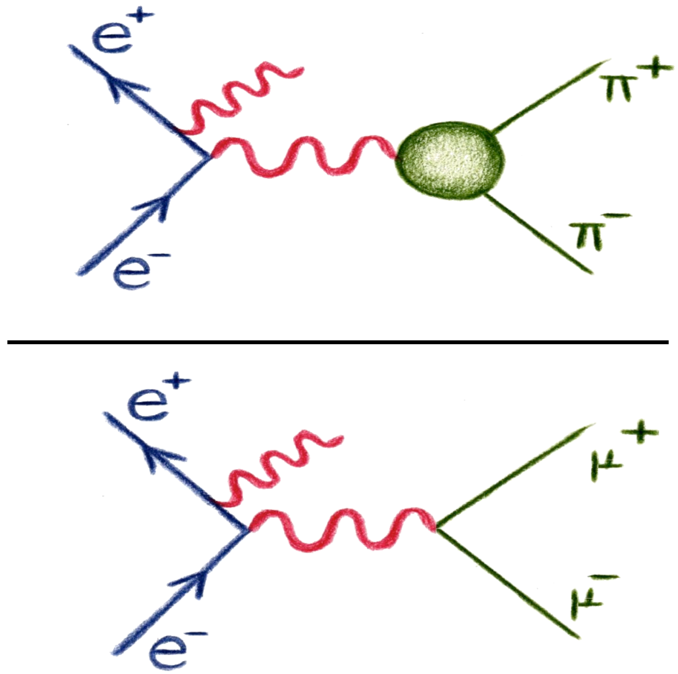
Extraction of $|F_\pi|^2$ from the ratio of $\pi\pi\gamma$ to $\mu\mu\gamma$ events and comparison with the absolute normalization

Federico Nguyen

Φ Decays 28-02-07

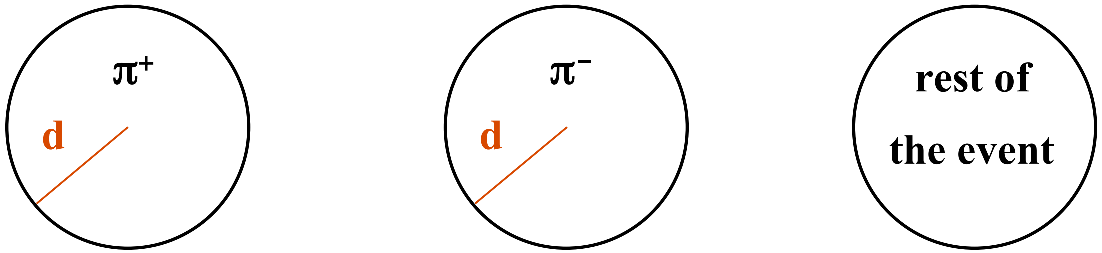


An outline

1) Improvements wrt the last General Meeting for the trigger
2) Estimate of a possible impact on 2001 data
3) DC trigger comparison
4) Studies and corrections for the formula of the ratio
5) Neural networks algorithms for control samples
6) Results: comparisons

Single particle method

• classification of all fired sectors according to the cluster position wrt the extrapolated π track:



• then multiplicities are evaluated: e.g. $P_{+,-,r}(0,1,2)$=probability for the π^+, π^- or the rest of firing 0,1,2 trigger sectors

• assumption: probabilities are independent no correlation among the categories

$$P(+=1,-=0,r=0) = P(+=1)\ P(-=0)\ P(r=0)$$

• single conditioned probabilities are built in an unbiased way,

e.g. $P_+(0,1,2)$ is estimated as the probability provided that the rest OR the π^- have fired 2 trigger sectors

above assumptions allow the following formula (M. Incagli, KLOE Memo 278):

$$\varepsilon_{trigger}(M_{\pi\pi}^2) = 1 - P_1^+ \cdot P_0^- \cdot P_0^r - P_0^+ \cdot P_1^- \cdot P_0^r - P_0^+ \cdot P_0^- \cdot P_1^r - P_0^+ \cdot P_0^- \cdot P_0^r$$

Used variables

$$\Delta R = |\vec{x}_{clu} - \vec{x}_{ext}|$$

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

$$\Delta T = t_{clu} - t_{\max}$$

$\mathbf{t_{max}}$ = time of the most energetic cluster within 60 cm from the extrapolated point

studying clusters with E > 30 MeV was evident that only a topological cut (sphere with R=60 cm) cannot account of all clusters correlated with charged pions

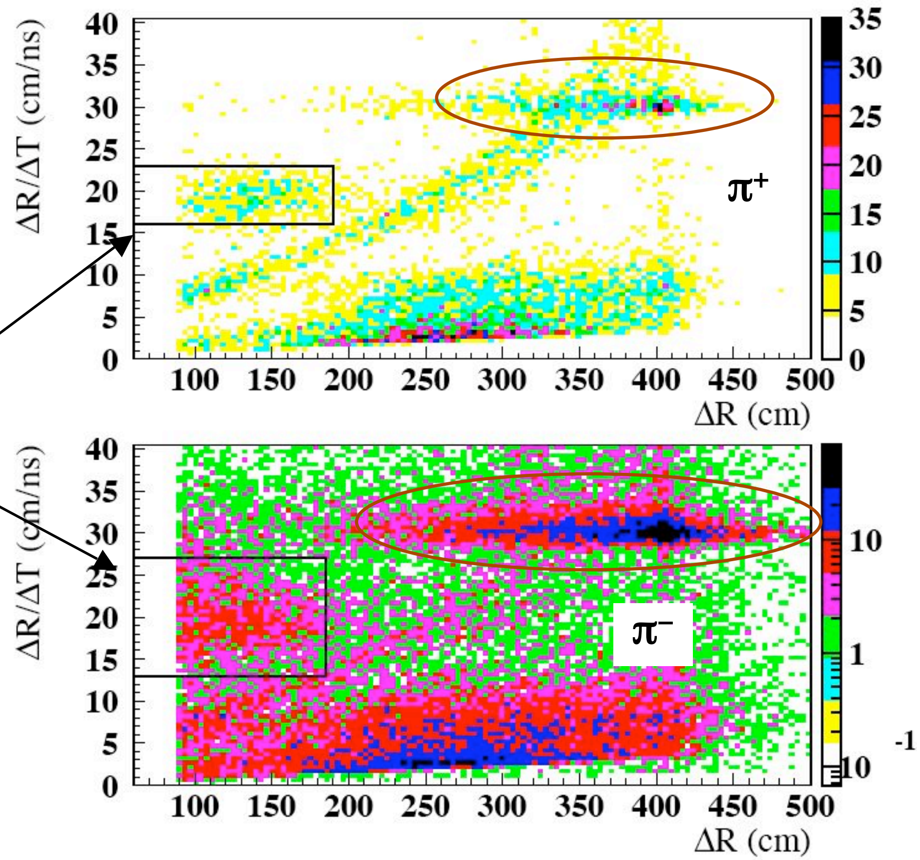
(moreover MC is different from data)

Assessed re-assignment

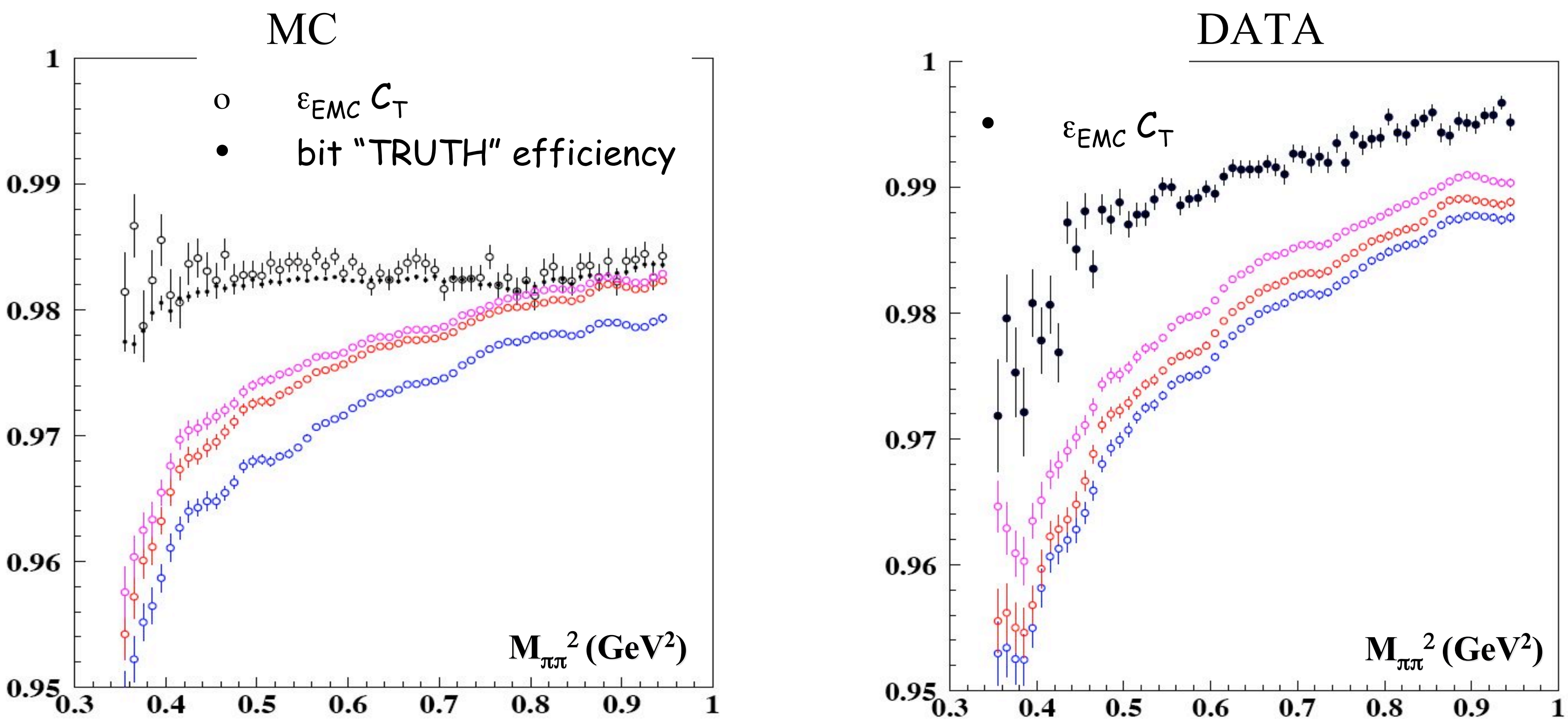
what's left over out of the 90 cm spheres?

photons (π^0)

fragments



From the last KGM



- R=90 cm sphere + photons + "fragments"
- R=90 cm sphere + photons
- R=90 cm sphere

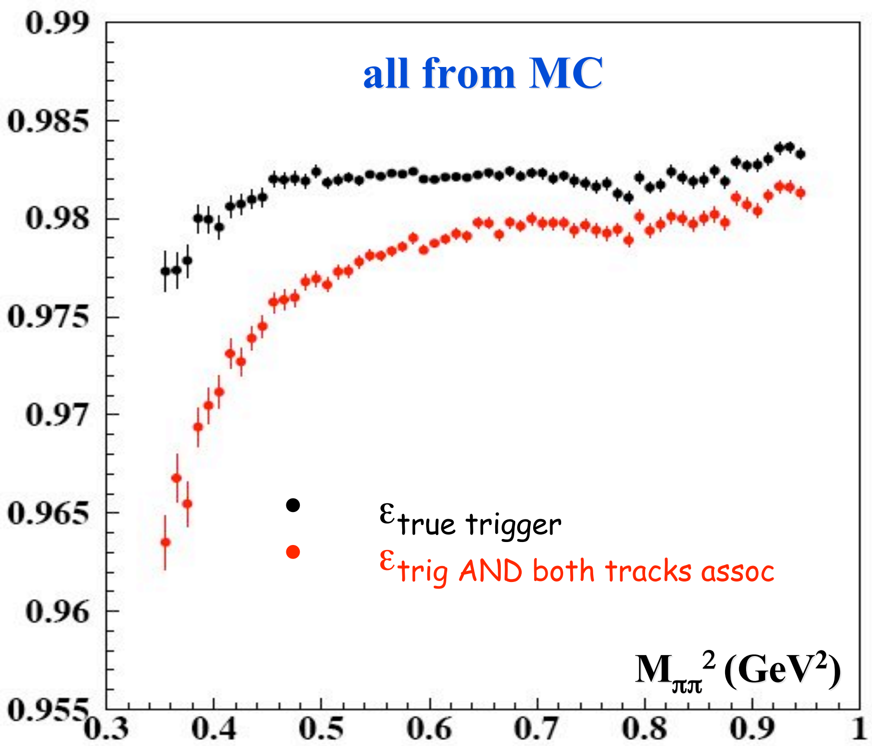
colour plots from single particle method

Checking single particle probabilities

if $P_{+,-,r}(0,1,2)$=probability for the π^+, π^- or the rest of firing 0,1,2 trigger sectors,

found a concept bug: probability not conditioned on the presence of the cluster,

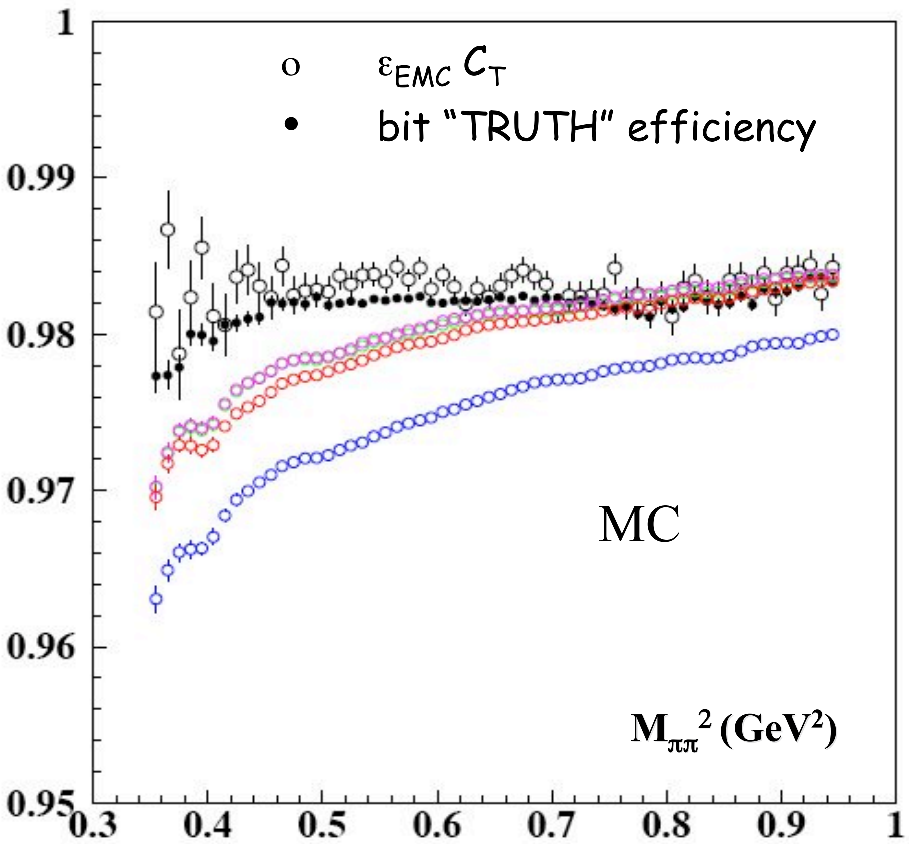
ex.: **P_+(1 sector ∩ 1 cluster)** instead of **P_+(1 sector | 1 cluster)**

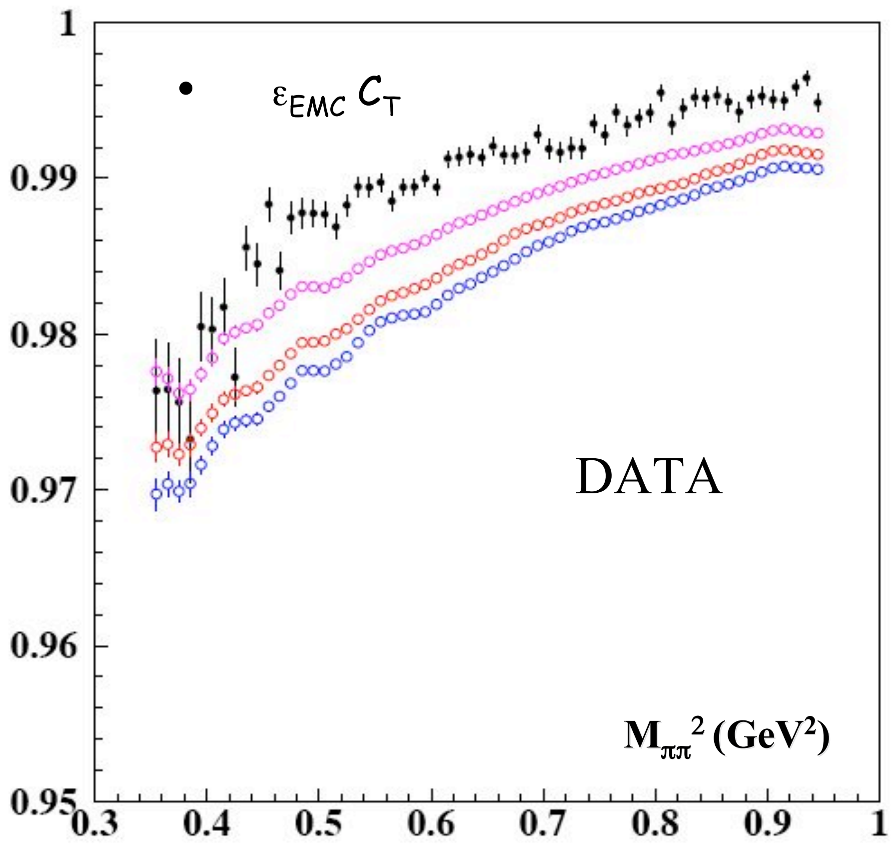


I reproduced the slope at low $M_{\pi\pi}$ values requiring the probability to trigger AND both tracks to have a cluster

decrease the trigger efficiency for the probability to reach the calorimeter (lower at lower $M_{\pi\pi}$)

Now it is better…





- R=90 cm sphere + photons + "fragments"
- R=90 cm sphere + photons
- R=90 cm sphere

colour plots from single particle method

Towards an uncertainty estimate

why keep separated DATA and MC for the trigger?

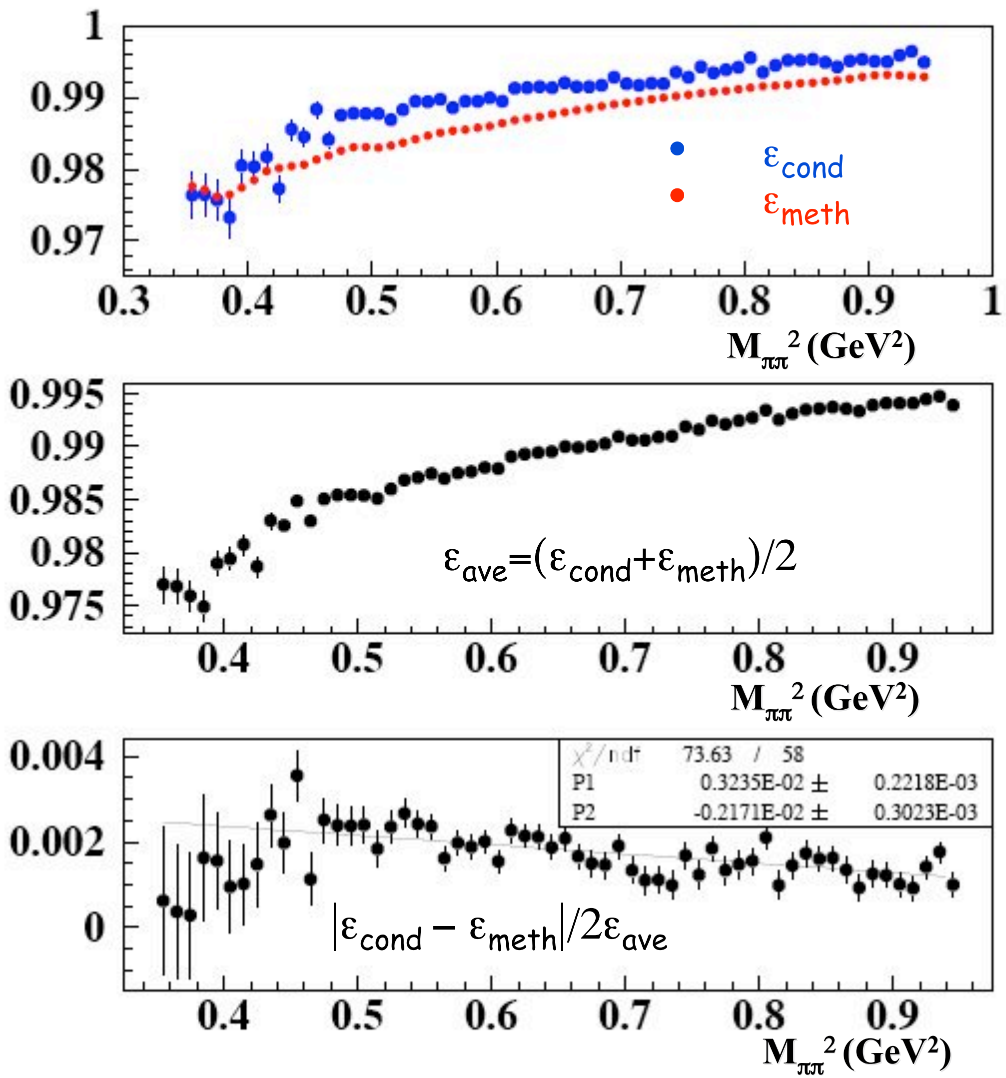
1) accidental clusters different by a factor ~ 2 (see Martini-Miscetti studies)
2) different $\pi^{\pm} N \to \pi^0 X$ cross section in the calorimeter (see my slides @ kgm65)
3) …other than different genuine trigger response

for a systematic error well below 1%, 2 independent methods from data is the preferred way

$\varepsilon_{cond} = \varepsilon_{EMC}^{trg} C_T$ (DC-EMC corr.)

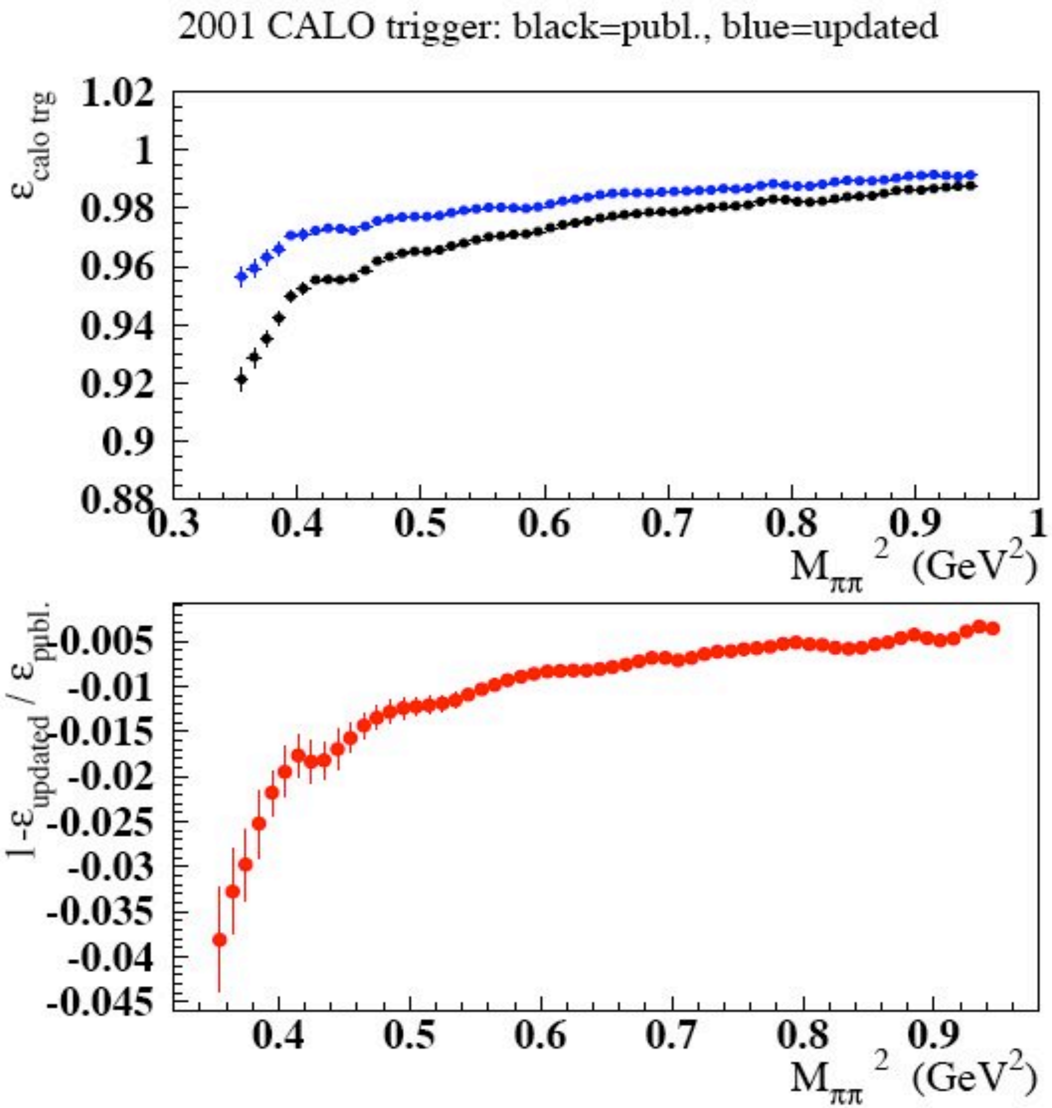
ε_{meth}: photons and "fragments" included

both blue and red curves are from data

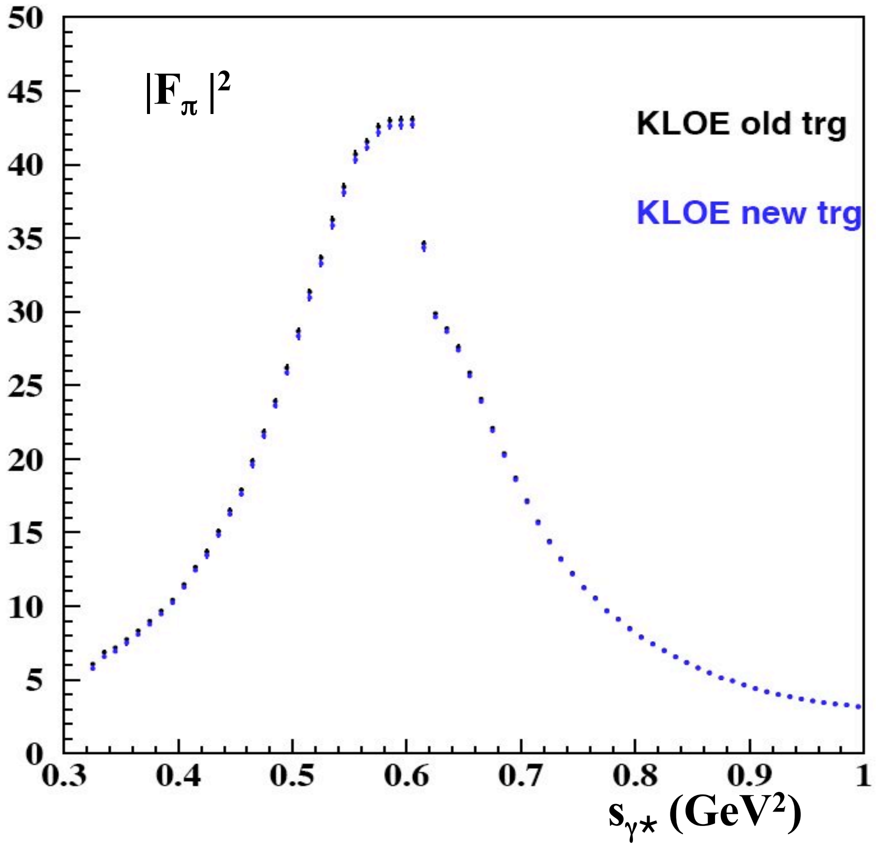


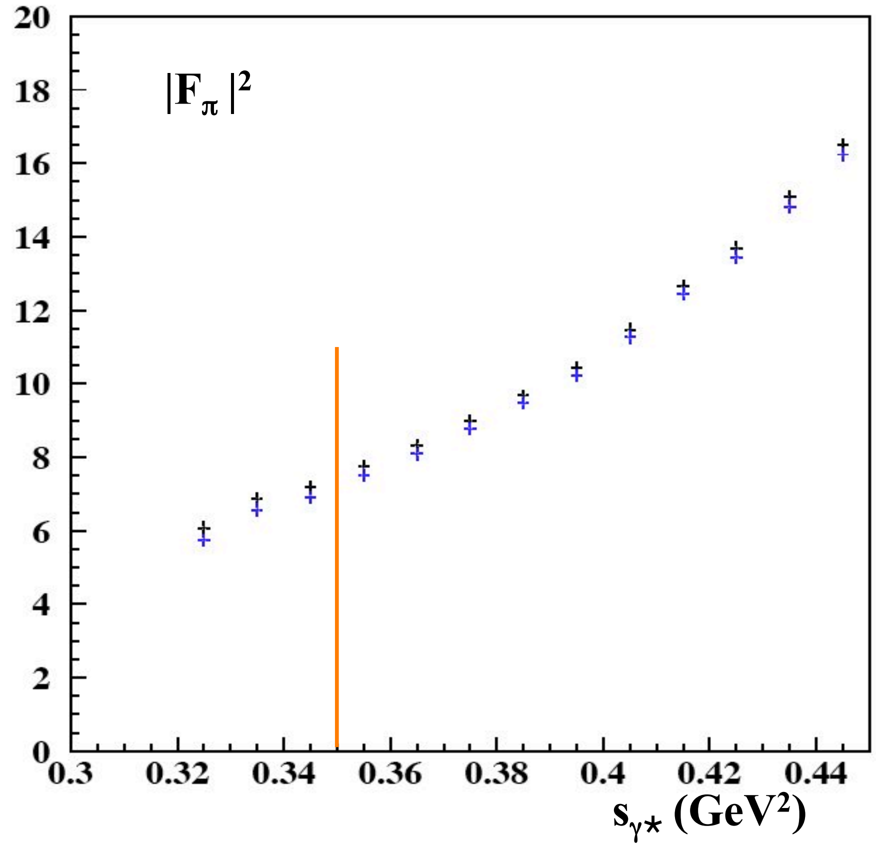
Revising 2001 trigger efficiency

I tried to fix the bug in old 2001 fashioned dst's (old FILFO, old ppgtag, Cosmic Veto…) and to estimate an efficiency a` la published way to be compared with that obtained with the same prescription of the previous slides



Possible impact on 2001 F_π





DC trigger studies

define

$$\varepsilon_{\text{Rel}} = \frac{N_{DC}}{N_{TRG}}$$

$$= \varepsilon_{DC} \frac{\cancel{N}_{TOT}}{\cancel{N}_{TOT}(1 - N_{FAIL}/N_{TOT})}$$

provided 2 tracks to reach the barrel (50° < θ < 130°) and with quite high (p > 200 MeV) mom.

we assume DC trigger does not care if pions or muons

we expect the overall trigger inefficiency N_{fail}/N_{tot} ~ 1%-4%

$$\frac{\varepsilon_{\text{Rel}}^{\pi\pi\gamma}}{\varepsilon_{\text{Rel}}^{\mu\mu\gamma}} = \frac{\varepsilon_{DC}^{\pi\pi\gamma}}{\varepsilon_{DC}^{\mu\mu\gamma}} \left(1 + \left.\frac{N_{FAIL}}{N_{TOT}}\right|_{\pi\pi\gamma} - \left.\frac{N_{FAIL}}{N_{TOT}}\right|_{\mu\mu\gamma} + \cancel{O\left[\left(\frac{N_{FAIL}}{N_{TOT}}\right)^2\right]} \right)$$

assumed 1

difference from 1 is checked in the following

Relative efficiencies from data

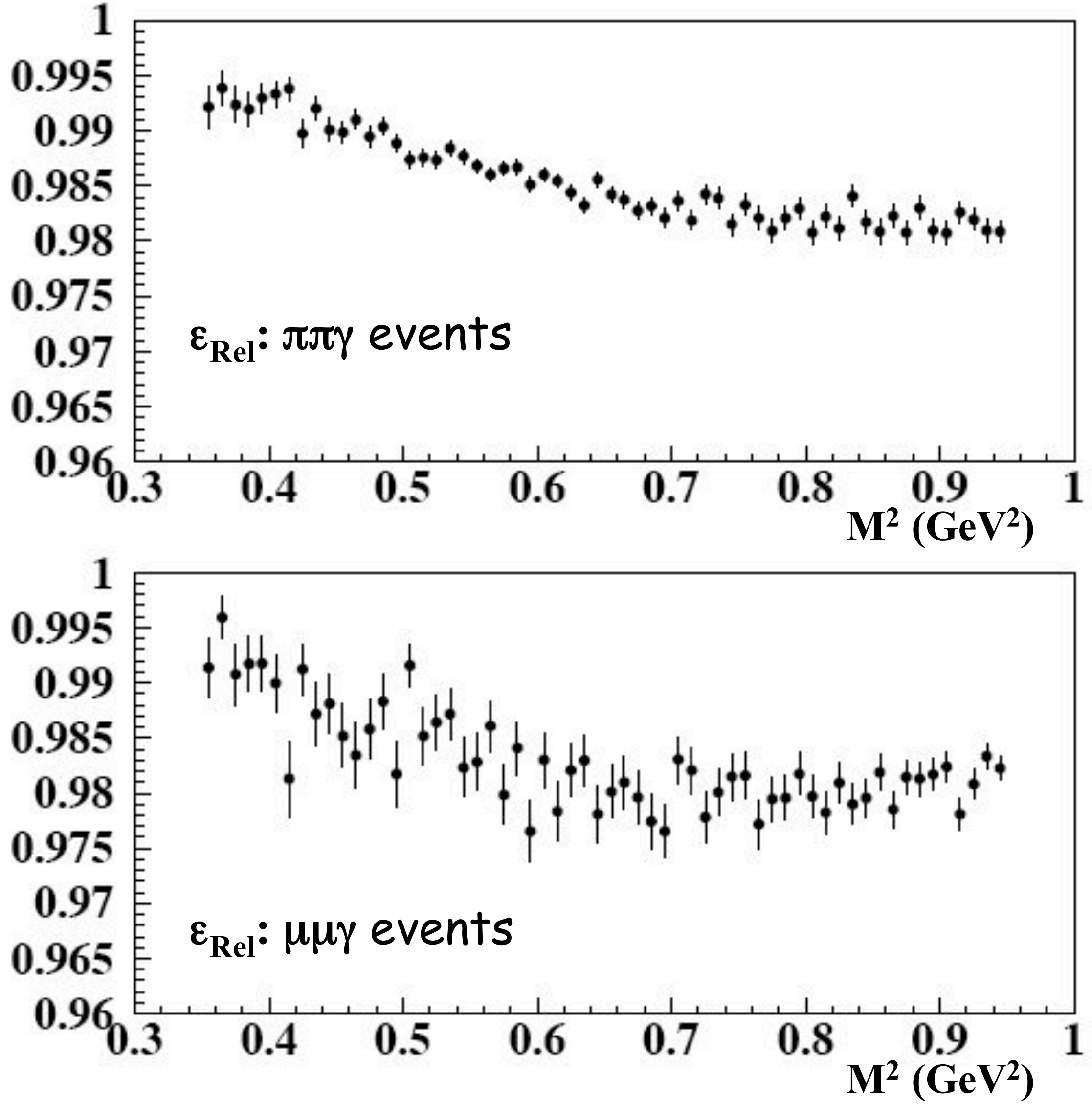
idea developed from several discussions with M. Incagli

usual small angle selection

from PPG dst's

Low momentum ⇒ lower radius ⇒ higher n. of hit DC superlayers

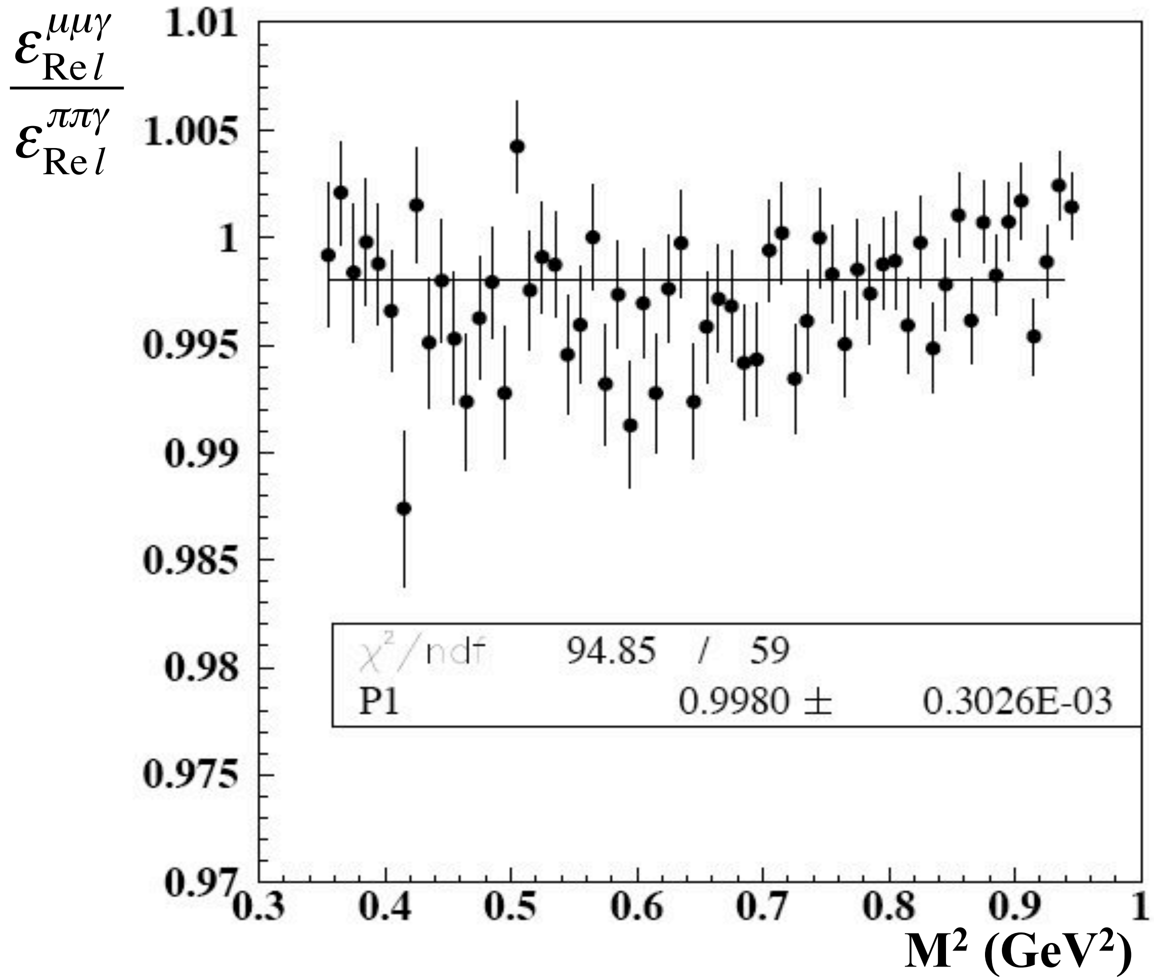
not an absolute scale to compare with CALO trigger!!!



Final correction is nearly 1

$$\frac{\varepsilon_{\mathrm{Rel}}^{\pi\pi\gamma}}{\varepsilon_{\mathrm{Rel}}^{\mu\mu\gamma}} \approx \frac{\varepsilon_{DC}^{\pi\pi\gamma}}{\varepsilon_{DC}^{\mu\mu\gamma}}$$ within 0.2%

at the moment we use it only as in the following check



A couple of steps further on

if the trigger type is marginally correlated with background

or other reconstruction efficiencies:

$$\frac{N^{dc}_{\pi\pi\gamma}}{N^{dc}_{\mu\mu\gamma}}\frac{\varepsilon^{dc}_{\mu\mu\gamma}}{\varepsilon^{dc}_{\pi\pi\gamma}} \approx \frac{N^{calo}_{\pi\pi\gamma}}{N^{calo}_{\mu\mu\gamma}}\frac{\varepsilon^{calo}_{\mu\mu\gamma}}{\varepsilon^{calo}_{\pi\pi\gamma}}$$

$N^{calo}_{\pi\pi\gamma}$ = ππγ data selected with CALO trg

$N^{calo}_{\mu\mu\gamma}$ = μμγ data selected with CALO trg

$N^{dc}_{\pi\pi\gamma}$ = ππγ data selected with DC trg

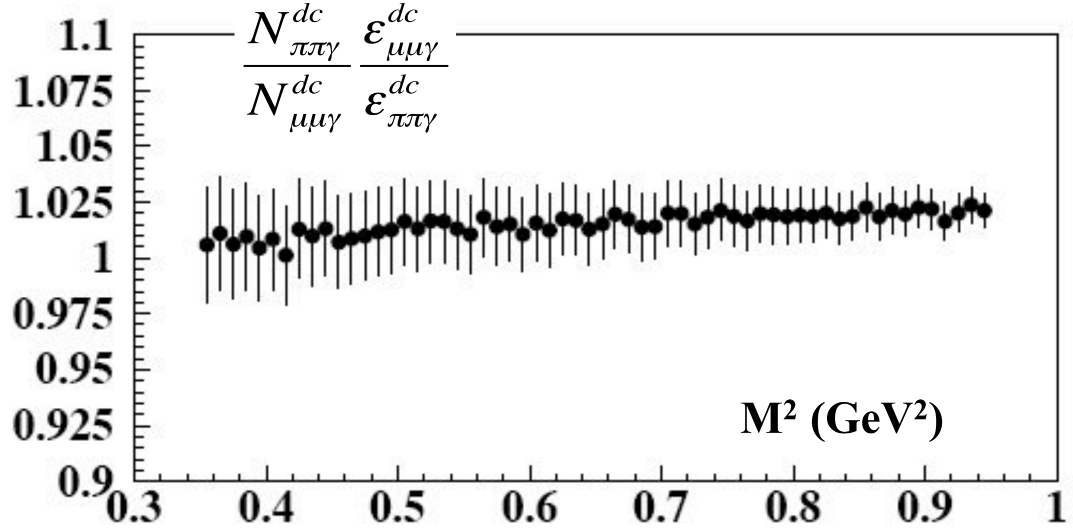
$N^{dc}_{\mu\mu\gamma}$ = μμγ data selected with DC trg

$\varepsilon^{calo}_{\pi\pi\gamma}$ = ππγ absolute CALO trg efficiency

$\varepsilon^{calo}_{\mu\mu\gamma}$ = μμγ absolute CALO trg efficiency

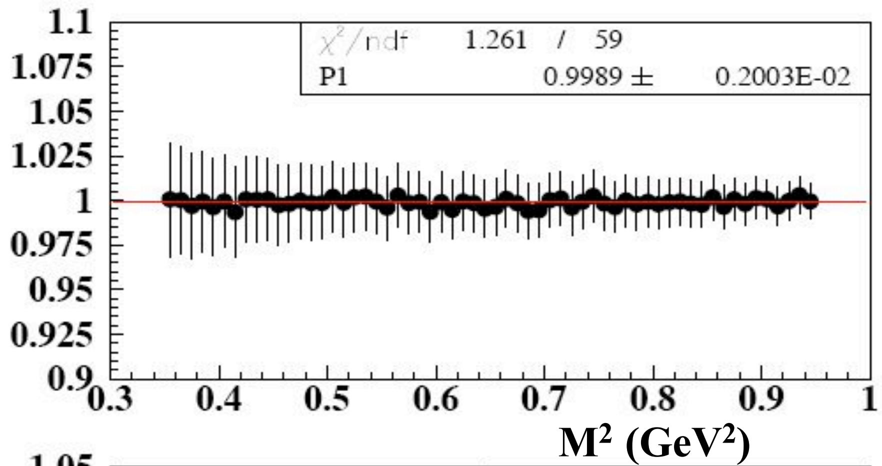
$\varepsilon^{dc}_{\pi\pi\gamma}$ = ππγ relative DC trg efficiency

$\varepsilon^{dc}_{\mu\mu\gamma}$ = μμγ relative DC trg efficiency



Checks allowed by the ratio

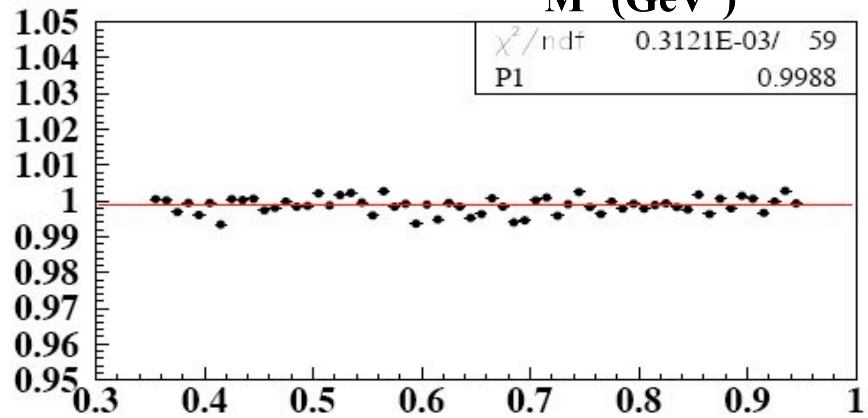
$$\frac{N^{dc}_{\pi\pi\gamma}}{N^{dc}_{\mu\mu\gamma}}\frac{\varepsilon^{dc}_{\mu\mu\gamma}}{\varepsilon^{dc}_{\pi\pi\gamma}} \Bigg/ \frac{N^{calo}_{\pi\pi\gamma}}{N^{calo}_{\mu\mu\gamma}}\frac{\varepsilon^{calo}_{\mu\mu\gamma}}{\varepsilon^{calo}_{\pi\pi\gamma}}$$



to extremely check the alignment,

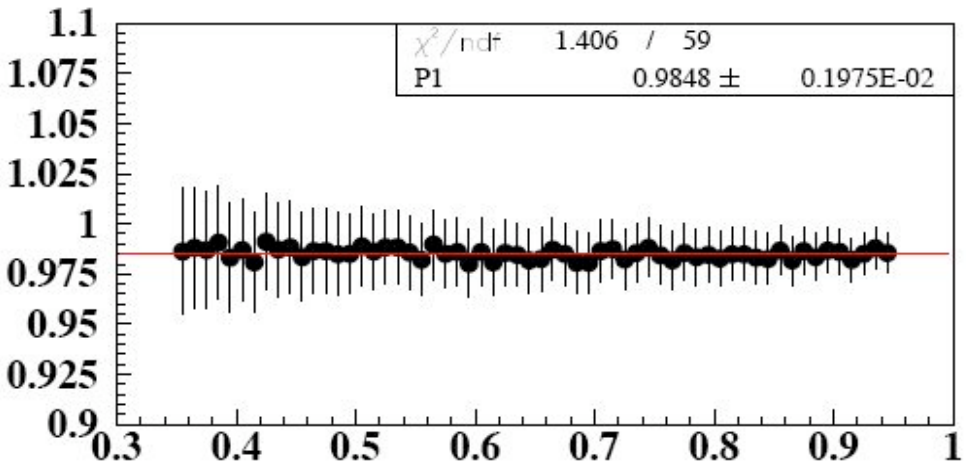
below is the same plot, fitted

without considering the errors,



what if I took a CALO trigger $\pi\pi\gamma$

efficiency different by 1.5-2%?



Partial conclusions

1) Systematic uncertainties have been assessed for both CALO and DC trigger issues
2) Revision of the 2001 trigger correction is done
3) At the moment the accuracy is (conservatively) below 0.5%

Master formula for the ratio

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

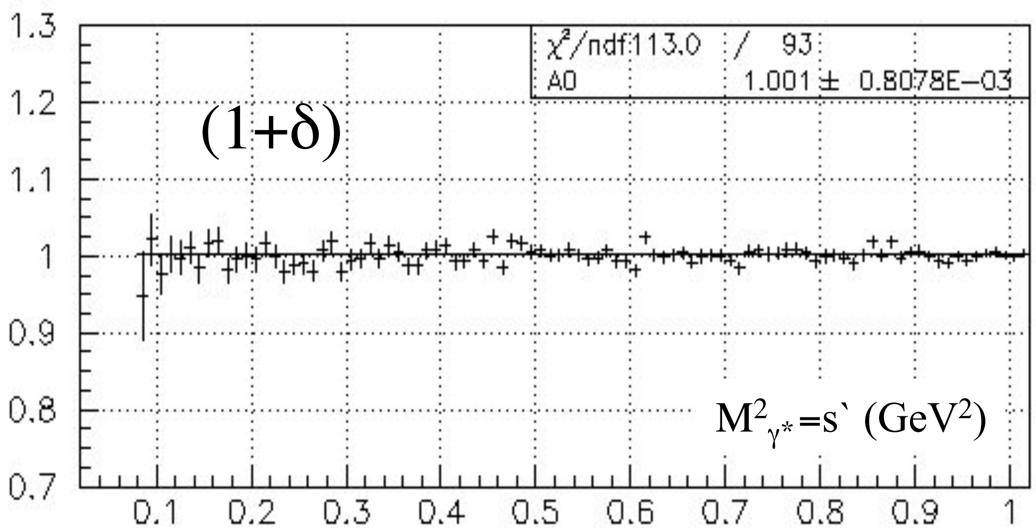
is exact only in the absence of FSR

in fact

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

corr. due to FSR

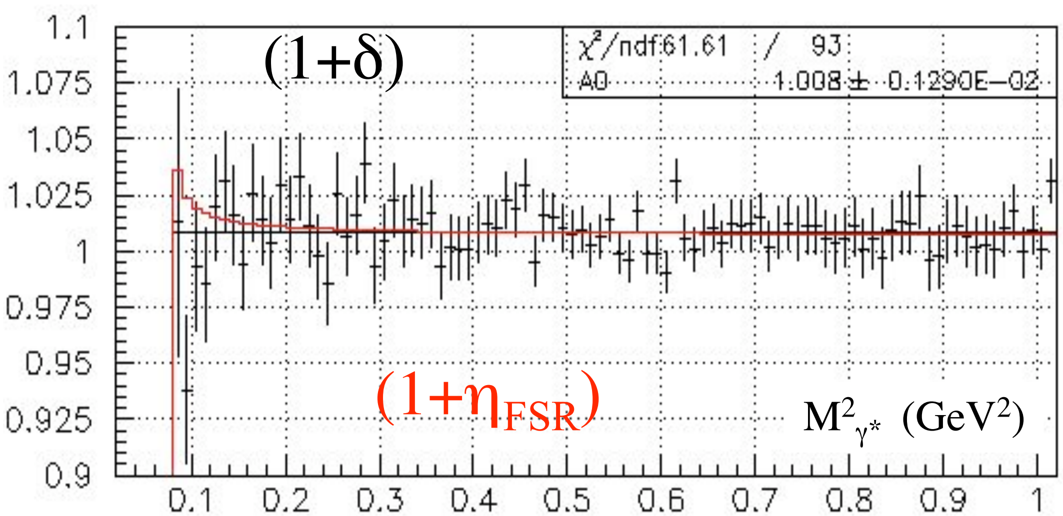
in principle: measured cross sections
for tests: MC generated ones



As expected, δ=0 for ISR only
Radiator function is independent of final state and cancels out exactly.

Accounting for FSR effects in the ratio

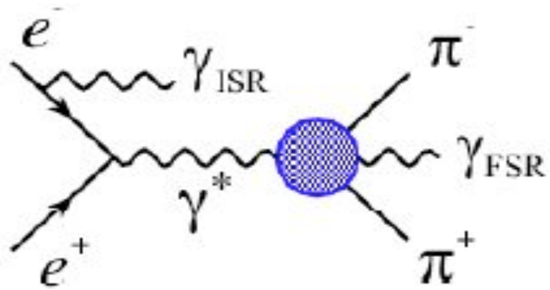
MC: ππγ ISR + FSR nlo („unshifted“) and μμγ



Dividing for $(1+\eta_{FSR})$ and fitting with a constant gives A0 = (1.000 ± 0.128E-02). Also here radiator cancels, leaving only FSR effects.

the idea is to rely on QED FSR corrections for μμγ events and extract F_π inclusive for ππγ FSR

$|F_\pi|^2 \cdot (1+\eta_{FSR})$ is the quantity to be put in the a_μ^{had} dispersion integral obtained directly from the ratio



$$|F_\pi(s')|^2 \cdot (1+\eta(s')) = \frac{4(1+2m_\mu^2/s')\beta_\mu}{\beta_\pi^3} \cdot \frac{\left(d\sigma_{\pi\pi\gamma}^{corr}(\theta^{\pi\pi} < 15^o)/ds'\right)}{\left(d\sigma_{\mu\mu\gamma}^{corr}(\theta^{\mu\mu} < 15^o)/ds'\right)} \cdot A(\theta^{I+FSR}/\theta^{ISR})$$

Roadmap

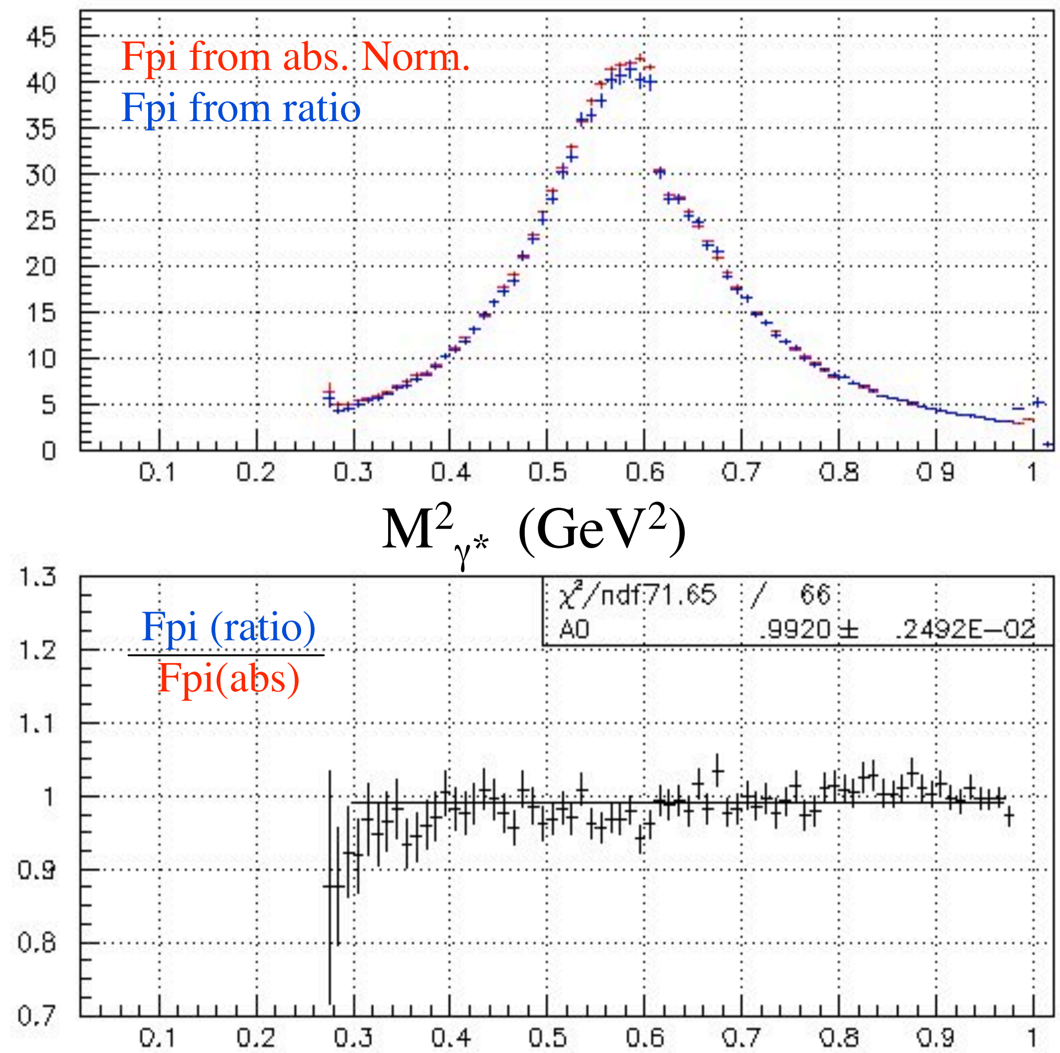
Filfo	from the prescaled events (unbiased vontrol sample) - syst. error is negligible	✓
Background	MC shapes fitted to data - small work on systematics to be done	(✓)
M_{Trk}, E_{Miss}	from MC re-weighted from data - cross check with data Distributions (optimize smearing) - check with UFO	(✓)
Trigger	Solid	✓
Vtx-Track(~ 0.6%)-Like	Up to now from MC, Agreement data-MC < 1%?? Use Neural Net for independent control samples.	
$Q^2_{Rec} \rightarrow Q^2_{Kine}$	From MC. Has to be revisited. Effect in ρ–ω Region.	
Acceptance	θ_π, p_T, p_z , θ . Data-MC comparison?	(✓)
Unshifting ($Q^2_{+-} \rightarrow Q^2_{\gamma*}$)	PHOKHARA_omega (only for pions!)	(✓)
Luminosity	VLAB. Eff. Cross section for 2002? New BABAYAGA?	(✓)
Radiator	Only for absolute measurement. (Cross check with muons).	✓

blue = estimated from MC

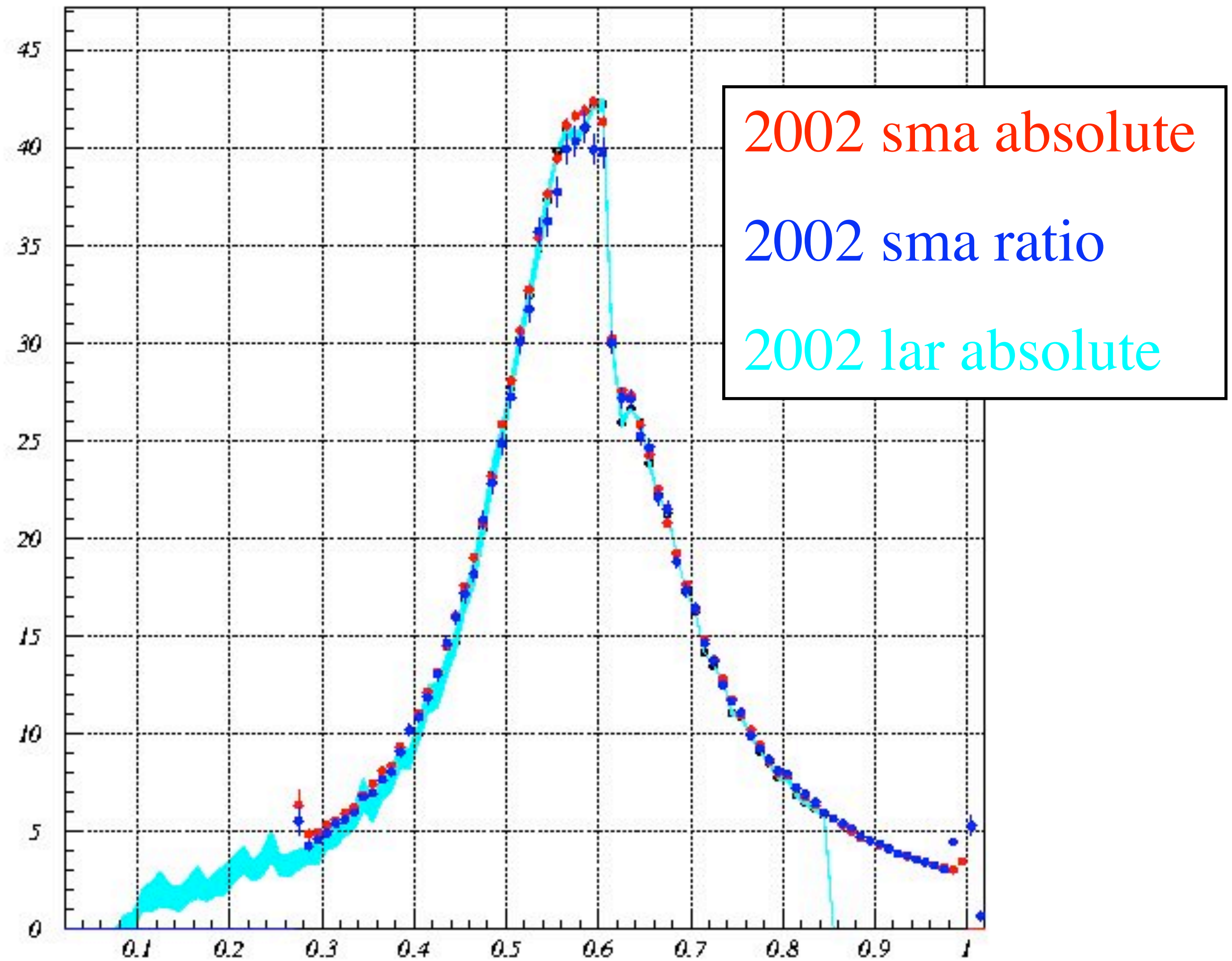
red = estimated from data

Extracting the form factor in 2 ways

$$\left|F_\pi(s')\right|^2 \propto \frac{1}{H \bullet VP}\left(d\sigma_{\pi\pi\gamma}/ds'\right)$$



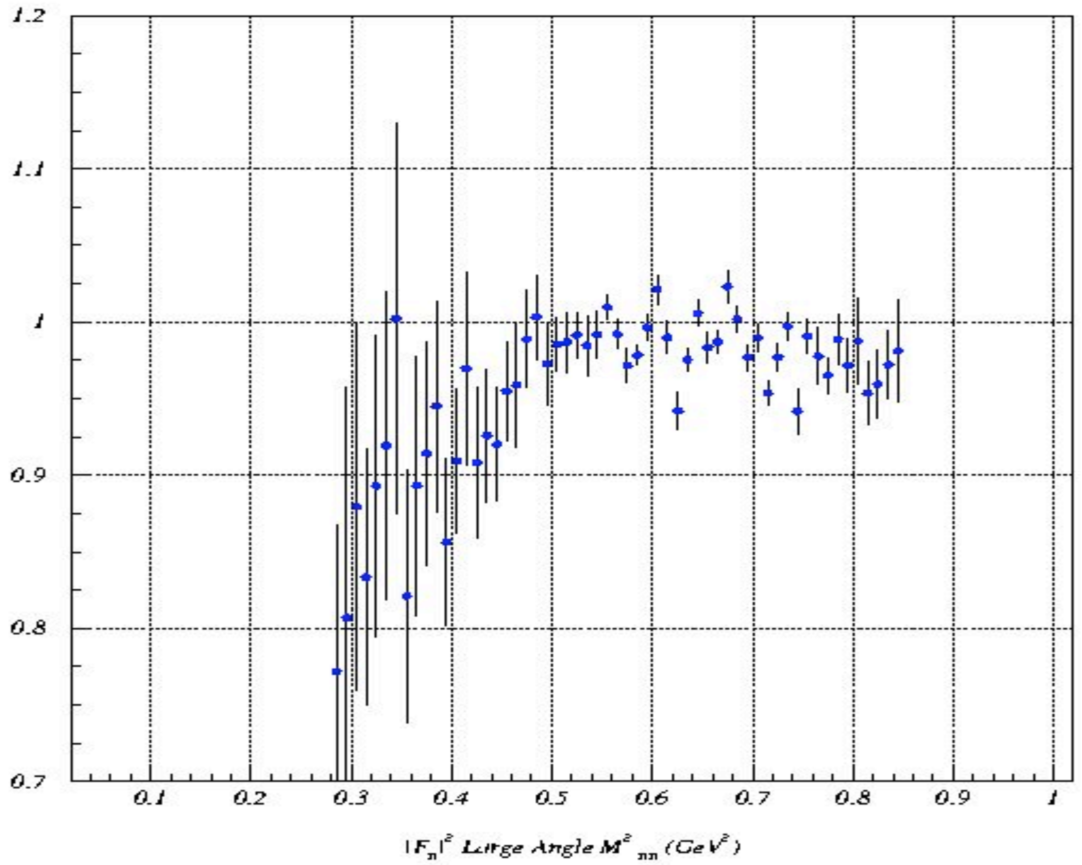
Comparisons of 2002 results



$|F_\pi|^2$ Large Angle $M^2_{\pi\pi}$ (GeV^2) $M^2_{\gamma^*}$ (GeV^2)

Relative comparison

2002 relative comparison SMA(abs) - LA(abs)



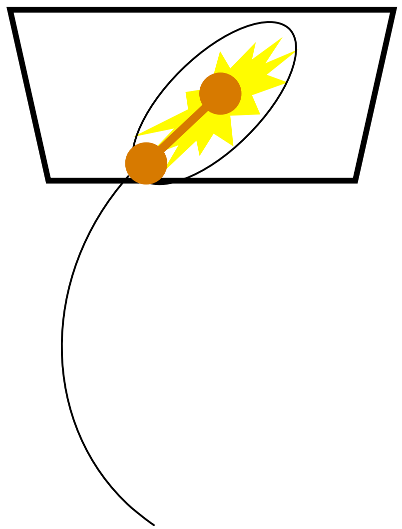
New tool

π/μ discrimination using Neural Network

- A clean sample of muons/pions useful for
  - Efficiencies
  - Background
- The idea is to discriminate pions/muons for single track, according to the different interaction with the calorimeter

Discriminant variables

- 4 discriminant variables were selected:
  - $V1 = E_{clu}/E_K(m_m)$
  - $V2 = |d_{clu}\text{-}d_{ext}|$
  - $V6 = b=L/cT_{clu}$
  - $V11 = dT=T_{CLU} - L_{TRK}E(m_m) /pc$

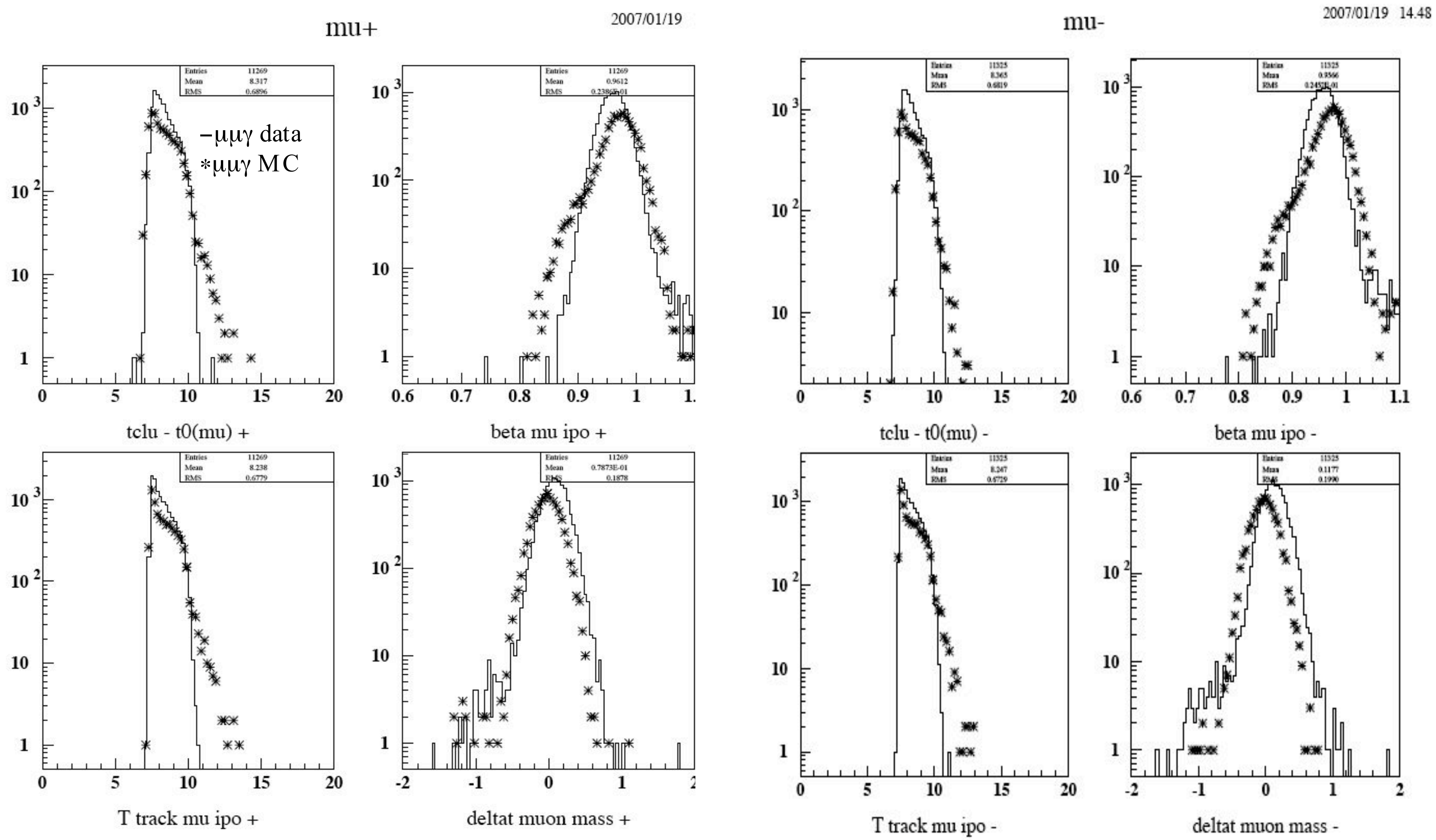


$L_{TRK}=L_{F.H.}+L_{D.C.}+L_{extp}+D_{clu}$

- The cluster is the most energetic associated to the track (within 60cm). Newextratom is used
- The track is required to satisfy the ppg acceptance:
  - 50<q<130, (PT>160 MeV *or* |PZ|>90 MeV)
  - r_{FH}<50cm, rhoP.C.A.<8cm,$|Z_{PCA}|$<7cm
- The vtx is not required (information from DTFS)

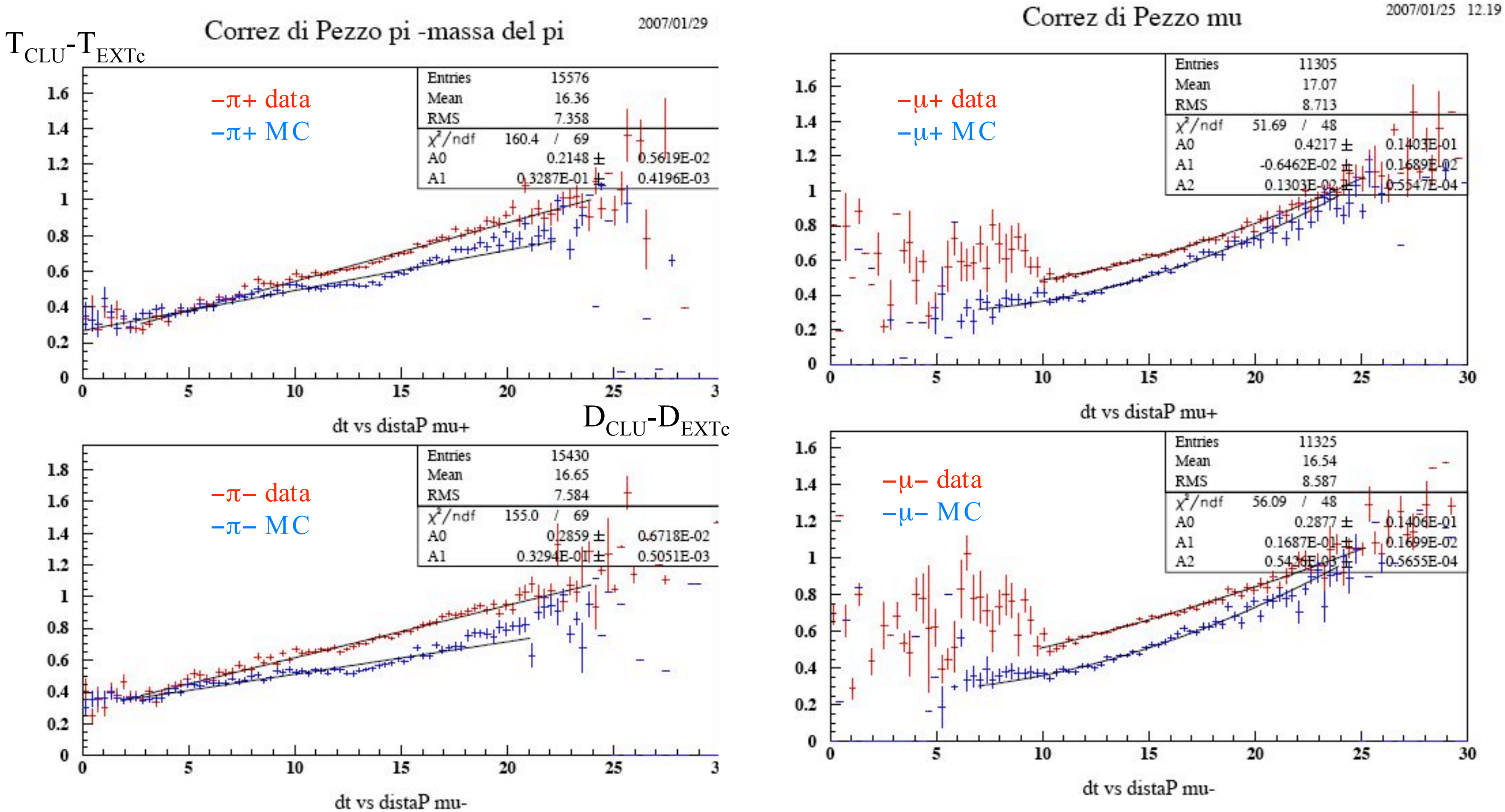
Condition on the candidate trk

Time distributions: data vs MC

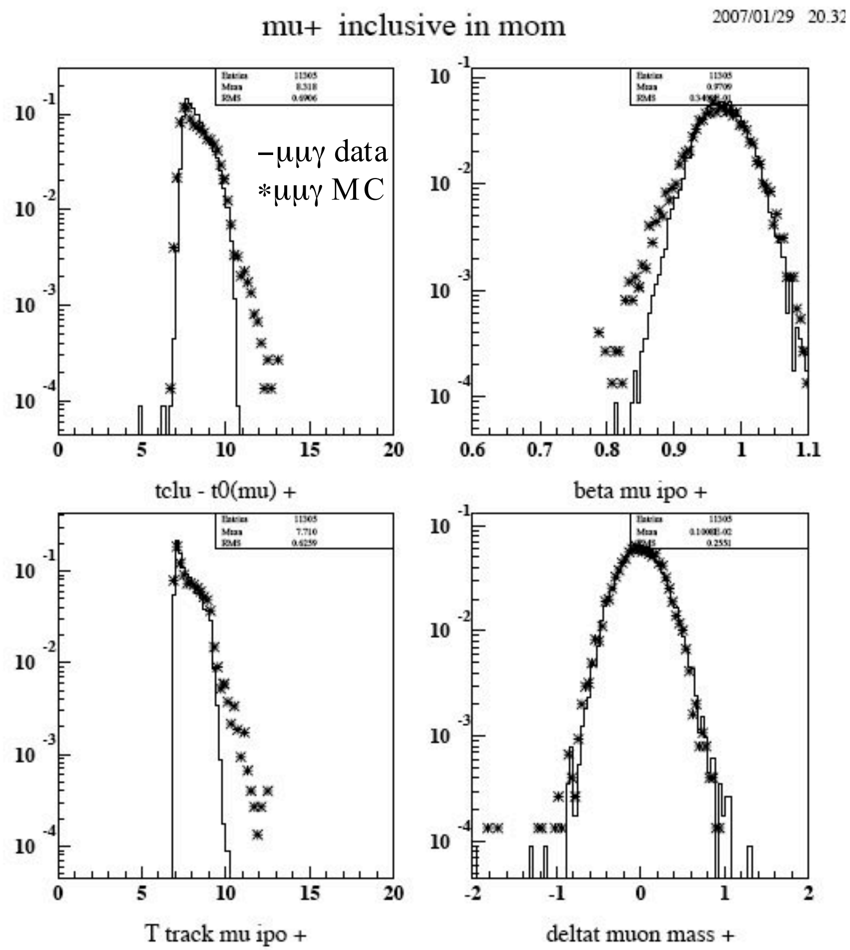


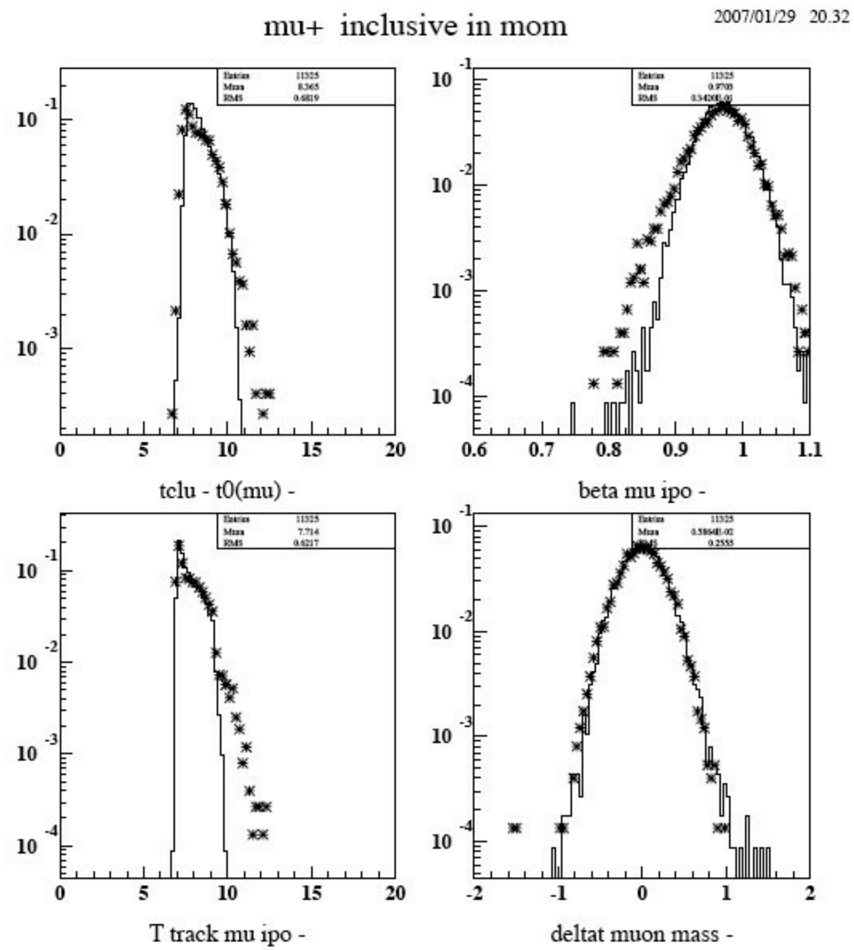
Time (pezzo) corrections

•We look at the time dependence in the EMC vs depth

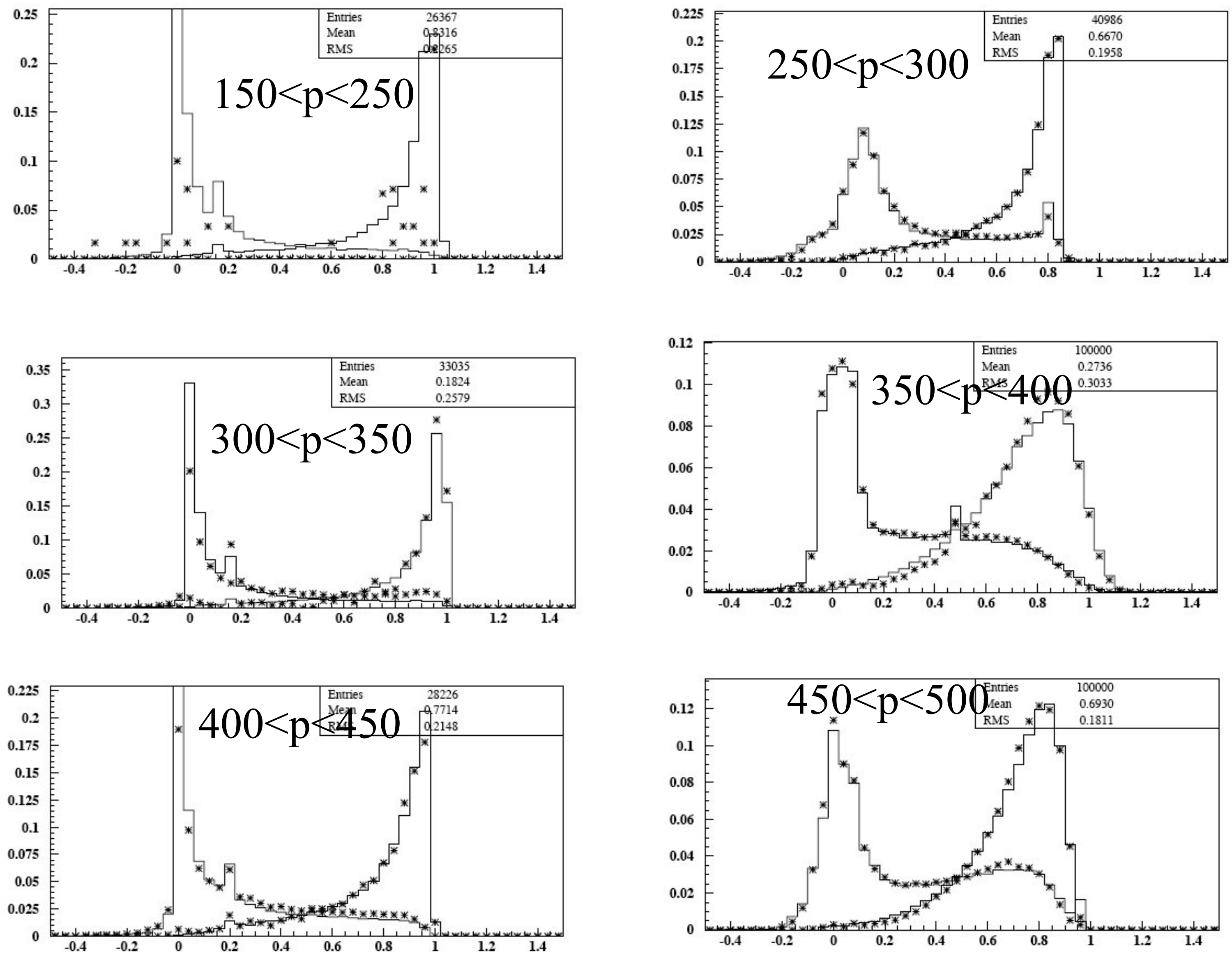


After corrections





NN output: positive track



Conclusions

1) both small angle analyses have reached an important point:

the form factor has been measured both in the absolute normalisation and the ratio.

2) estimate of some systematics are still missing and work is going on in this direction with use of new tools and exchanging ideas with large angle people

3) we expect only small corrections from the missing studies

The goal is to have results ready for the summer conferences

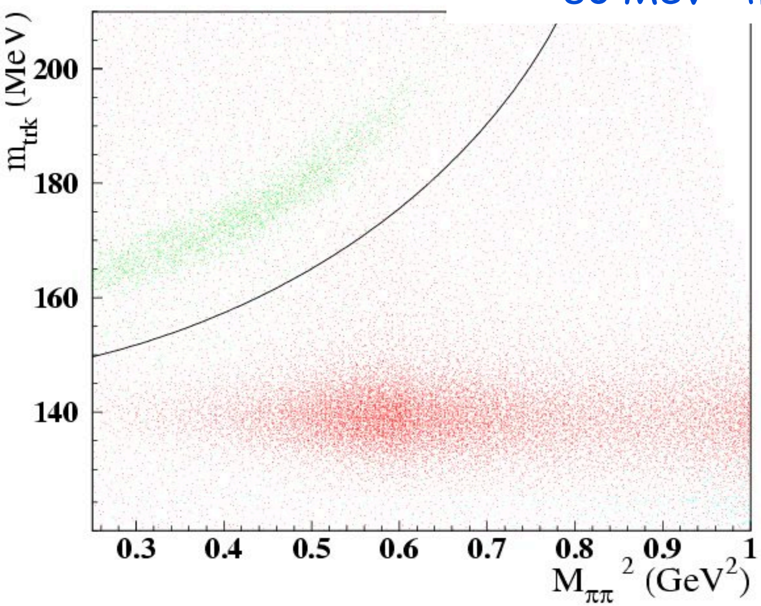
Selection steps: a reminder

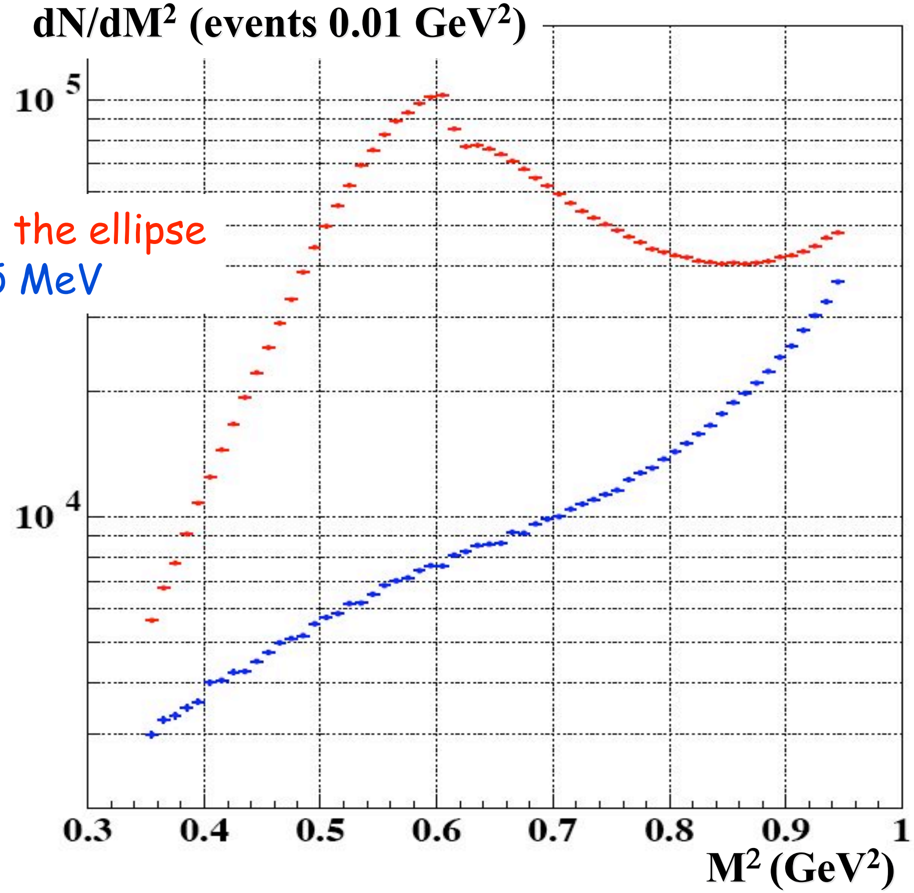
New FILFO
New PPGTAG
No Cosmic VETO

a) 1 vertex ($|z| < 7$ cm) connected to 2 and only 2 tracks
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 $\log L_\pi / L_e > 0$

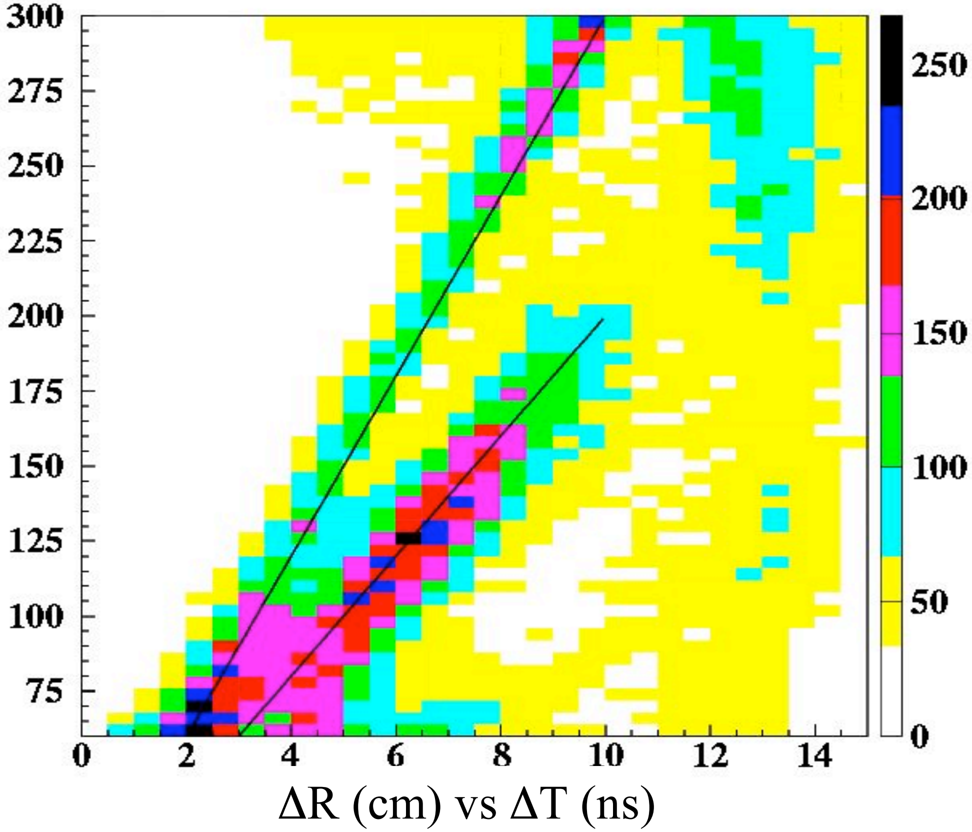
2002 data: $L = 242.6$ pb^{-1}

- $m_{trk} > 130$ MeV and the ellipse
- $80 \text{ MeV} < m_{trk} < 115$ MeV





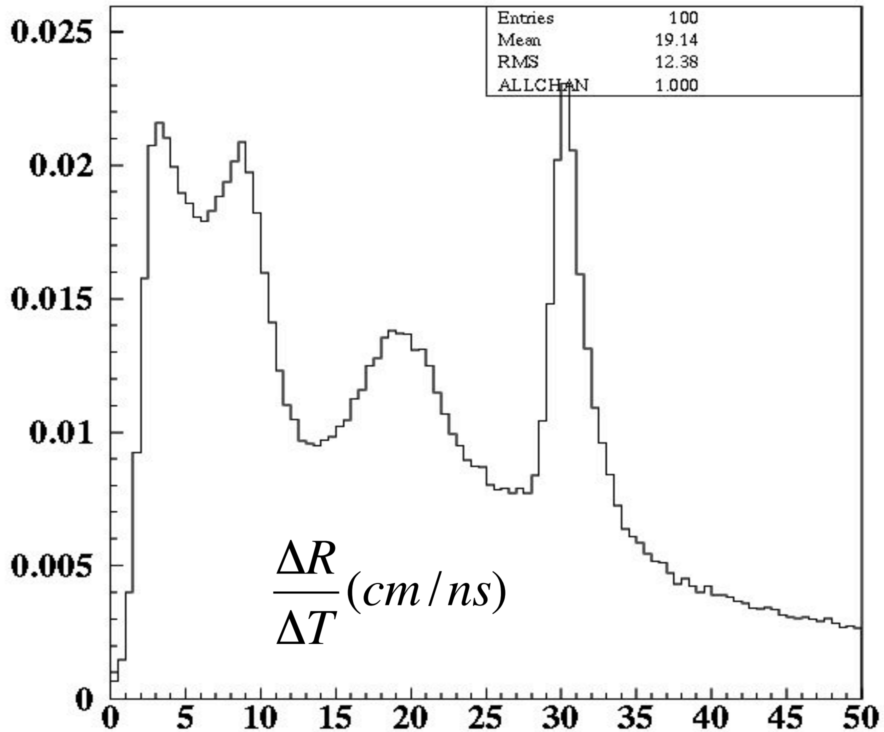
E>30 MeV clusters in the rest - MC (1)



$$\Delta R = |\vec{x}_{clu} - \vec{x}_{ext}|$$

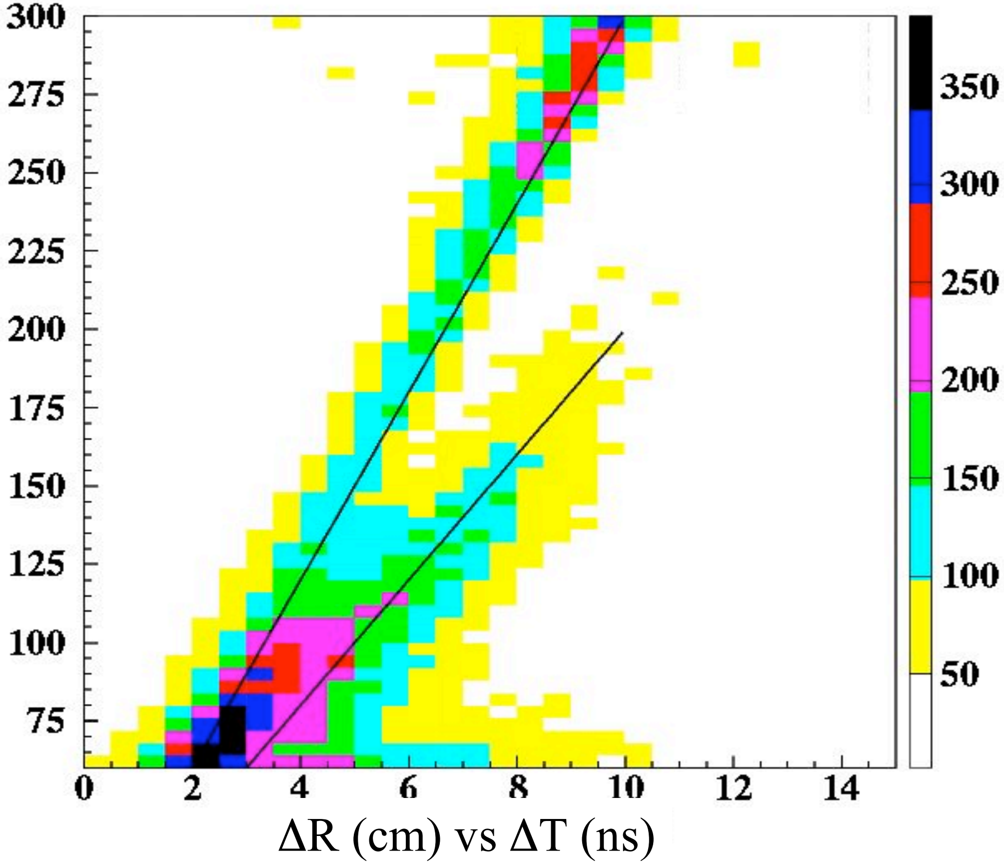
$$\Delta T = t_{clu} - t_{\max}$$

$\mathbf{t_{max}}$ = time of most energetic cluster within 60 cm from extrapolated point



2. the rest is correlated with both pions

E>30 MeV clusters in the rest - MC (2)



$$\Delta R = |\vec{x}_{clu} - \vec{x}_{ext}|$$

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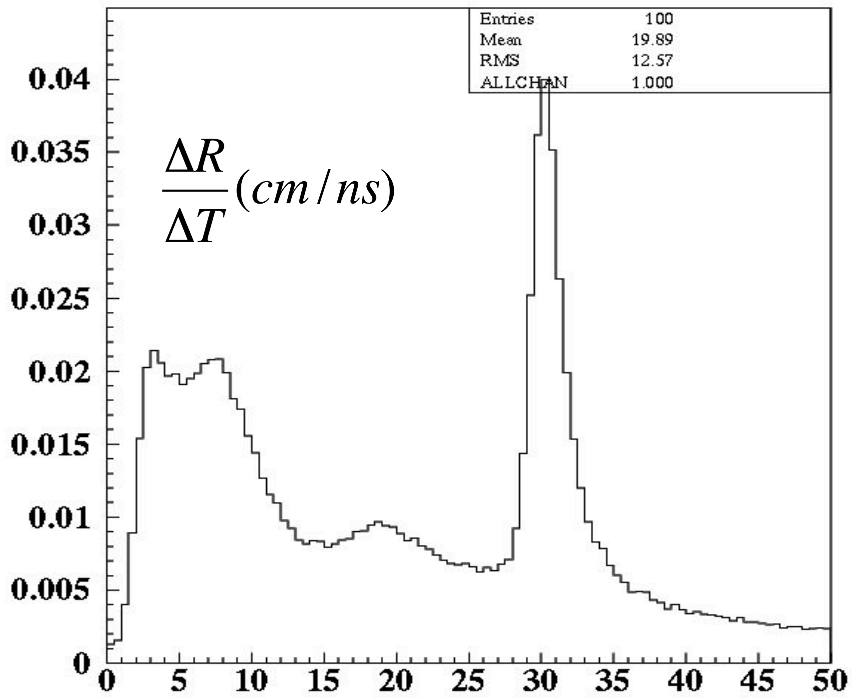
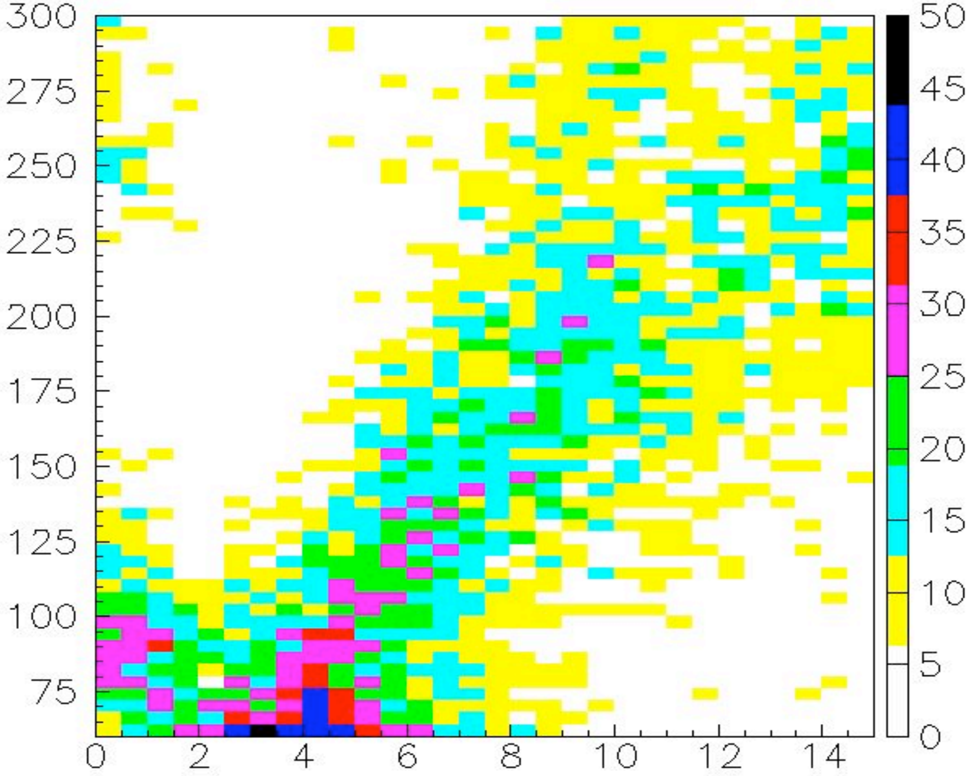
t_{max} = time of most energetic cluster within 60 cm from extrapolated point



message: association radius better be increased to 90 cm

E>30 MeV clusters in the rest - data (1)

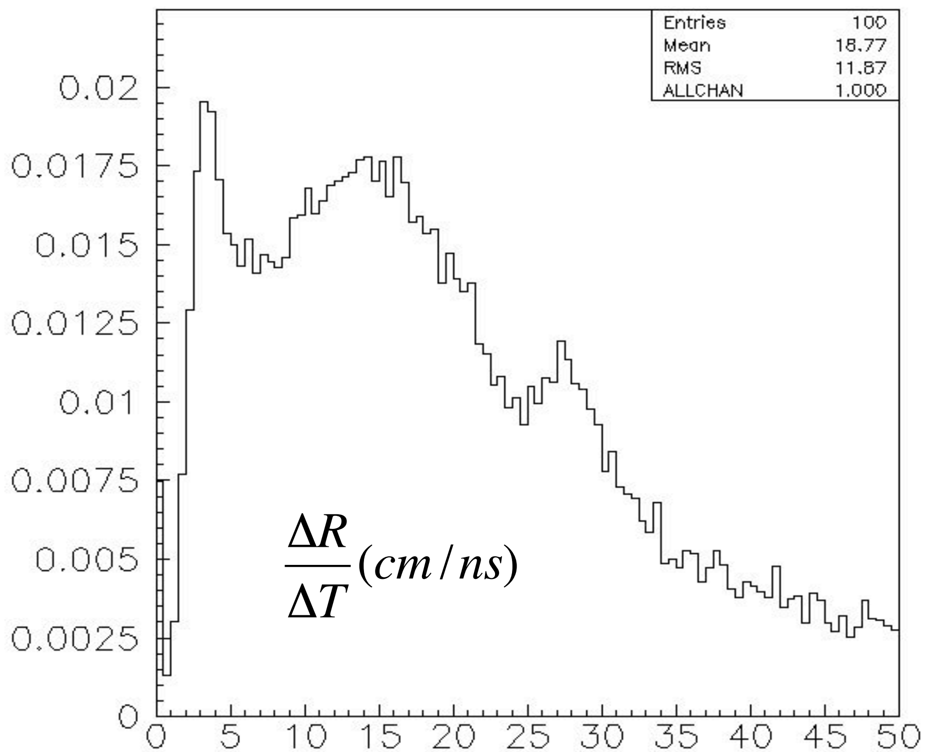


ΔR (cm) vs ΔT (ns)

$$\Delta R = |\vec{x}_{clu} - \vec{x}_{ext}|$$

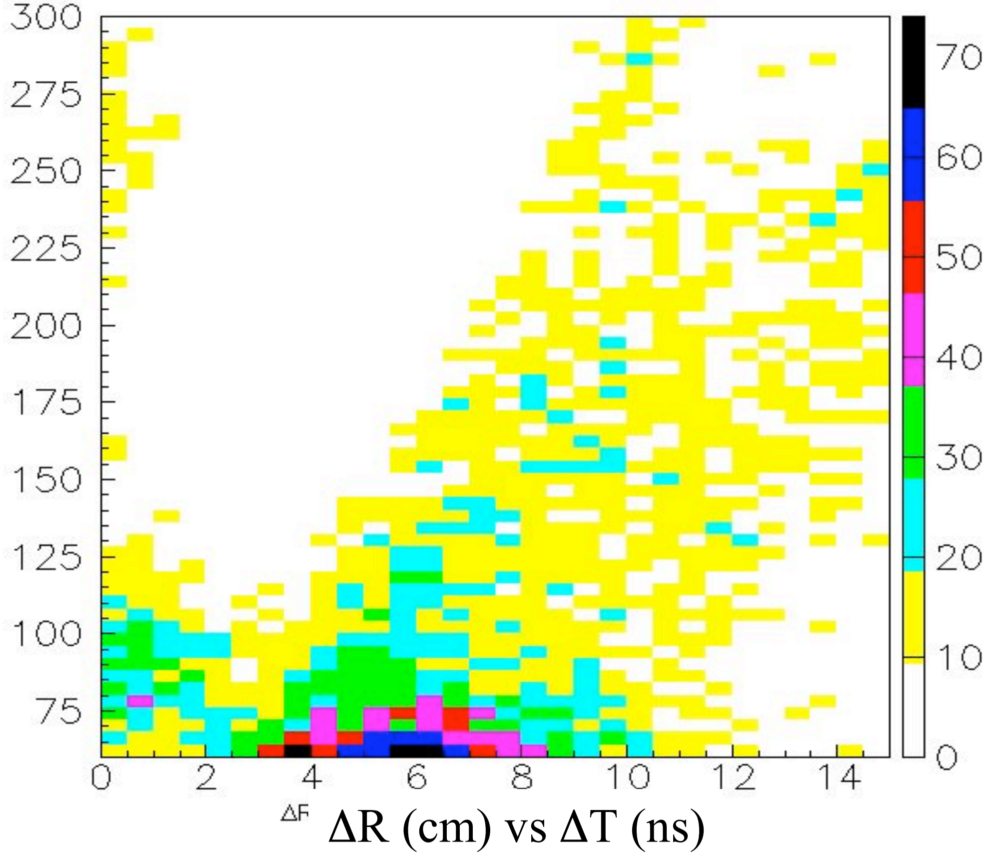
$$\Delta T = t_{clu} - t_{\max}$$

$\mathbf{t_{max}}$ = time of most energetic cluster within 60 cm from extrapolated point



3. impact from photons much less relevant in real life

E>30 MeV clusters in the rest - data (2)



$$\Delta R = |\vec{x}_{clu} - \vec{x}_{ext}|$$

$$\Delta T = t_{clu} - t_{max}$$

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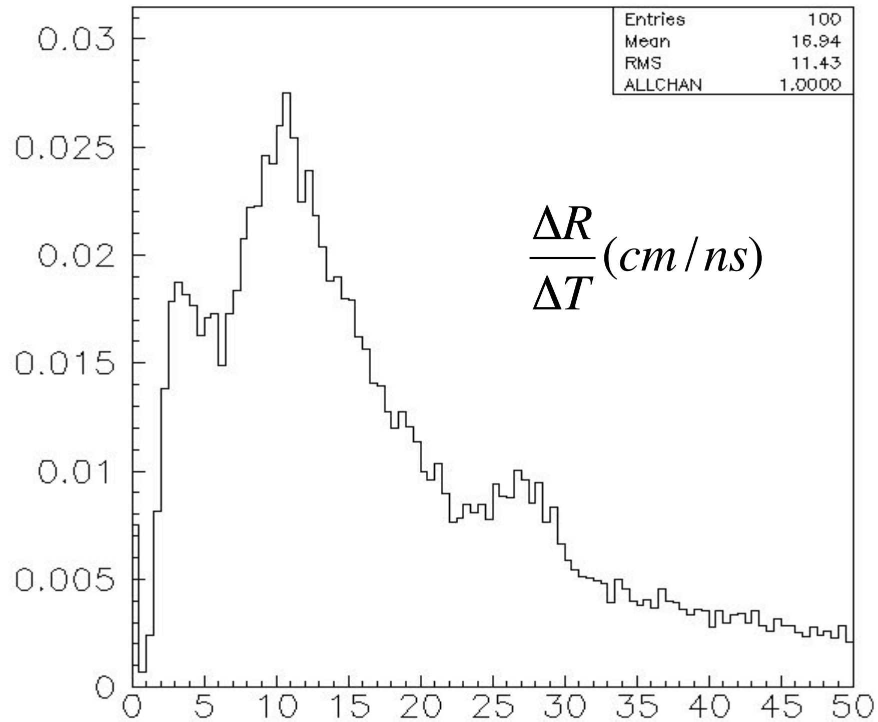
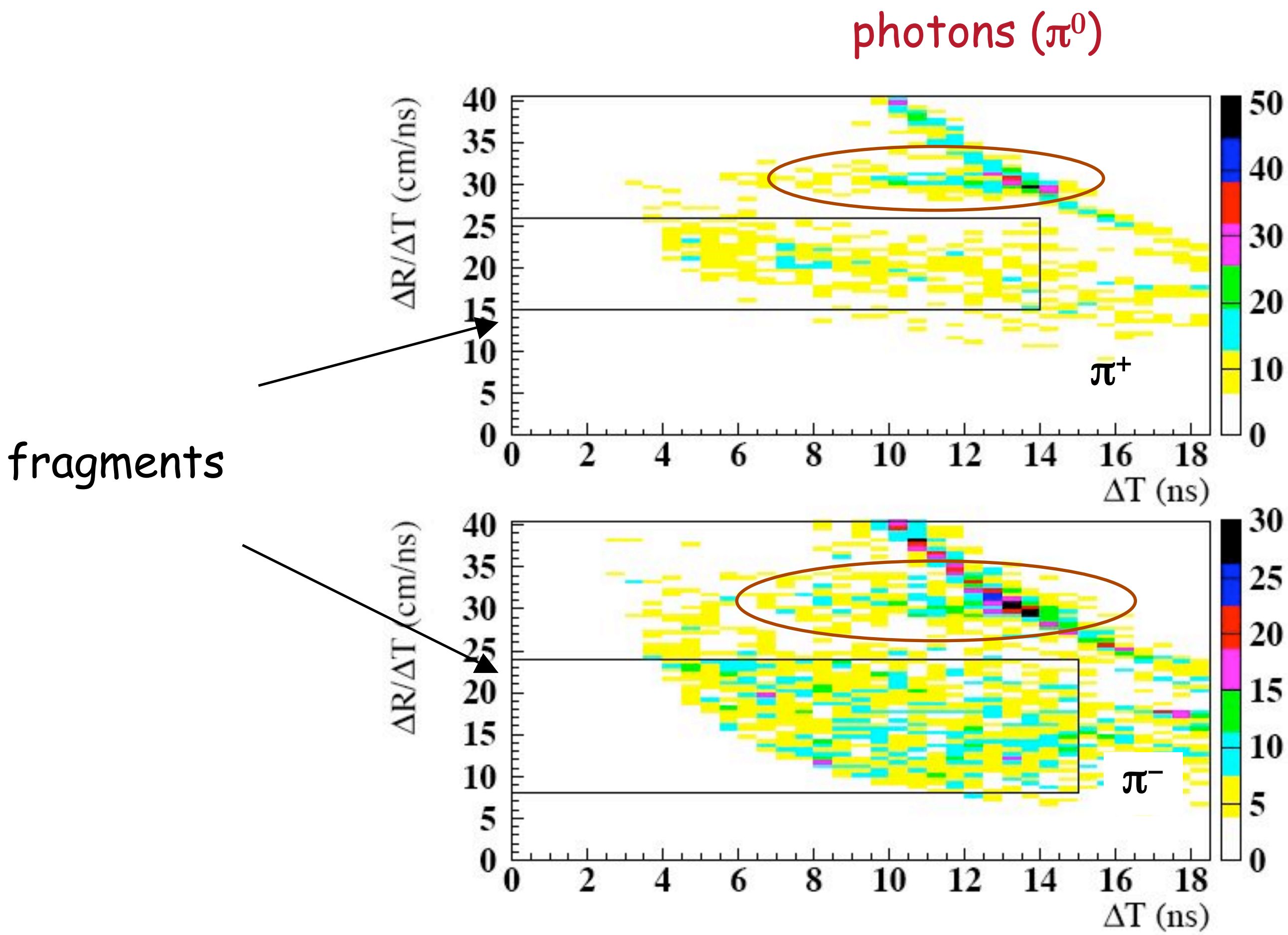


Assessed re-assignment

what's left over out of the 90 cm spheres?



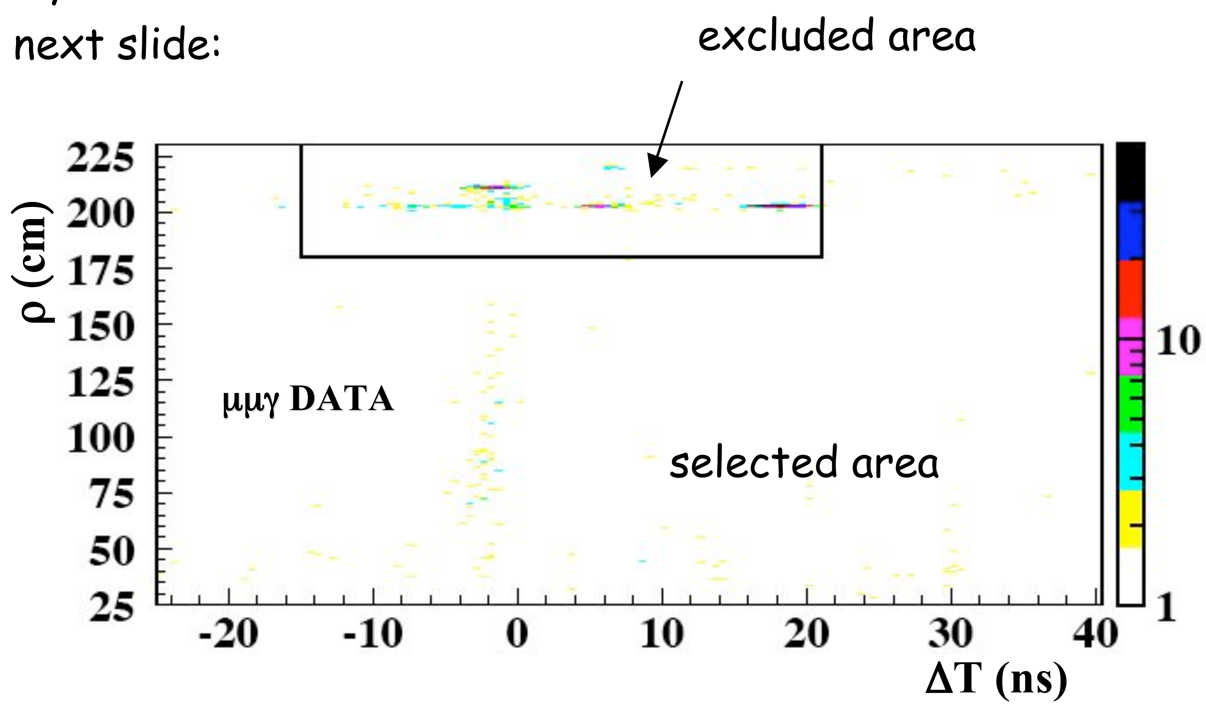
Correct identification of the rest (I)

our analysis: track polar angles must be directed on CALO barrel only, so End Cap clusters are good candidates for the rest of the event, namely accidentals or photons uncorrelated with charged particles

the following requirements to identify clusters of the rest are applied in OR with those in the next slide:

$$\rho = \sqrt{x_{clu}^2 + y_{clu}^2}$$

1. $\rho < 180$ cm, OR
2. $|\Delta T - 2.5 \text{ ns}| > 20$ ns



Correct identification of the rest (II)