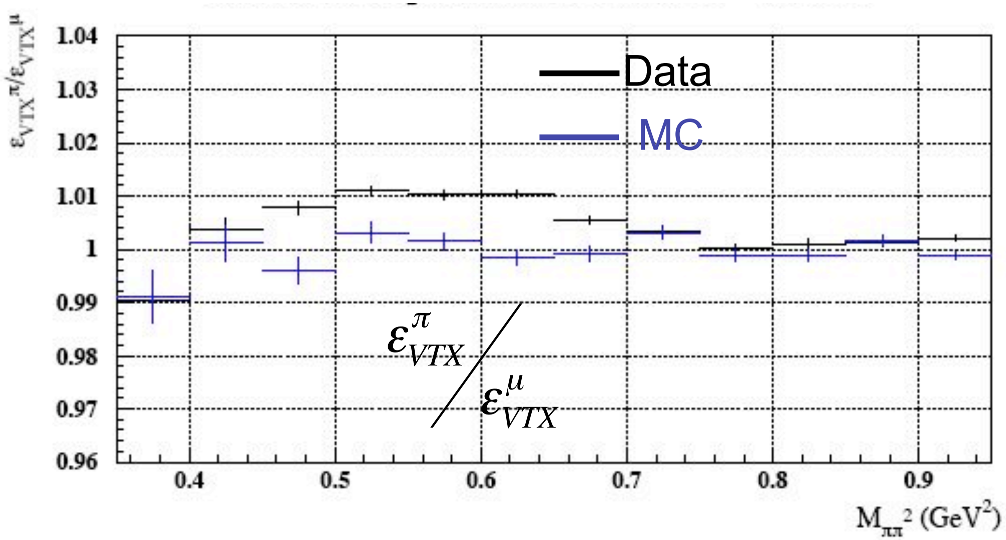
both tracks should satisfy usual selection, in particular:

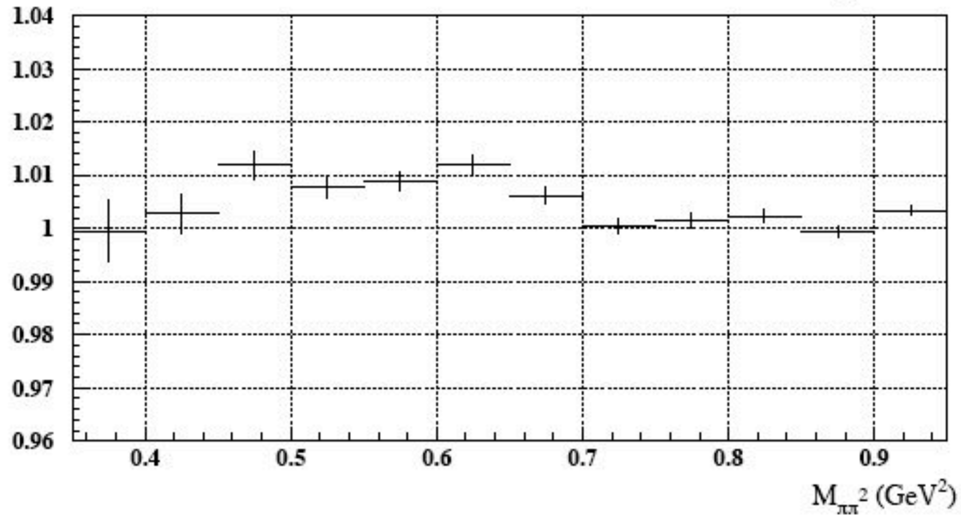
$$\rho_{F.H.} < 50cm; \rho_{PCA} < 8cm; |z_{PCA}| < 7cm$$

with:

103 MeV<m_{TRK}<108 MeV







New: tracking corrections for $\mu\mu\gamma$ events

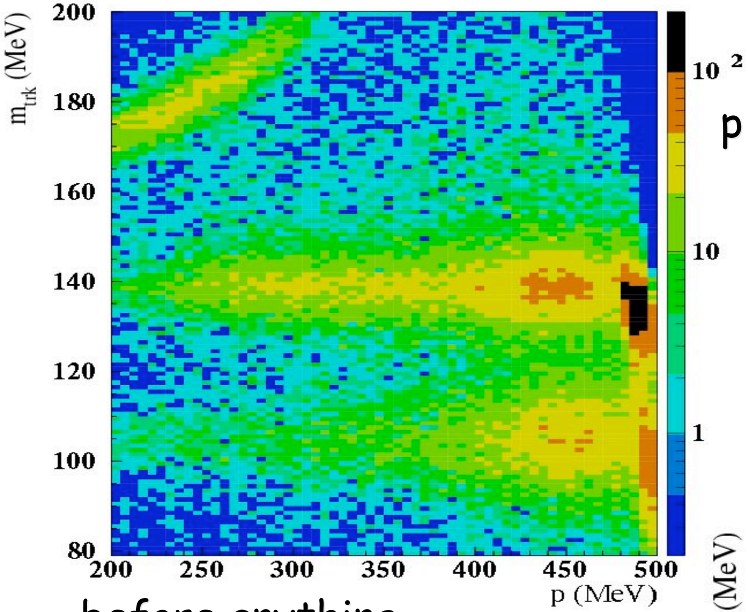
the whole 2002 UFO provides only with 240/20 = 12 pb^{-1},

we refiltered 50 pb^{-1} of 2002 RAW data

- at least a "good tagging track" (first hit with $\rho_{FH} < 50$ cm, point of closest approach (PCA) of backward track extrapolation must have $\rho_{PCA} < 8$ cm and $|z_{PCA}| < 7$ cm)
- the track must have associated (`newextratom`) cluster with log $L_\pi/L_e > 1$ (it also provides with t0) and MLP > 0.7
- 1 and only 1 cluster ("good photon") prompt (according to `ECL_NEURAD`) and neutral (not associated to the tagging track, nor to `TCLO` links) with E > 50 MeV
- photon energy χ^2-constrained to provide a "missing track" of mass = m_μ from momenta of the photon and the tagging track

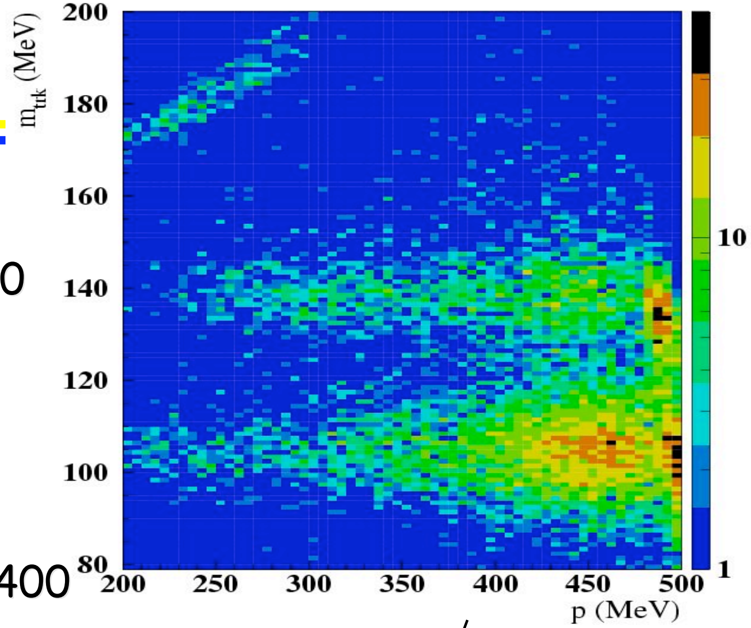
<u>still limited statistics, more CPU/processing time is needed!</u>

Checks of the procedure

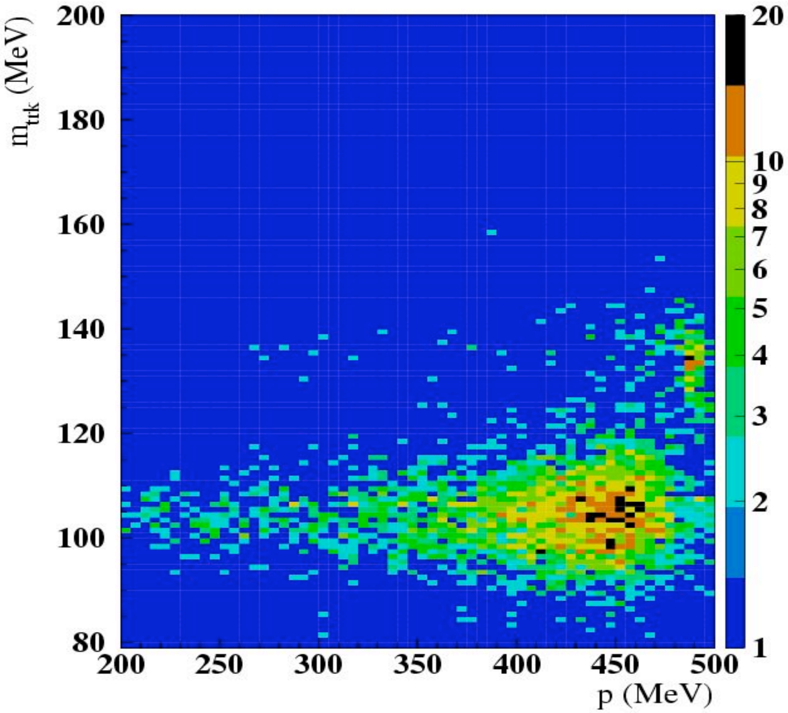


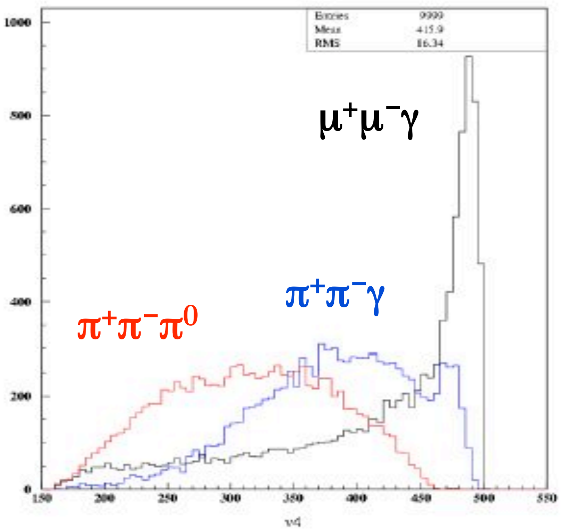
before anything

p (other track) > 400



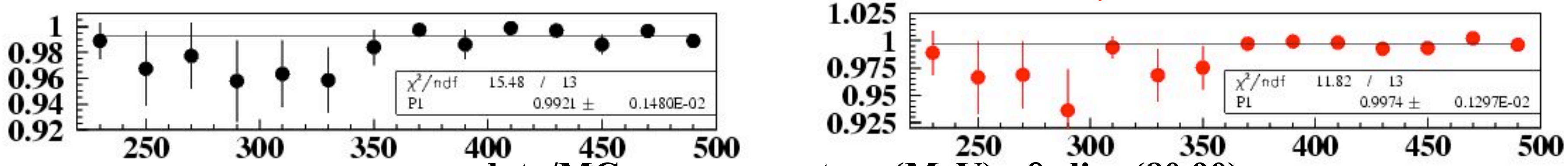
p (other track) > 400
and MLP > 0.7



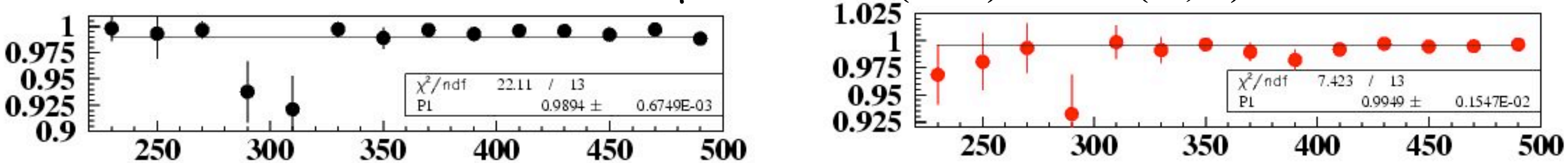


Preliminary Data/MC corrections

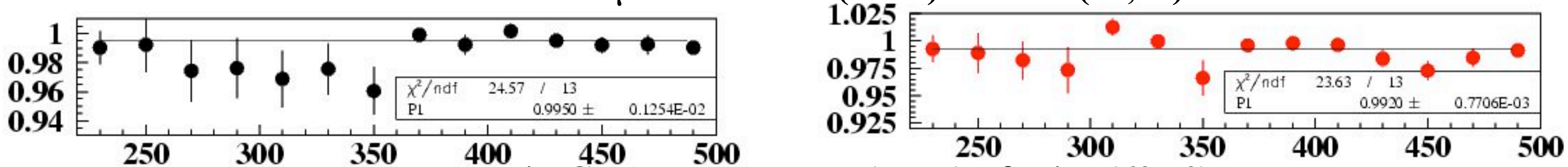
μ− μ+



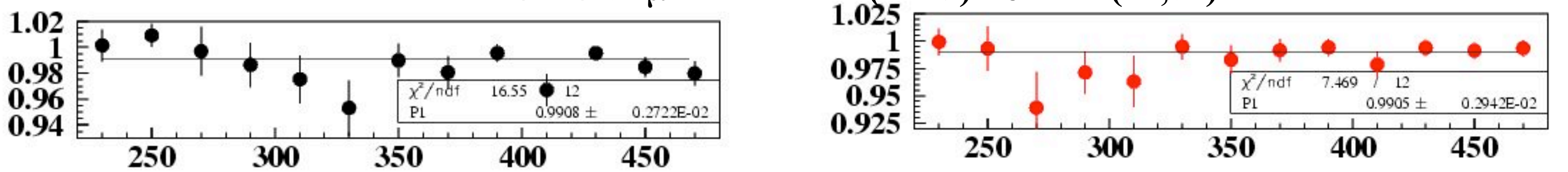
data/MC vs μ momentum (MeV) - θ slice (80,90)



data/MC vs μ momentum (MeV) - θ slice (70,80)



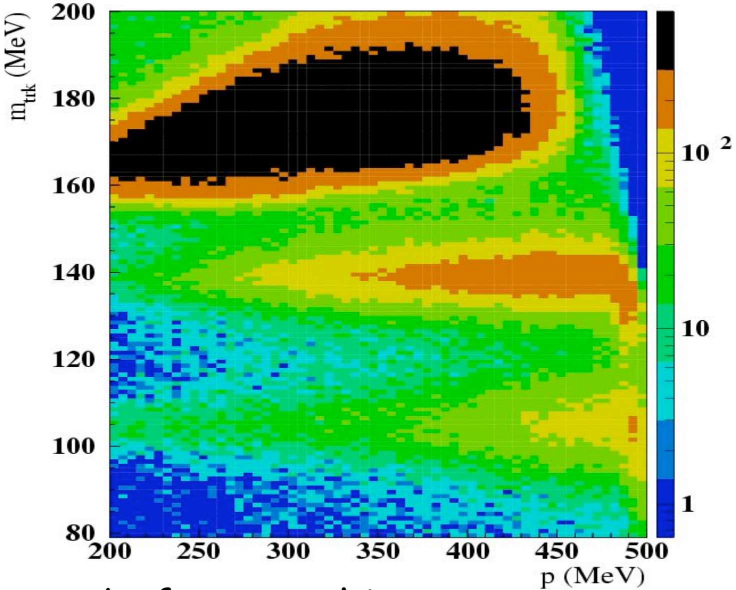
data/MC vs μ momentum (MeV) - θ slice (60,70)



data/MC vs μ momentum (MeV) - θ slice (50,60)

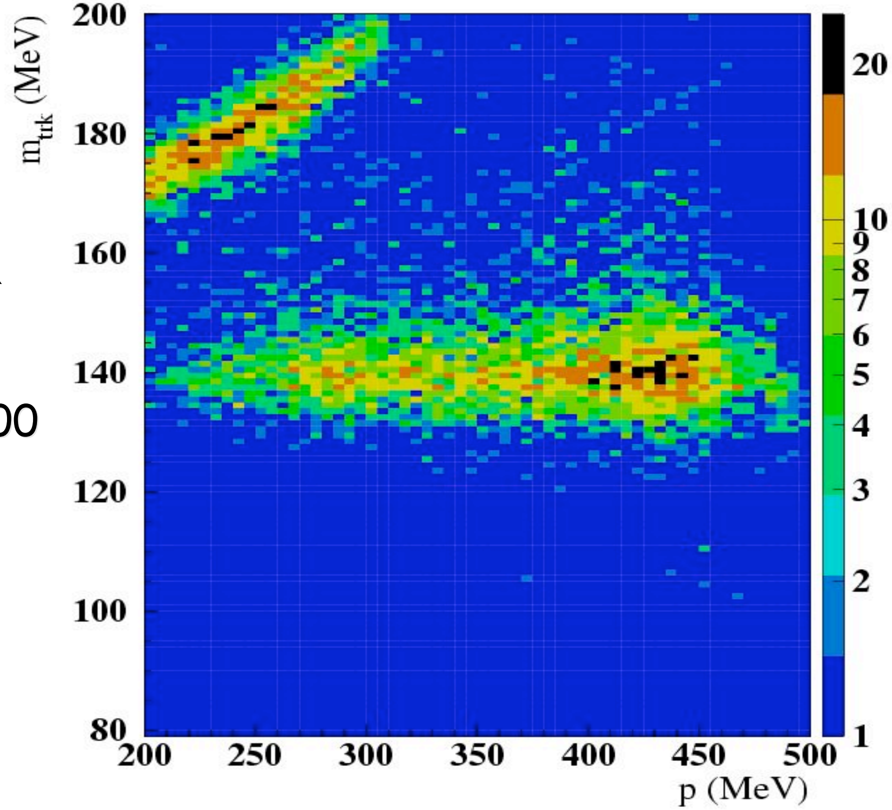
Federico Nguyen
10-12-2007

Checks of the procedure for pions



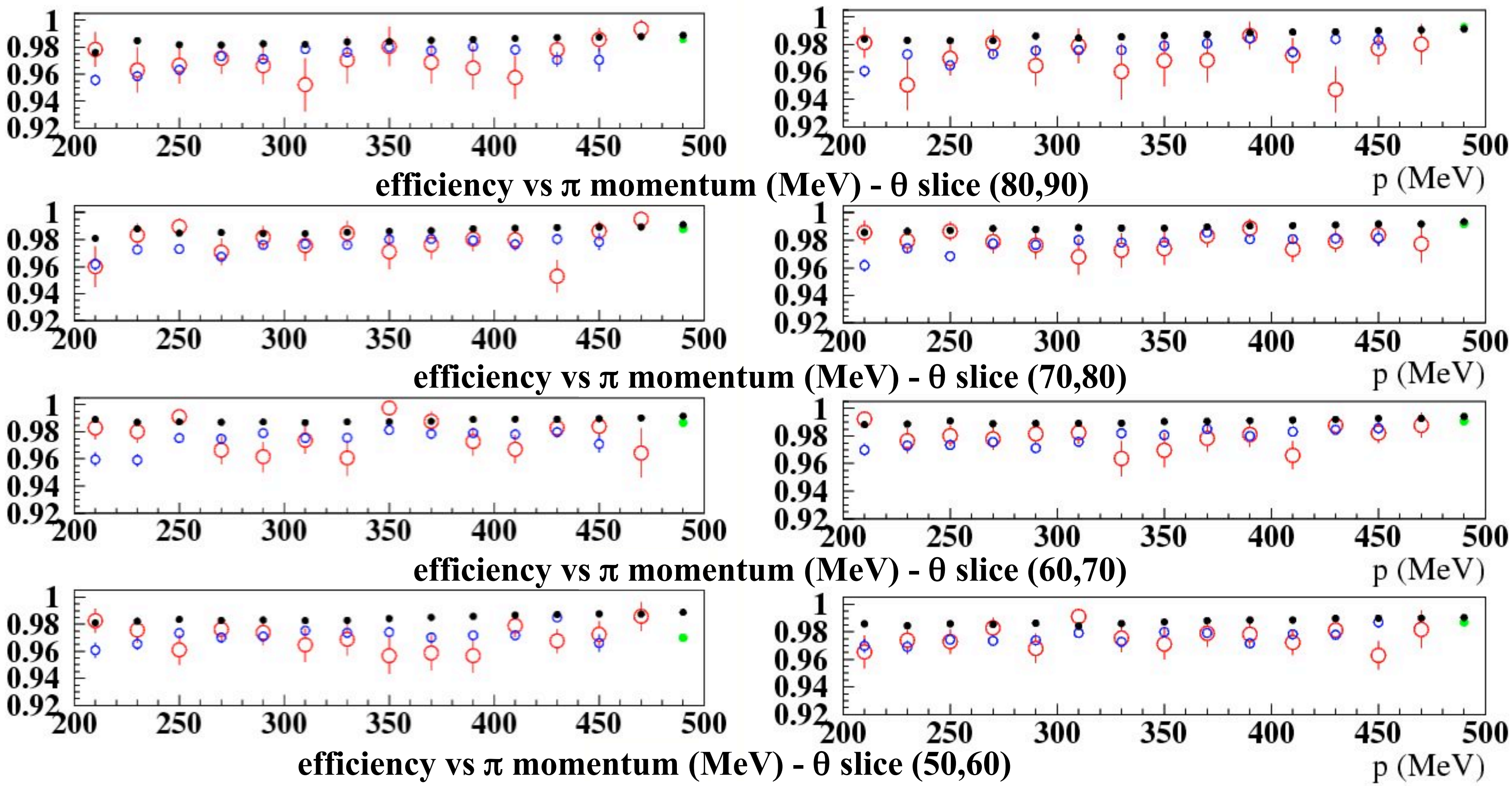
before anything

p (other track) > 400
and MLP < 0.2



also for $\pi+\pi-\pi0$ the MLP is a pion,
and photon energy (the other is lost)
is constrained to a missing mass=m_π

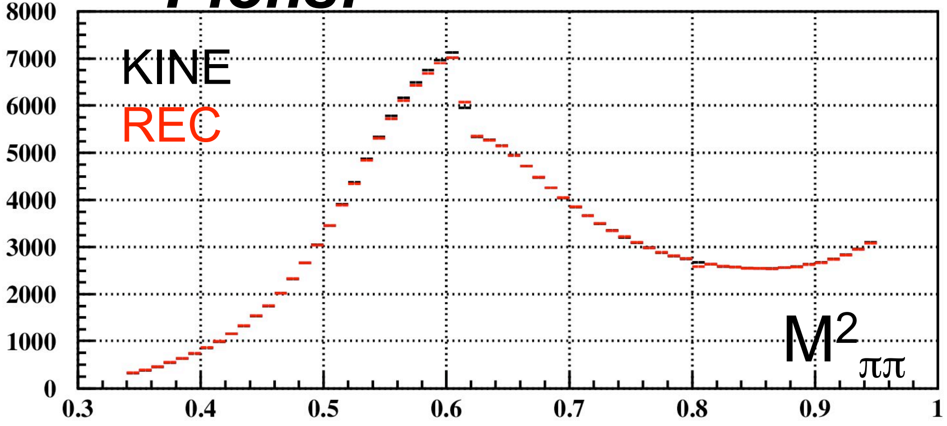
Back to the tracking efficiencies for pions

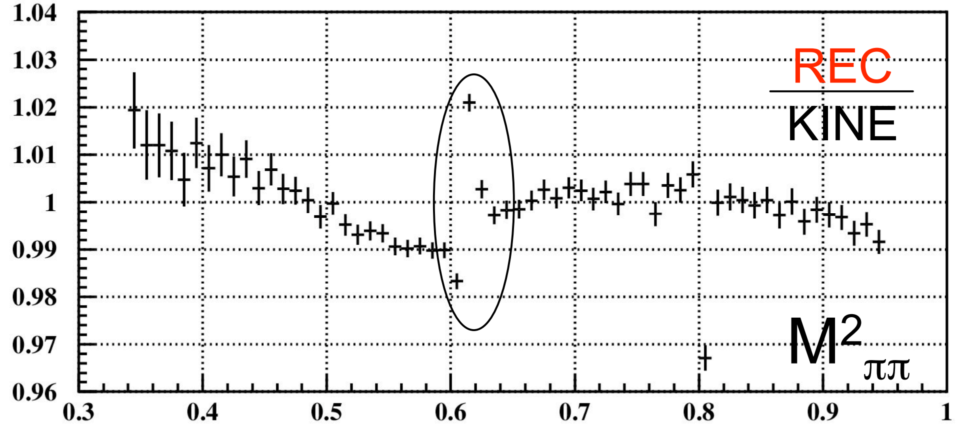


- MC π+π-γ
- π+π-
- π+π-π0
- π+π- γ

Unfolding the absolute spectrum

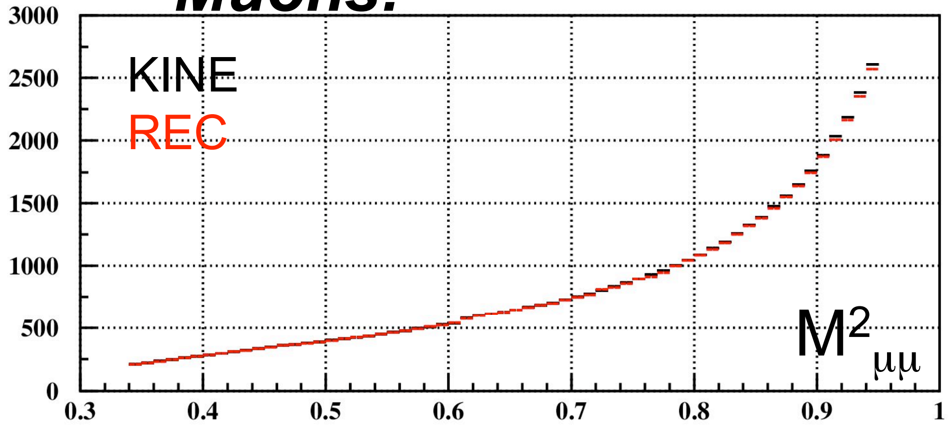
Pions:

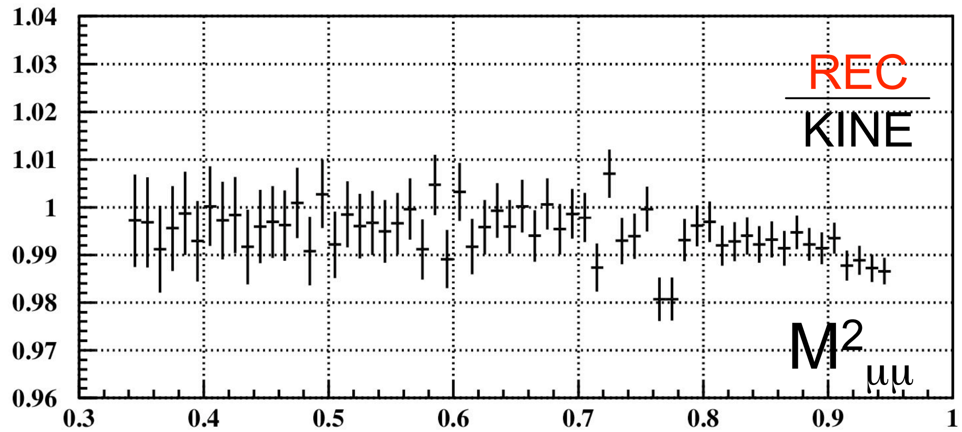




Effect of 1% for pions, with larger fluctuations around ω-mass + 1 nasty point at 0.8 GeV^2

Muons:

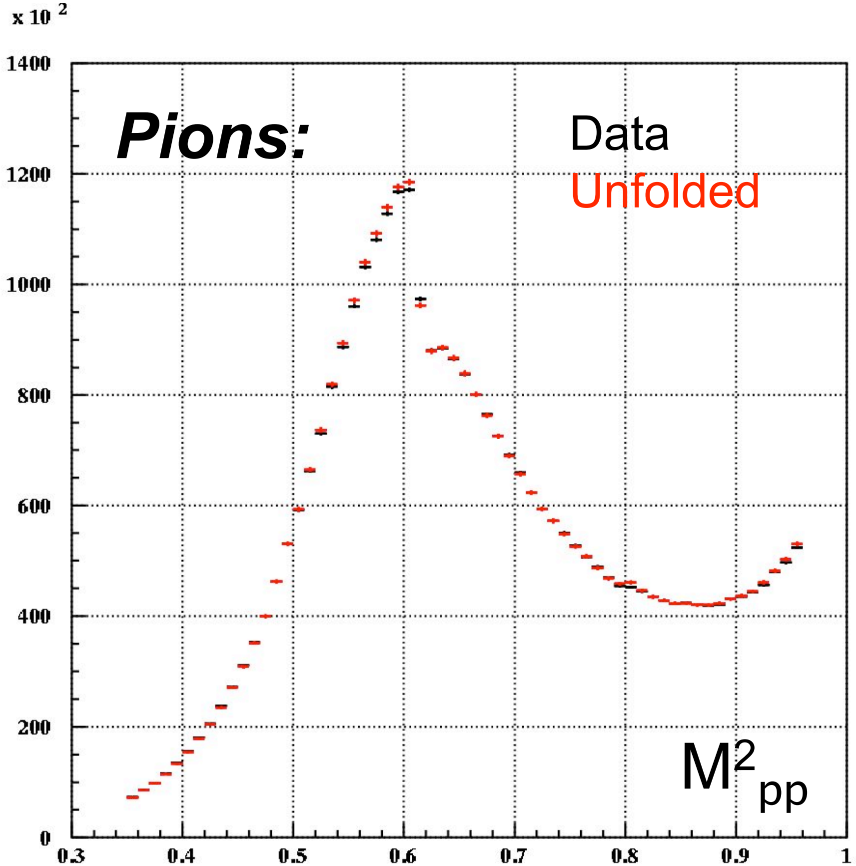


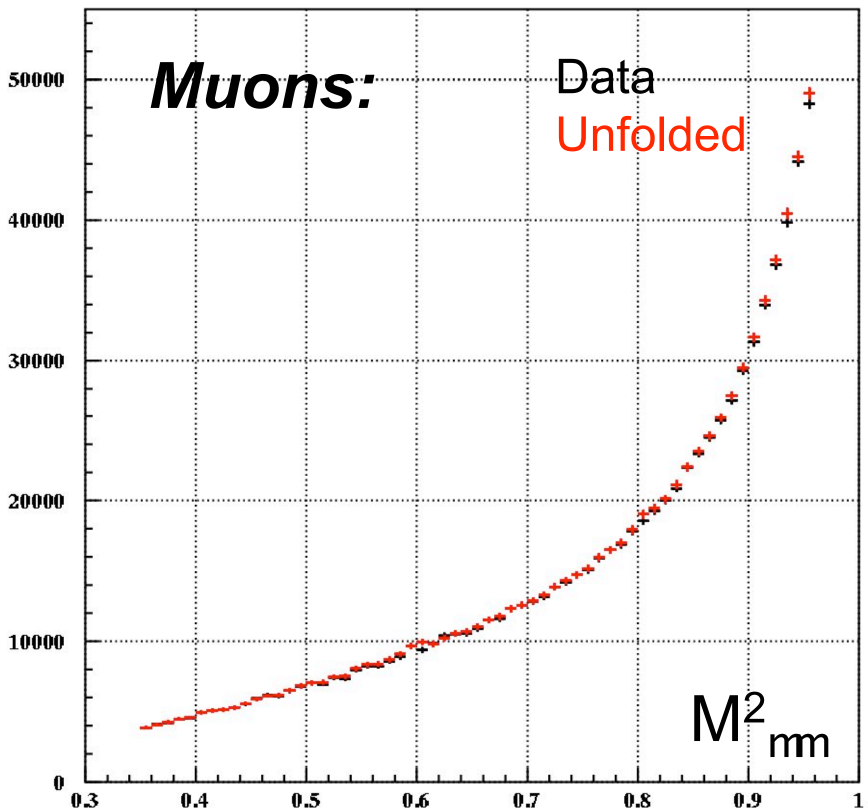


For muons, the effect is smaller
(biggest effect > 0.95 GeV^2)

Federico Nguyen
10-12-2007

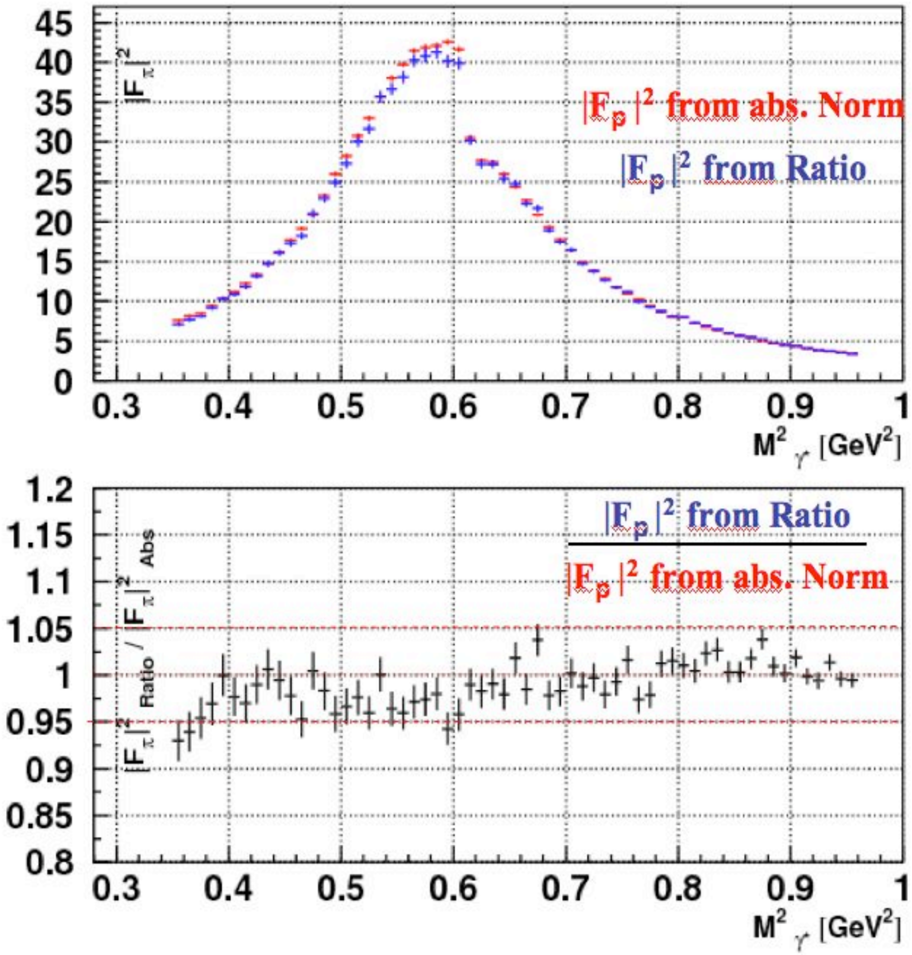
Application on data





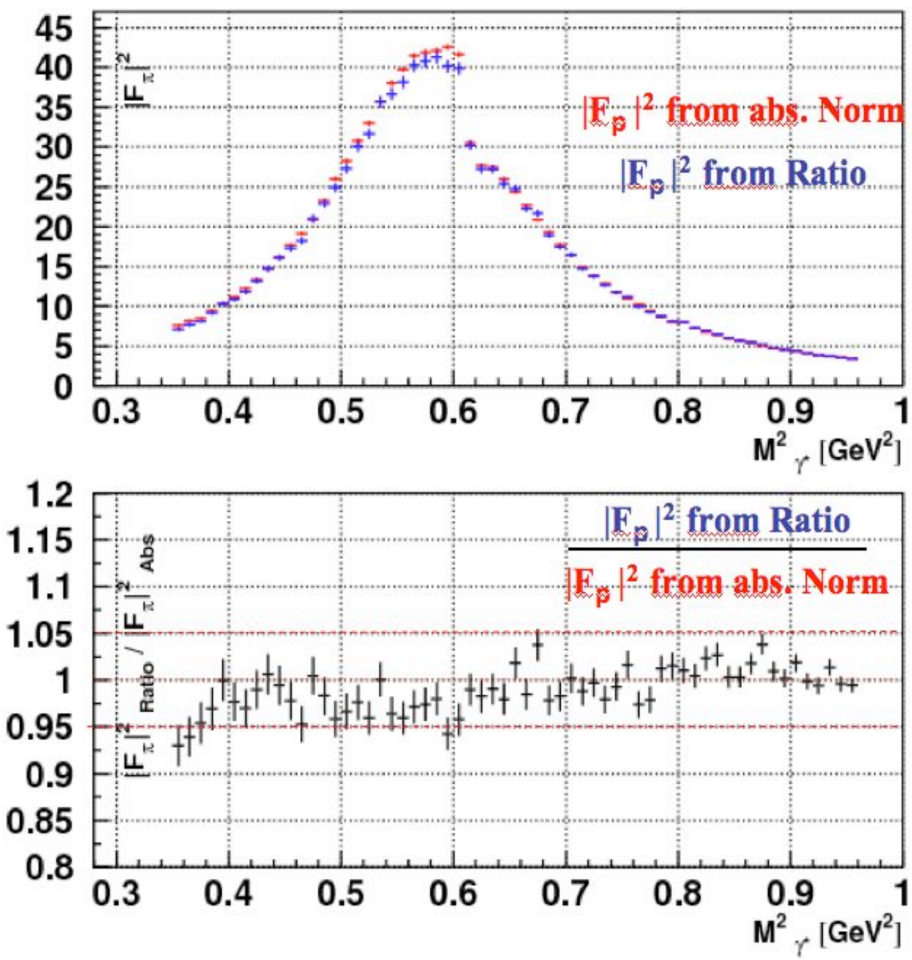
- Bin-by-Bin division does not allow full control of correlations between bins
  - *→ use „population“-matrix mapping M^2_{rec} to M^2_{kine}*
- Depends on pion form factor parametrization of MonteCarlo (ppgphok3, now)
  - *→ use different parametrization in MC and compare (first step)*
  - *→ better: Use dedicated packages (GURU or Bayesian Unfolding...)*

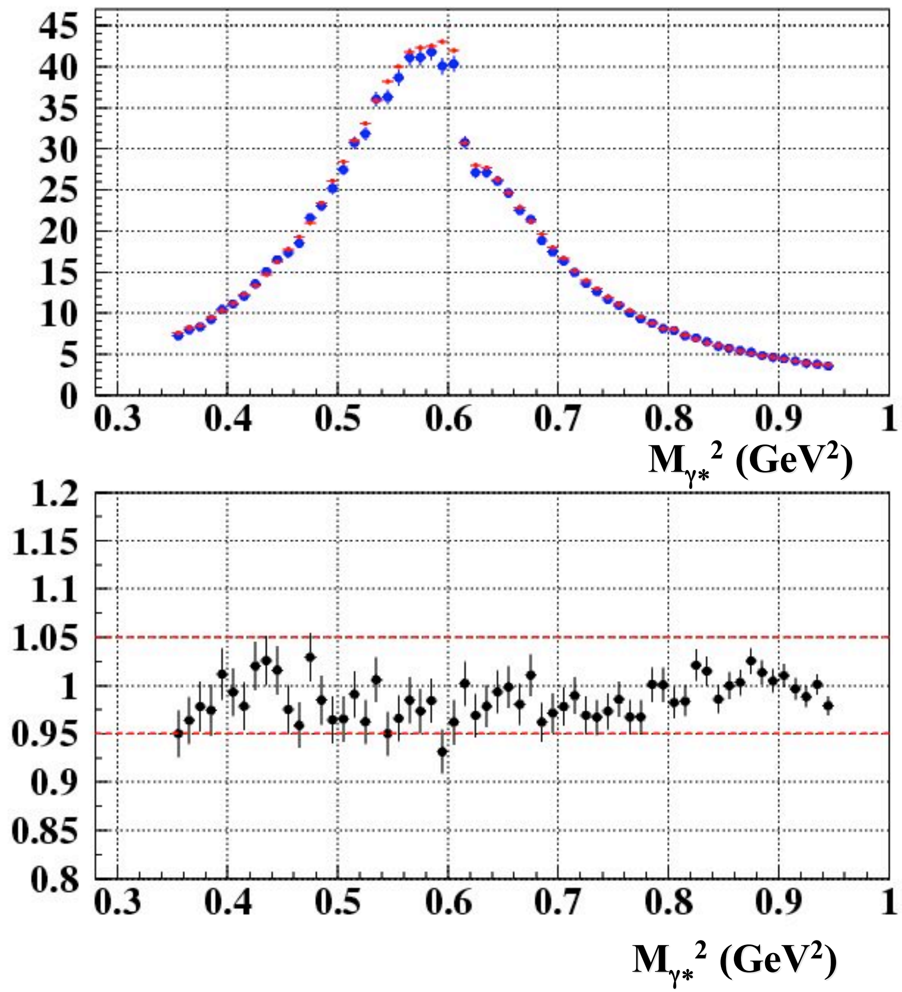
Comparison between the two approaches



from last summer: Capri, EPS, etc…

Comparison between the two approaches

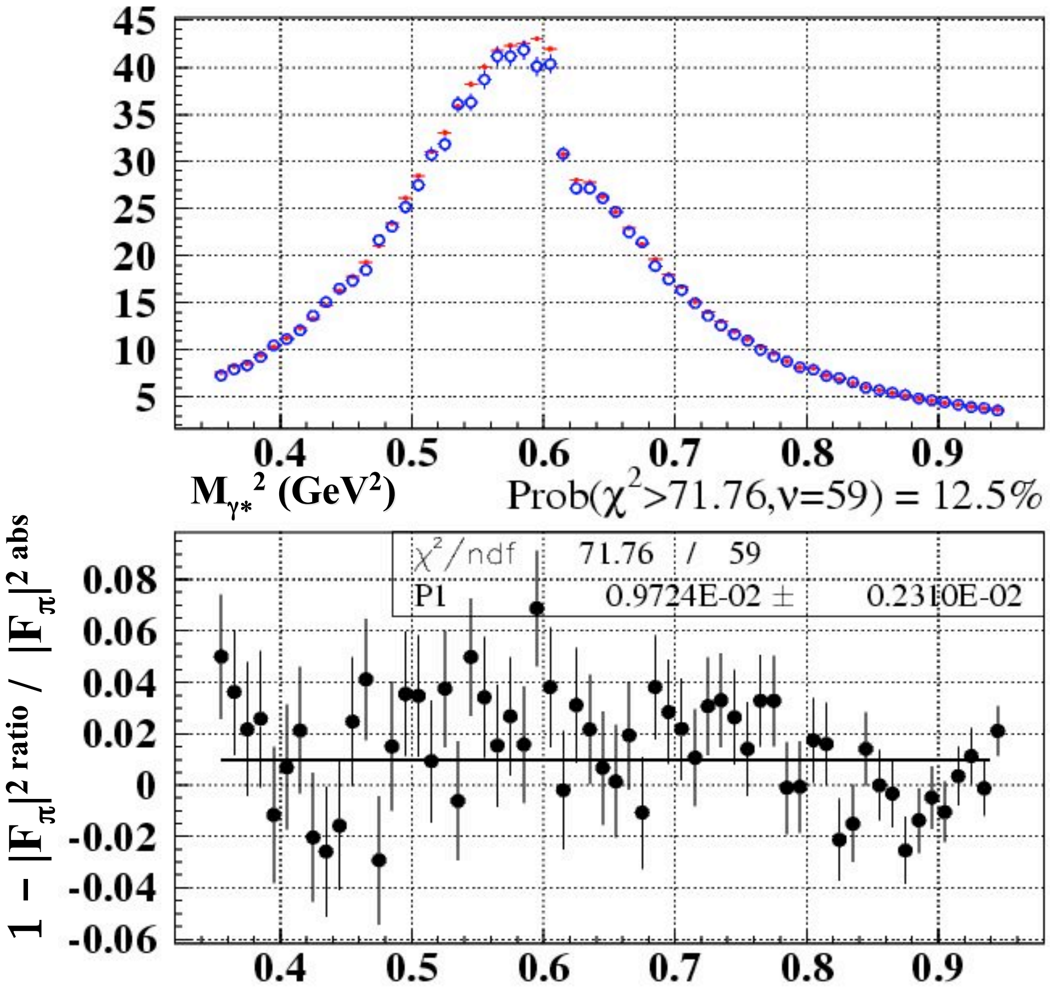




from last summer: Capri, EPS, etc…

Federico Nguyen
10-12-2007

Let's zoom on the comparison



- ✓ overall agreement ~ 1%,
- ✓ no relevant slope,
- ✓ ~ 2% agreement in the region around the ρ
- ✓checks are going on

Systematics table left unchanged

$\pi\pi\gamma$

FILFO	0.0%
Background	QQ dep., known
Trackmass/Miss. Mass	0.2% (2001)
Likelihood+TCA	0.3%
Vertex	0.5%
Tracking	0.4%
Trigger	0.2%
Acceptance (θ_π)	0.0%
Unshifting	??
Unfolding	QQ dep.
L3 Trigger	0.1 %

$\mu\mu\gamma$

FILFO	0.0%
Background	QQ dep., known
Trackmass/Miss. Mass	0.2% (2001)
Likelihood+TCA	0.3%
Vertex	0.5%
Tracking	0.5%
Trigger	0.2%
Acceptance (θ_π)	0.0%
FSR-> ISR corrections	??
Unfolding	0.0%
L3-Trigger	0.1%

Luminosity	0.3%
Acceptance (θ_Σ)	$-0.004+0.0051*M^2_{\pi\pi}$
Radiator H	0.5%
Vacuum polarization	QQ dep., known

$|F_\pi|^2$ from absolute Measurement

Acceptance ($\theta_\Sigma^{\mu\mu,ISR} / \theta_\Sigma^{\pi\pi,IFSR}$)	$-0.004+0.0051*M^2_{\pi\pi}$ $-0.0047+0.0057*M^2_{\mu\mu}$

$|F_\pi|^2$ from Ratio

~ 25 effects to have under control!!

Amusing a_μ's...

2001 published result (PLB606 (2005) 12):

$$a_\mu^{\pi\pi}(0.35\text{-}0.95\text{GeV}^2) = (388.7 \pm 0.8_{stat} \pm 3.5_{syst} \pm 3.5_{theo}) \cdot 10^{-10}$$

Applying corr. for trigger eff. and change in VLAB-xsect:

$$a_\mu^{\pi\pi}(0.35\text{-}0.95\text{GeV}^2) = (384.4 \pm 0.8_{stat} \pm 3.5_{syst} \pm 3.5_{theo}) \cdot 10^{-10}$$

2002 prelim. from abs. norm. (summer'07):

$$a_\mu^{\pi\pi}(0.35\text{-}0.95\text{GeV}^2) = (386.3 \pm 0.6_{stat} \pm 4.3_{syst}) \cdot 10^{-10}$$

2002 prelim. from ratio (summer'07):

$$a_\mu^{\pi\pi}(0.35\text{-}0.95\text{GeV}^2) = (375.0 \pm 1.3_{stat} \pm 4.2_{syst}) \cdot 10^{-10}$$

} stable

2002 prelim. from abs. norm. (fall'07):

$$a_\mu^{\pi\pi}(0.35\text{-}0.95\text{GeV}^2) = (384.2 \pm 0.6_{stat} \pm 4.3_{syst}) \cdot 10^{-10}$$

2002 prelim. from ratio (fall'07):

$$a_\mu^{\pi\pi}(0.35\text{-}0.95\text{GeV}^2) = (376.8 \pm 1.5_{stat} \pm 4.2_{syst}) \cdot 10^{-10}$$

} 1.2-1.5σ

Summary and outlook

small refinements in the absolute measurement, a_μ consistent

large work in the $\pi\pi\gamma/\mu\mu\gamma$ analysis, especially for μ tracking efficiency (MLP developed and wide momentum spectrum covered), clean data sample

overall agreement between the two spectra ~ 1% (2% around the r region), improved wrt to last summer

writing documentation in progress (first version of the Memo/Note as a X-mas gift to the referees)

Everybody is really welcome

Università Roma Tre
Dipartimento di Fisica e Sezione INFN
via della Vasca Navale 84 – 00146 Roma

GIOVEDI 13 DICEMBRE 2007
ore 14:15 Aula Magna Università Roma Tre
Via Ostiense 159

X Roma Tre Topical Seminar on Subnuclear Physics:

SUSY today : theory and experimental limits one year before LHC

Programma:

14:15 **A.Masiero**: Supersymmetry, astrophysics and cosmology
15:00 **V.Buescher**: Present collider limits to Supersymmetry
15:30 **G.Isidori**: Supersymmetry and flavour physics

16:15 **coffee break**

16:45 **M.Spiropulu**: The search for Supersymmetry at LHC
17:15 **G.Altarelli** : Overview and perspectives

Small Angle analysis

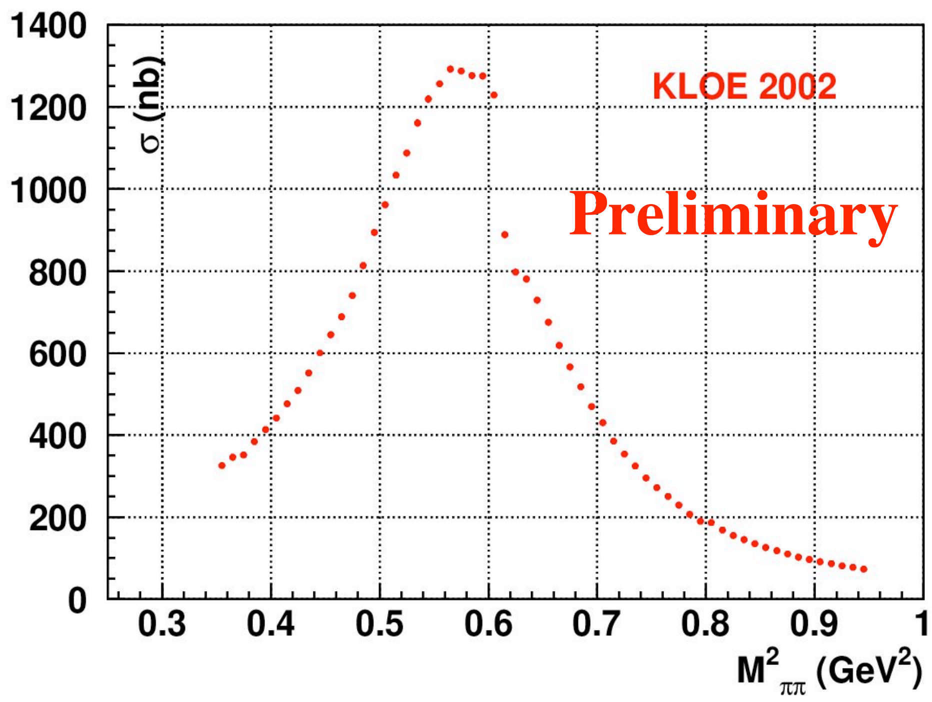
$$\sigma_{\pi\pi}\left(M^2_{\pi\pi}\right) \approx M^2_{\pi\pi} \frac{d\sigma^{obs}_{\pi\pi+\gamma(\gamma)}}{dM^2_{\pi\pi}} \frac{1}{H(M^2_{\pi\pi})}$$

$$\frac{d\sigma^{obs}_{\pi\pi+\gamma(\gamma)}}{dM^2_{\pi\pi}} = \frac{N_{\rm Obs} - N_{\rm Bkg}}{\Delta M^2_{\pi\pi}} \frac{1}{\varepsilon_{\rm Sel} L}$$

	2001 data PLB606(2005)12	2002 data arXiv:0707.4078
Offline Filter	0.6%	negligible
Background	0.3%	0.3%
Trackmass/Miss. Mass	0.2%	0.2%
p/e-ID	0.1%	0.3%
Vertex	0.3%	0.5%
Tracking	0.3%	0.4%
Trigger	0.3%	0.2%
Acceptance (θ_π)	0.3%	negligible
$M_{pp}^2 \rightarrow M_{g*}$ (FSR corr.)	0.3%	0.3%
Luminosity	0.6%	0.3%
Radiator H	0.5%	0.5%
Vacuum polarization	negligible	negligible

σ_{tot} = **1.3%** **1.1%**

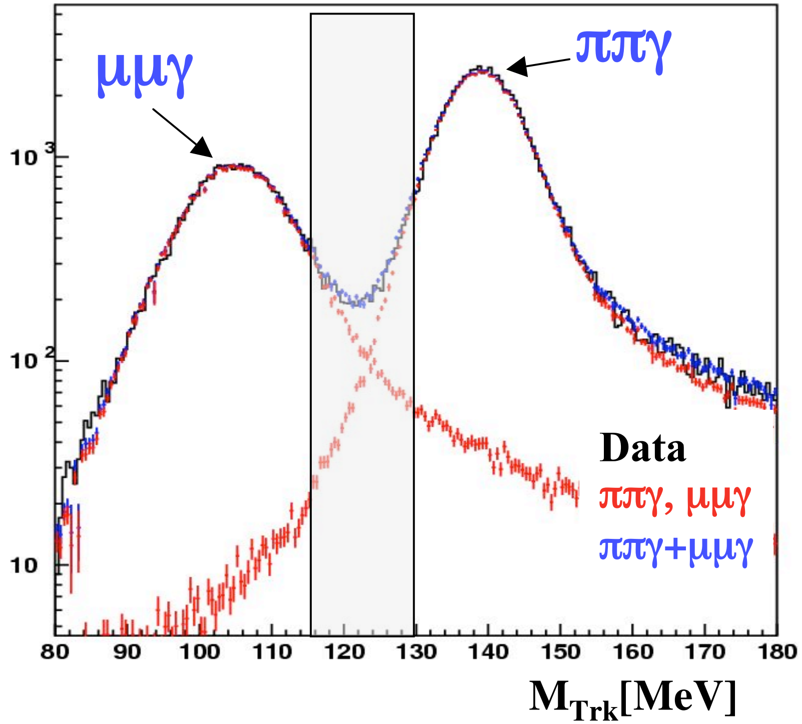
systematic errors on $a_\mu^{\pi\pi}$ from the absolute normalization analysis



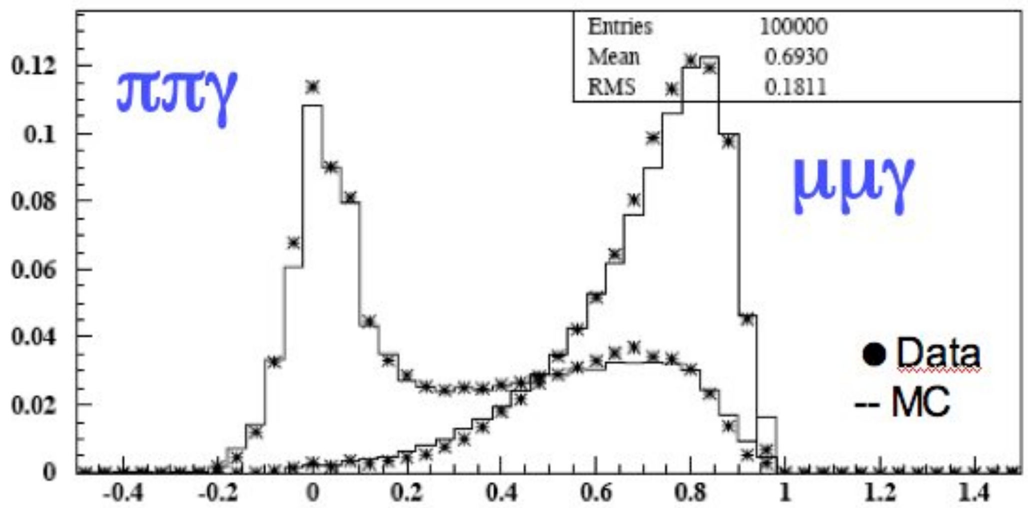
2002 analysis almost completed: a dedicated resolution unfolding procedure is under way

Status of μμγ analysis: PRELIMINARY

Analysis is in advanced state, several studies to achieve π/μ separation, both on the selection of two tracks and also at the level of single track (relevant for efficiencies and systematics estimate)



M_{Trk} = mass under the hypothesis of 2 tracks of equal mass and 1 photon



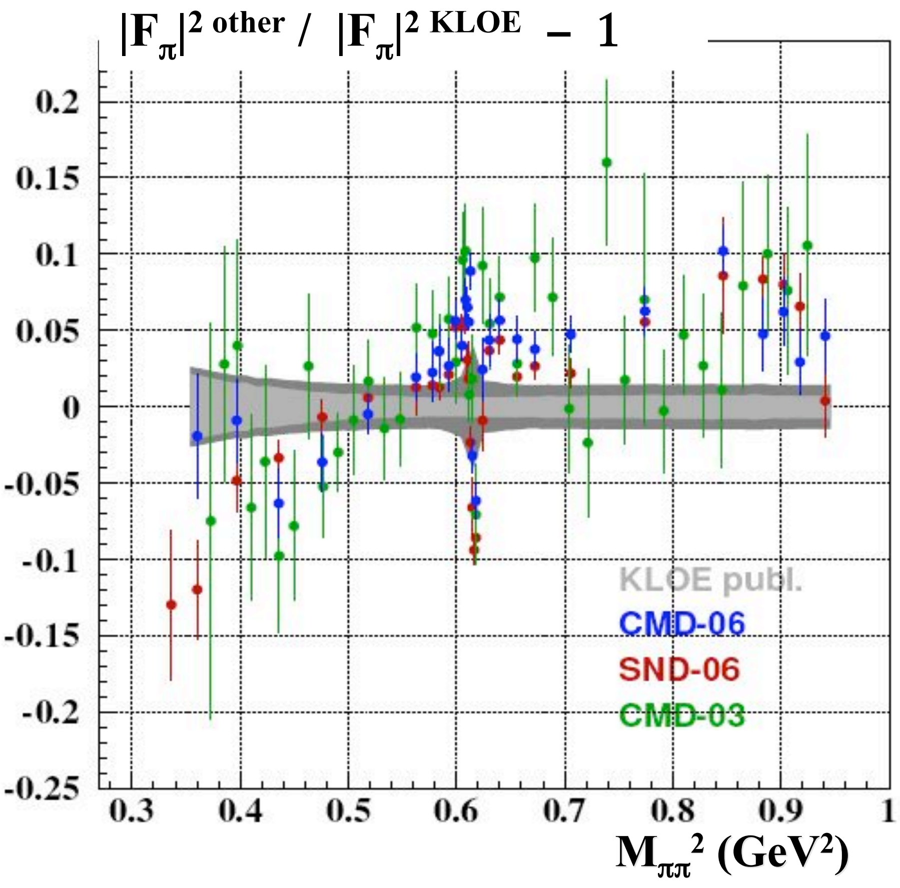
NN output, based on the time of flight, depth and amount of the energy deposit in the calorimeter

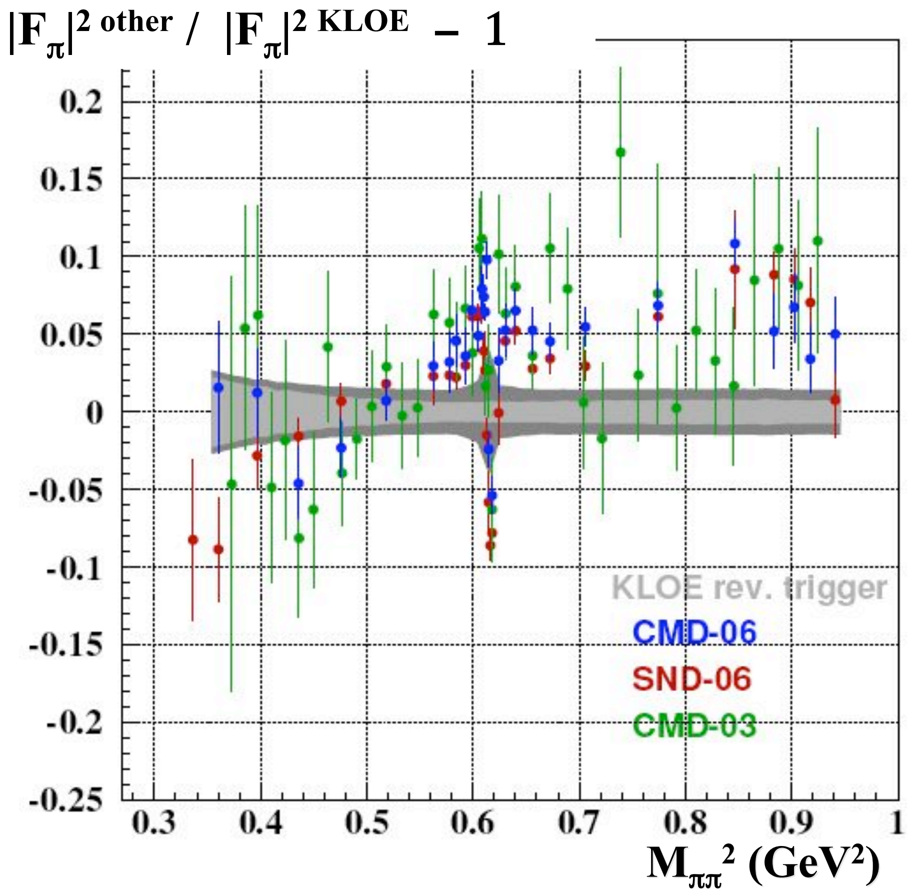
SPARES

Present Situation: updates

trigger update: double counting fixed, 3.5% at low $M_{\pi\pi}$ values (a few bins), 0.4% on $a_\mu^{\pi\pi}$

***L*: according to Nucl. Phys. B758(2006)227, equivalent to decrease $|F_\pi|^2$ of 0.7%**

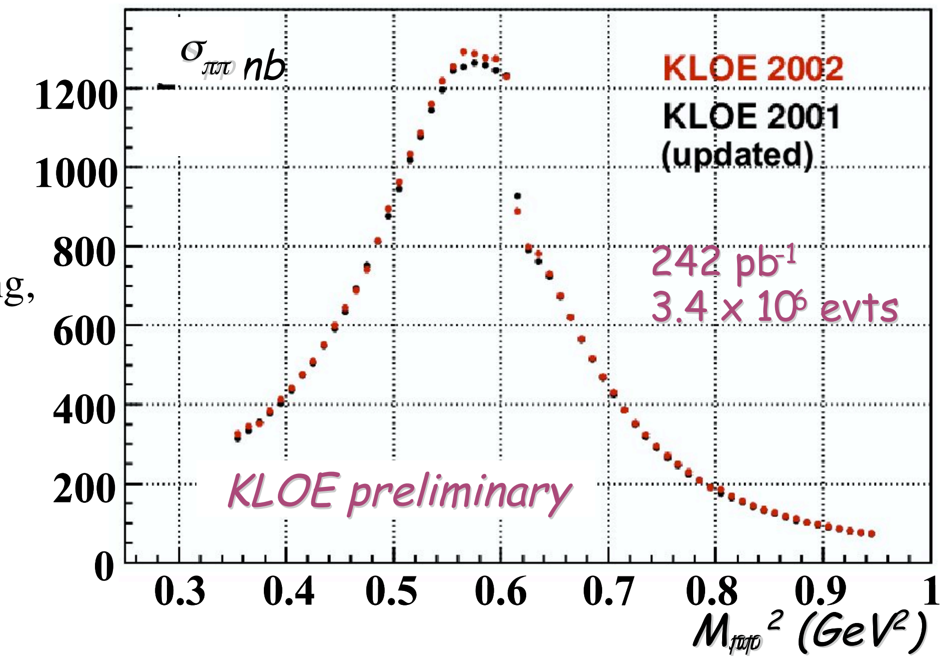


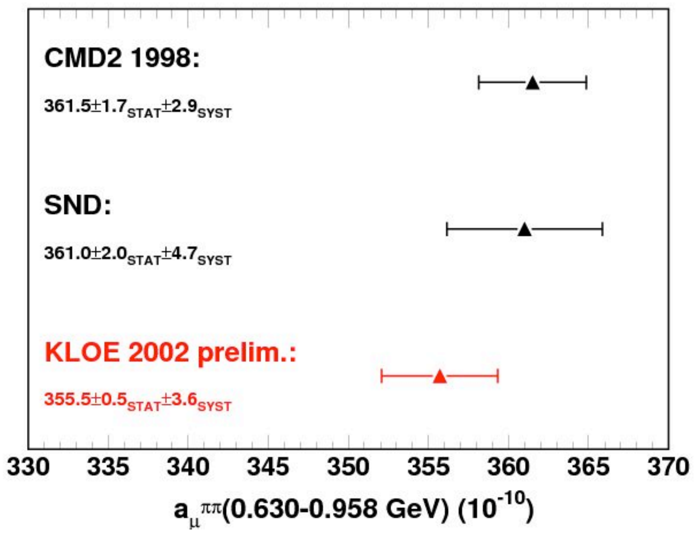


World comparison

Improvements/updates *vs* 2001 data

- 30% cosmic-rays veto inefficiency recovered by additional software trigger level
- Improved offline-event filter → syst.error <0.1%
- Trigger efficiency updated due to a double counting, down by 0.4%
- new generator BABAYAGA@NLO: error from 0.5% to 0.1%, cross section down by 0.7%





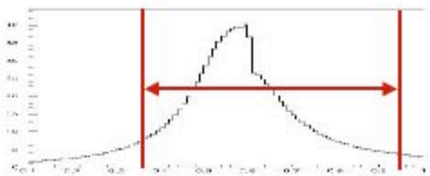
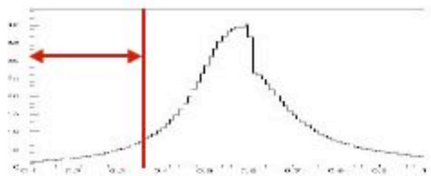
a_μ(0.35,0.95)(10^{-11} units)

2001	$3887 \pm 8_{stat} \pm 49_{syst}$
2001 update	$3844 \pm 8_{stat} \pm 49_{syst}$
2002	$3863 \pm 6_{stat} \pm 39_{syst}$

a_μ(exp) – a_μ(theory) = 287(91)10^{-11}

Jegerlehner hep-ph/0703125

Summary and outlook

Analysis	$\int L dt$	Syst. $0.6<M_{\pi\pi}<0.95$ GeV² 	Syst. $M_{\pi\pi}<0.6$ GeV² 
γ_{ISR} untagged 2001 data	140 pb^{-1}	1.3 % (published)	(kinematically forbidden)
γ_{ISR} untagged 2002 data	240 pb^{-1}	1.1 %	(kinematically forbidden)
γ_{ISR} tagged 2002 data	240 pb^{-1}	0.9 % $\oplus$ f_0(980) contribution	limited by model dependence of irreducible background $\phi \to f_0(980)\,\gamma$
Off-Peak 2006 **$\sqrt{s}$ = 1.00 GeV**	230 pb^{-1}	<< 1 %	suppressed f_0(980) contribution

ππγ: paper draft
μμγ: internal doc.

internal documentation

in progress

Federico Nguyen
10-12-2007