UNIVERSITY OF LIVERPOOL

LEVERHULME TRUST

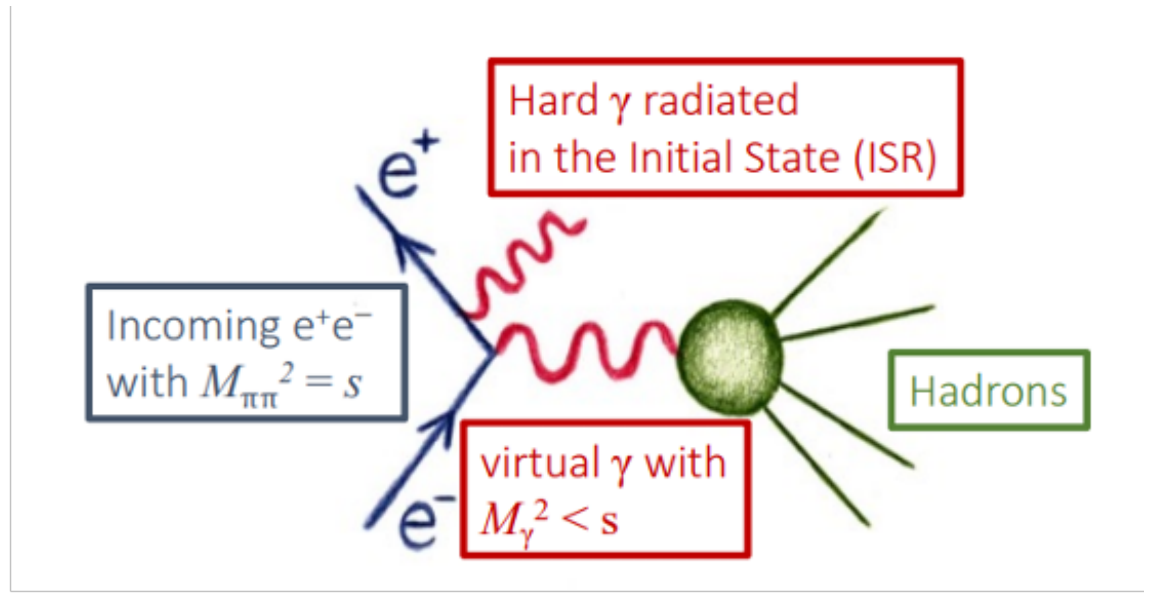
*Muon meeting- February 2025*

# Status Report on the KLOE $\pi\pi\gamma/\mu\mu\gamma$ Analysis

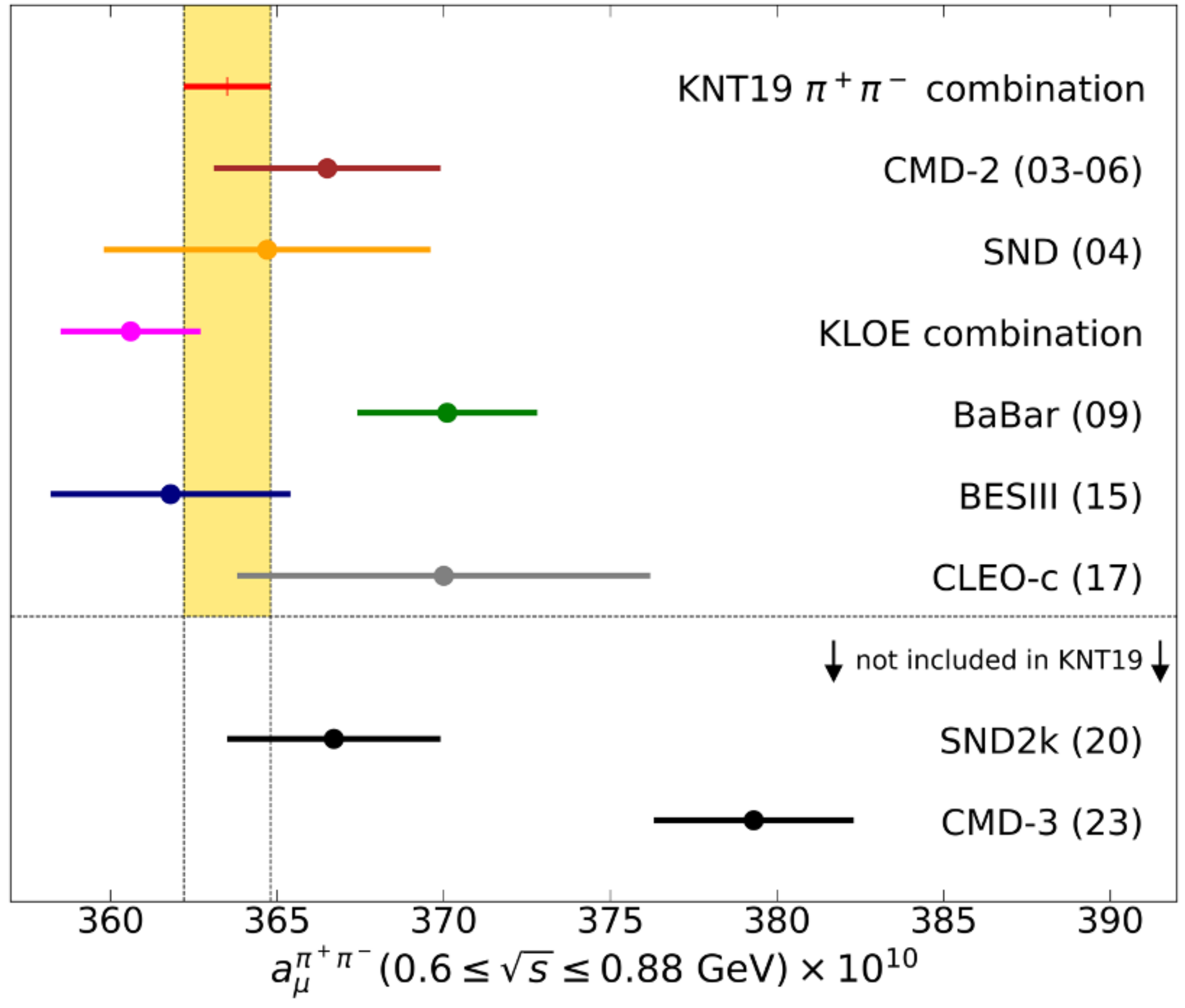
Estifa'a Zaid on behalf of KLOE HVP group

# Measurement of $a_\mu$

- There is a current experimental effort to **discern tensions in the dispersive approach** to determining muon g-2 prediction
- The main contribution to the evaluation of the hadronic contribution to the muon anomaly ($a_\mu^{HLO}$) is taken from the $e^+e^- \to$ hadron cross section

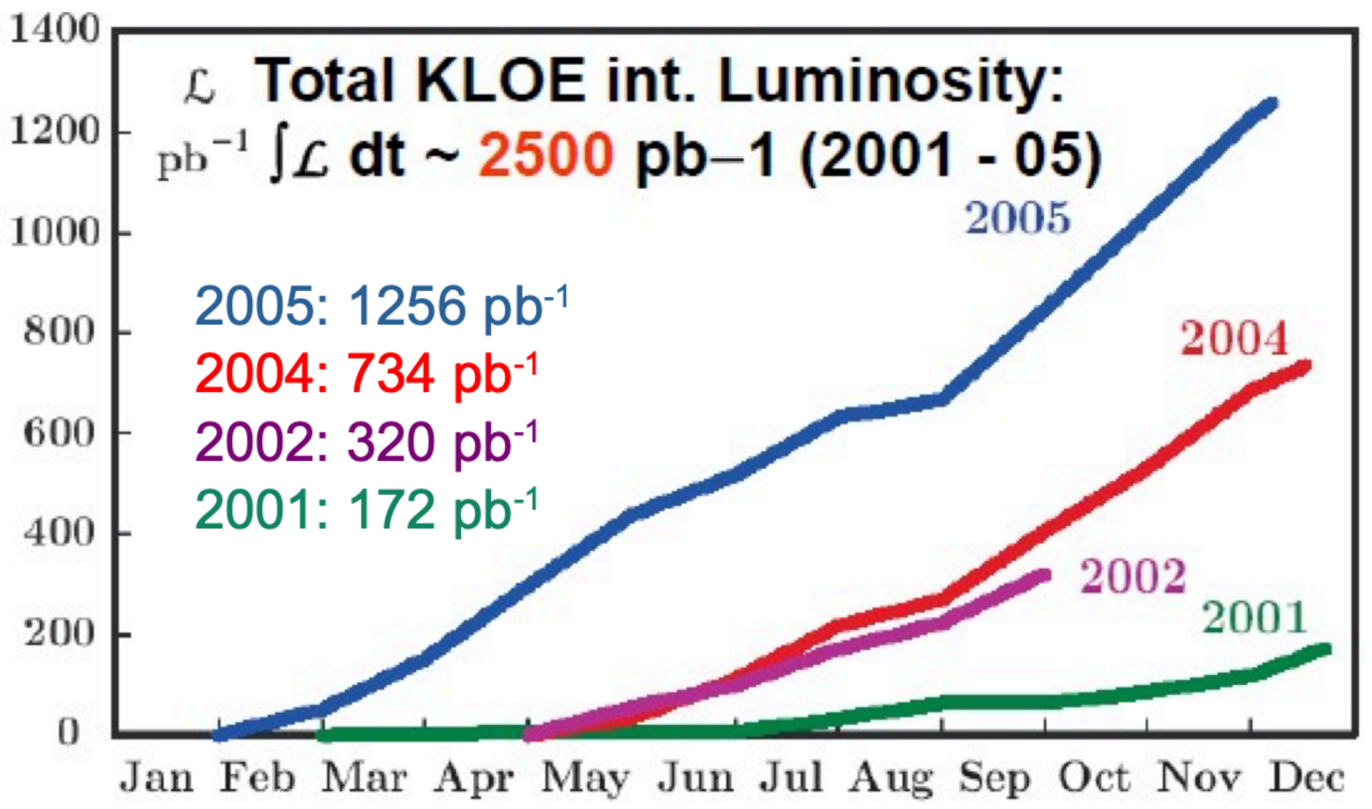



- A long-standing tension ( $\simeq 2.8\sigma$) exists between KLOE cross section measurements and BaBar
- New CMD-3 $e^+e^- \to \pi^+\pi^-$ cross section measurement is in tension with both BaBar ( $\simeq 2.3\sigma$) and KLOE ( $\simeq 5.1\sigma$)
- Combined theoretical prediction for the dispersive approach is limited by tensions between KLOE and BaBar measurements. Even without including CMD-3 measurement

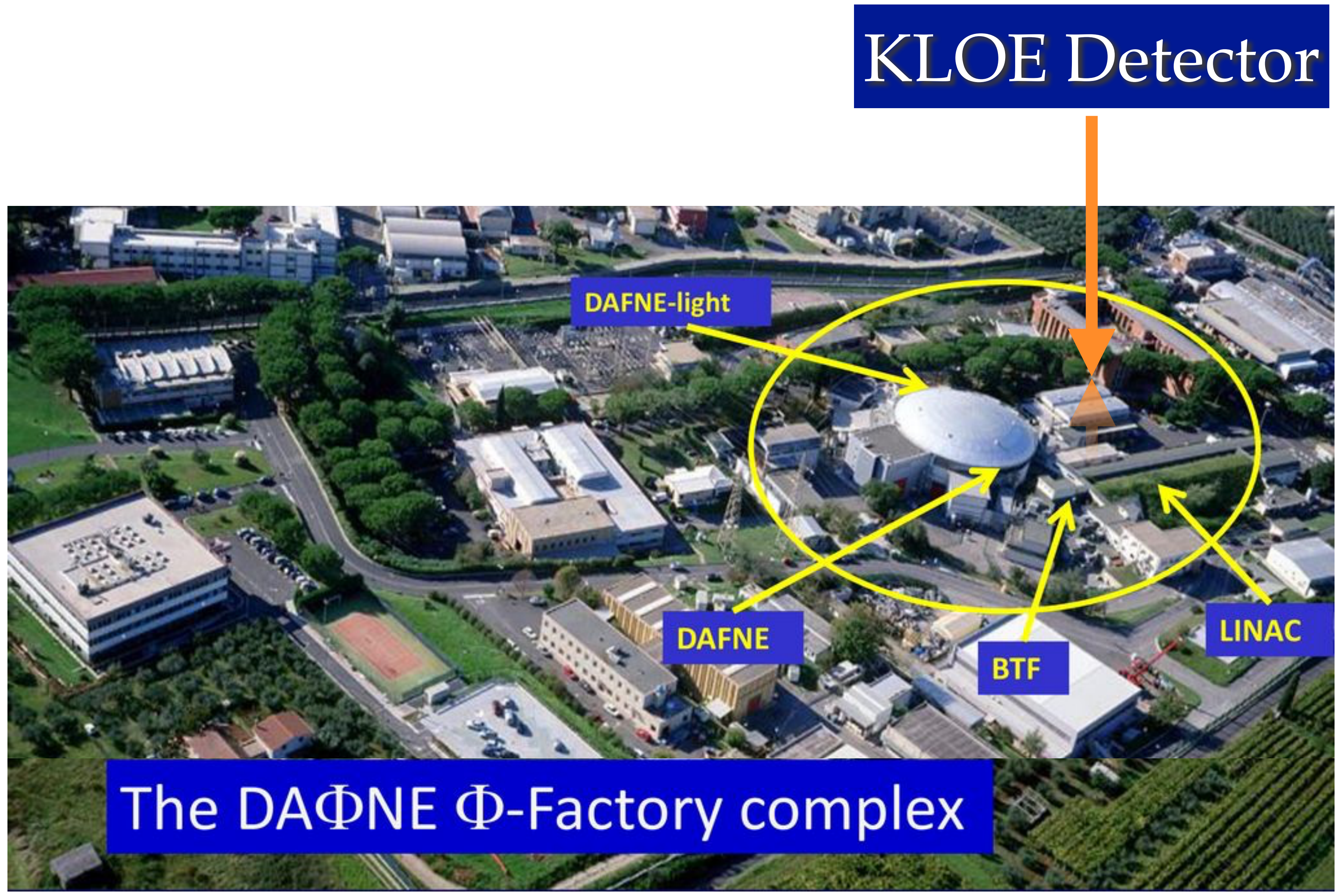


# KLOE at DA$\phi$NE

- DA$\phi$NE, located in Frascati is an $e^+e^-$ collider running at a fixed **CoM energy (~1020 MeV)** equal to the mass of the $\phi$-meson
- The $e^+e^-$ particles collide in one of two interaction regions, where the KLOE detector is located
- KLOE **data-taking years were 2001-2006**, with a total integrated luminosity of 2.5 $\text{fb}^{-1}$ + 250 $\text{pb}^{-1}$ off-peak at $\sqrt{s} = 1$ GeV
- Peak luminosity was reached during 2005 run with ~ 8.5 $\text{pb}^{-1}$/day
- **Previous KLOE analyses were done on 240** $\text{pb}^{-1}$ **(~ 3.5 million $\pi\pi\gamma$ events) of data taken in 2002 and 232** $\text{pb}^{-1}$ **from 2006**

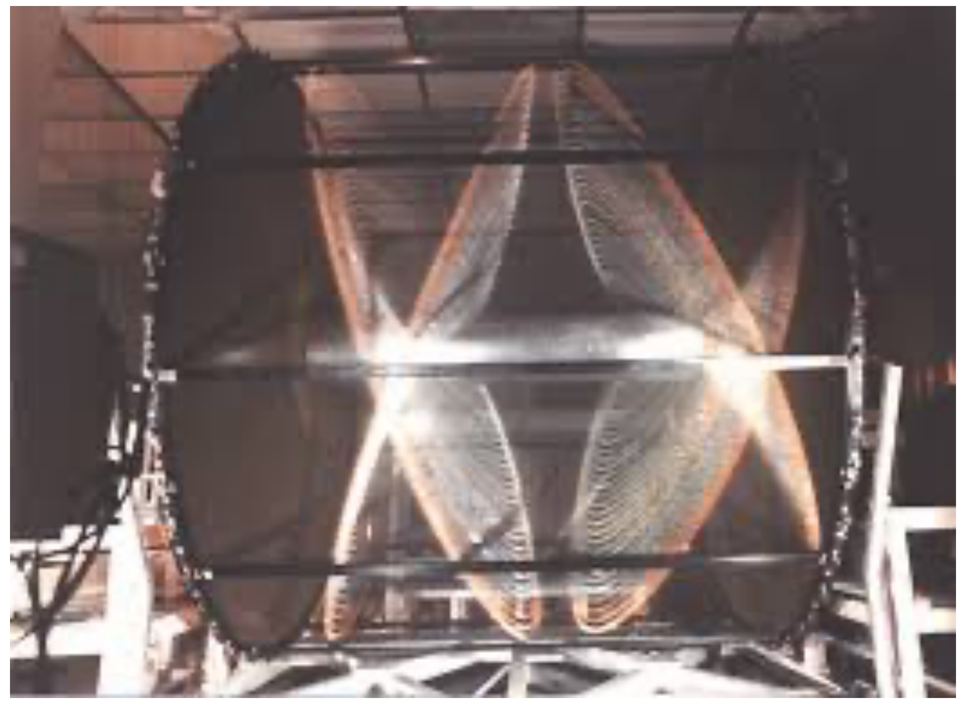



- This ongoing analysis aims to use **2004/2005 KLOE data** to carry out a new measurement. The ~1.7 $\text{fb}^{-1}$ includes ~ **25 million $\pi\pi\gamma$ events** which have **never been used** before in such an analysis. 2006 off-peak data will be used for additional cross checks and systematic studies

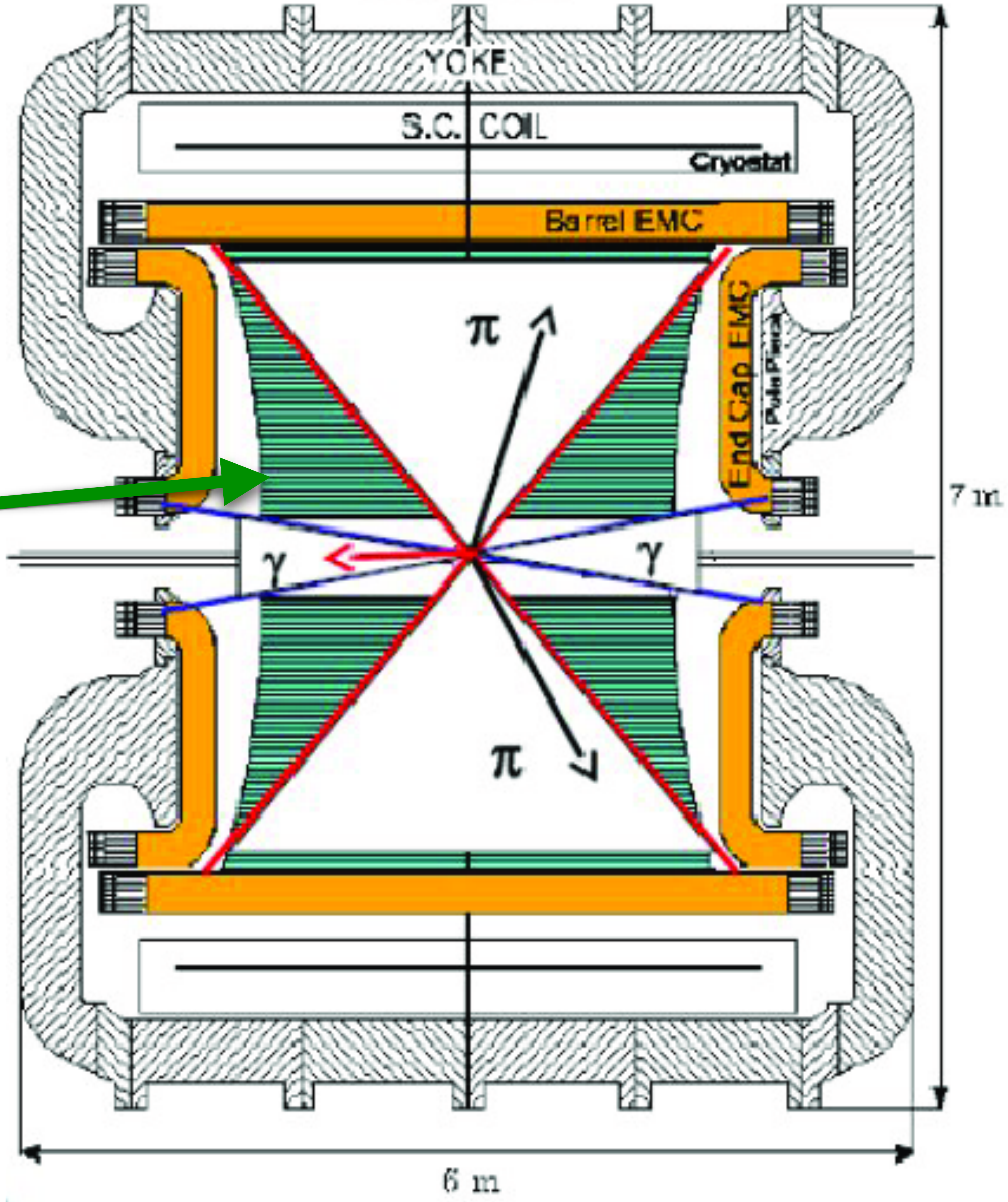


# KLOE Detector - Drift Chamber[1]

- **Drift Chamber**
  - Drift chamber is a full stereo **3.3m long cylinder with a radius of 2m** outside the beam pipe hole that is 25 cm in radius
  - Chamber is filled with **90% helium and 10% isobutane**
  - DC is made up of over 50,000 wires with a **field:sense ratio of 3:1** to make drift cells arranged in layers



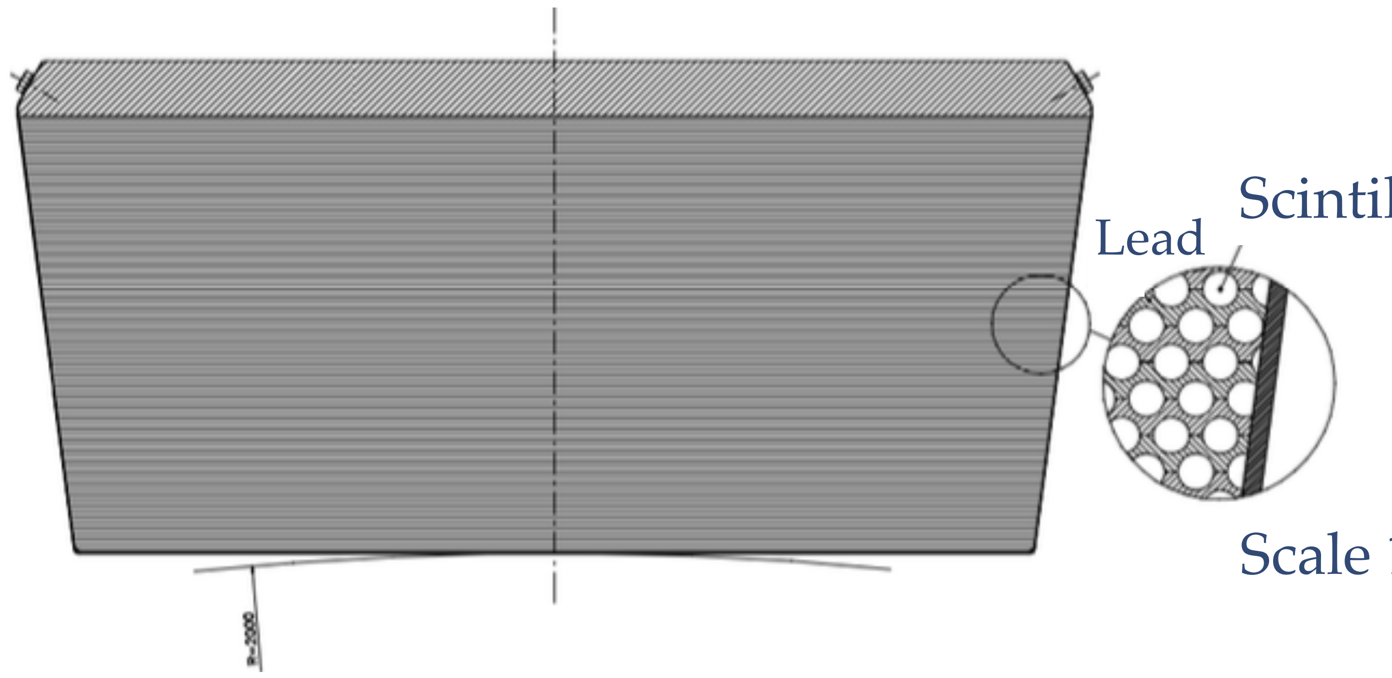
  - Wires in the same layer are parallel to each other and have the same stereo angle wrt to z-axis
  - Good resolution of the z-coordinate is achieved by varying the stereo angle of different layers
  - **Resolution:**
    - $\sigma_{xy} \approx 150\,\mu\text{m}$; $\sigma_z \approx 2\,\text{mm}$; $\sigma_{\text{vertex}} \approx 3\,\text{mm}$; $\delta p/p_T \approx 0.4\%$
    - Momentum resolution of the drift chamber is excellent (important for detector effects, mass unfolding, etc… )



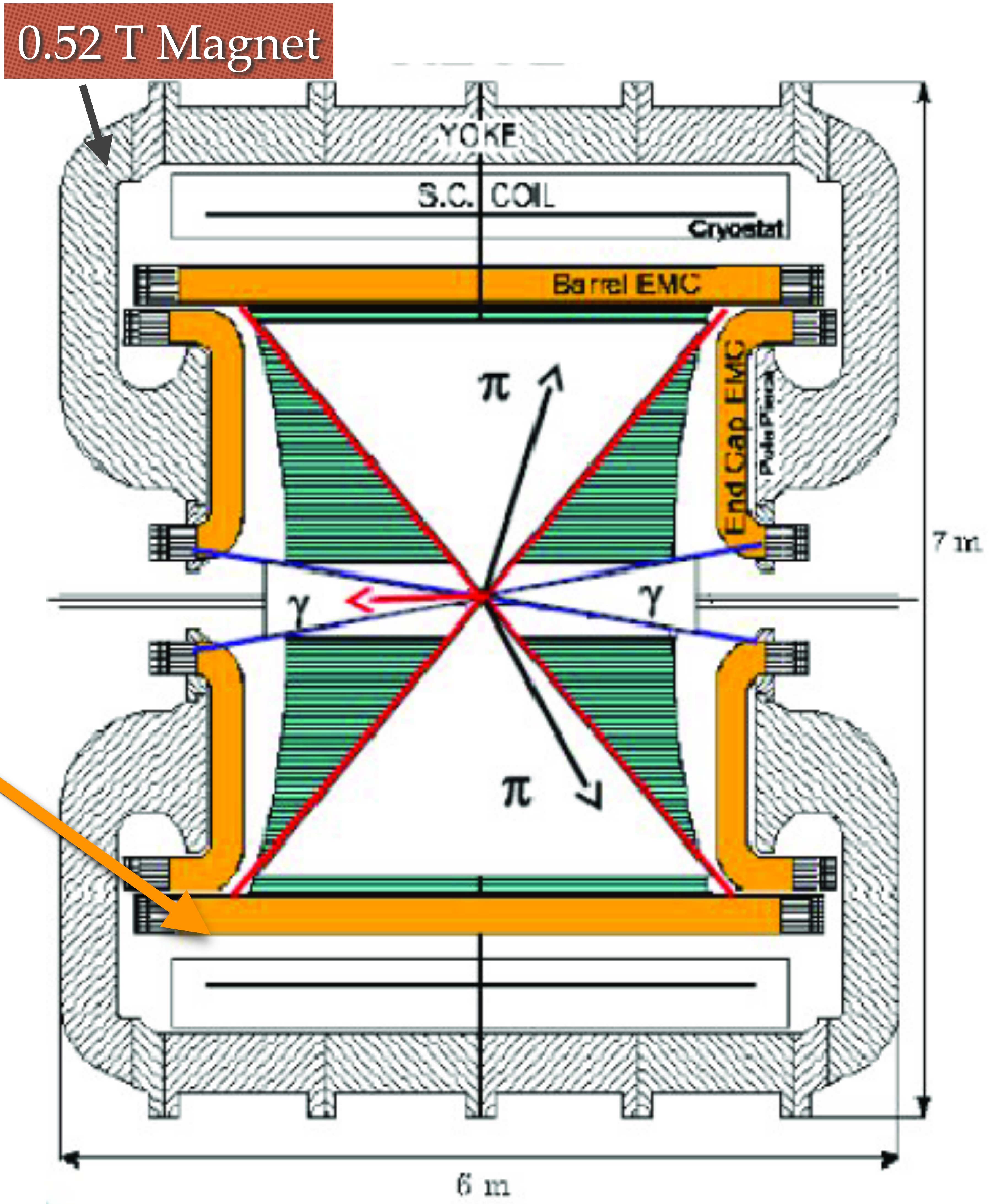

[1] Adinolfi, M., Ambrosino, F., Andryakov, A., et al. (2002). The tracking detector of the KLOE experiment. Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment, 488(1–2), 51-73. https://doi.org/10.1016/S0168-9002(02)00514-4.

# KLOE Detector - Calorimeter[2]

- **EM Calorimeter**
  - **Detects photons of 20 to 500 MeV** and has 98% $4\pi$ coverage
  - Sampling Calorimeter with **lead passive layers and scintillating fibre sensing layers**




  - 24 calorimeter modules form the barrel
  - 32 calorimeter modules form the end-caps
  - The fibres are read out on both ends by light guides which then feed into photomultipliers.
  - Calorimeter modules are organised in **4.4 x 4.4** $cm^2$ **areas (cells) in five layers**
  - **Resolution:**
    - $\sigma_E/E = 5.7\,\%/\sqrt{E(GeV)}$; $\sigma_t(ps) = 5.4/\sqrt{E(GeV)} \oplus 140$;
  - **This calorimeter is now on the way to DUNE!**



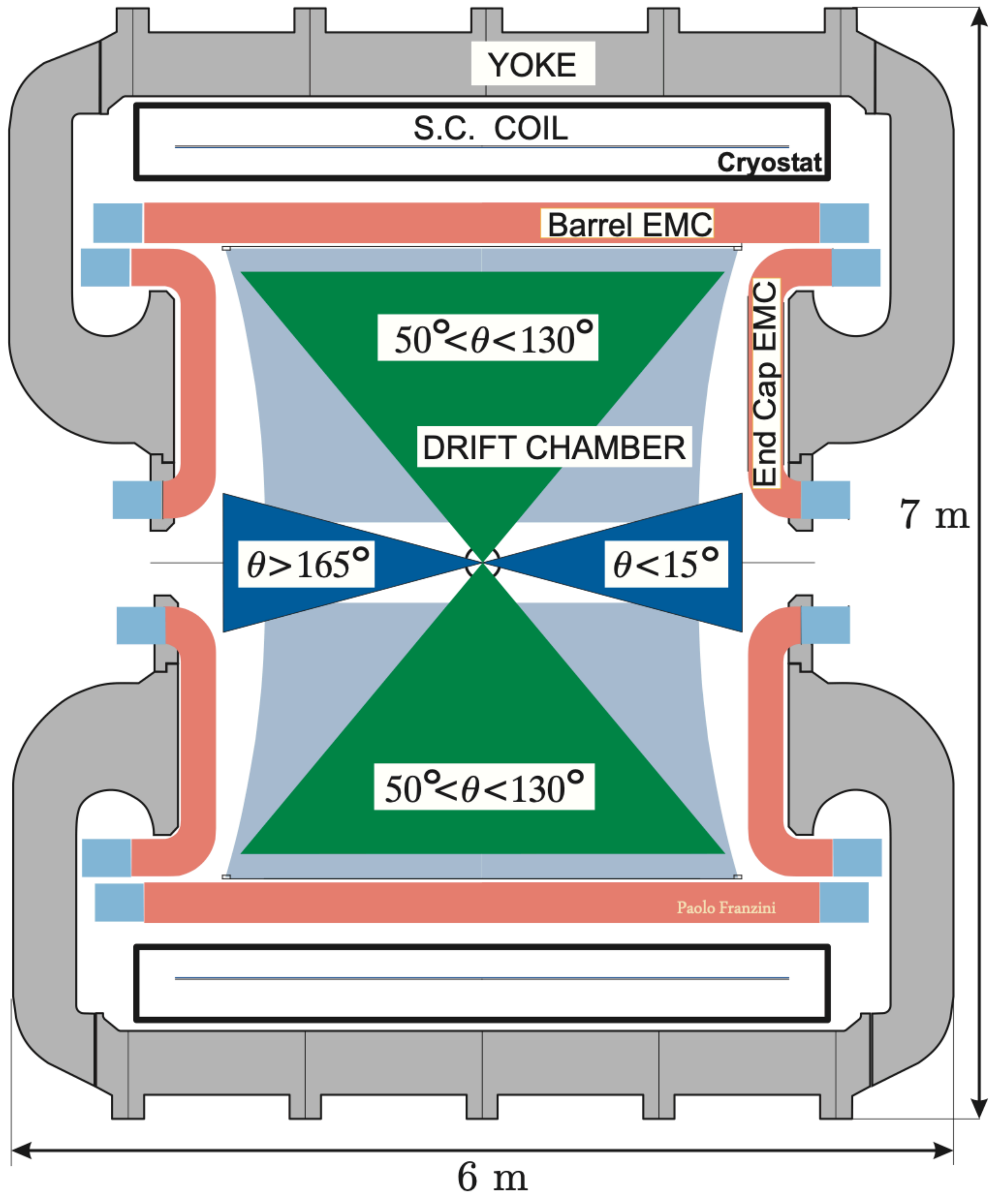

[2] Adinolfi, M., Ambrosino, F., Antonelli, A., et al. (2002). The KLOE electromagnetic calorimeter. Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment, 482(1–2), 364-386. https://doi.org/10.1016/S0168-9002(01)01502-9.

# Small Angle (KLOE08) measurement

**Small Angle KLOE08 analysis - arXiv:0809.3950 [hep-ex]**

**60 points between 0.35 < $M^2_{\pi\pi}$ < 0.95 $GeV^2$**

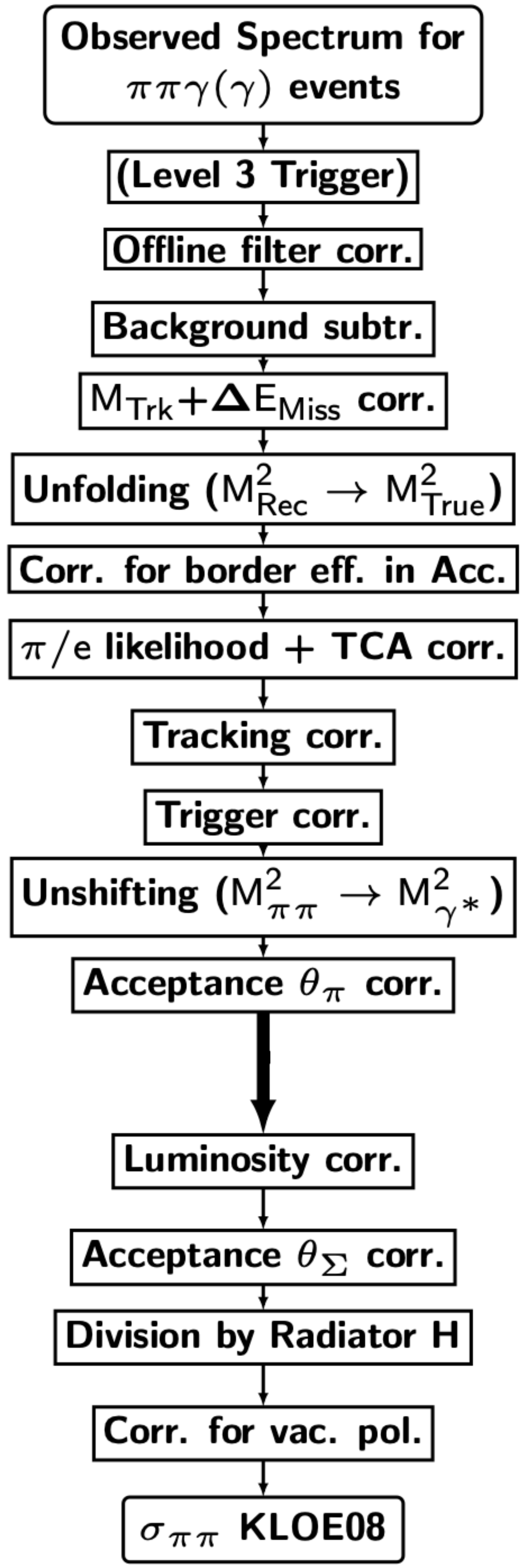
- based on 240.0 $pb^{-1}$ data taken in 2002
- **selection cuts:**
  - **2 pion tracks at large angles** $50^\circ < \theta_\pi < 130^\circ$
  - **small angle cuts:**
    - **photons at small angles** $\theta_{miss} < 15^\circ$ **or** $\theta_{miss} > 165^\circ$
    - photon momentum from kinematics: $\vec{p}_{miss} = -(\vec{p}_+ + \vec{p}_-)$
    - high statistics for ISR events
    - low FSR contribution
    - suppression of $\phi \to \pi^+\pi^-\pi^0$ background
    - threshold region not accessible
- **normalisation to Bhabha and PHOKHARA radiator**




In order to measure $\sigma_{\pi\pi}(s_{\pi\pi})$ while operating at fixed $\sqrt{s}$ **Initial State Radiation** is used:

$$s\frac{d\sigma(e^+e^- \to \pi\pi\gamma)}{ds_{\pi\pi}}\bigg|_{ISR} = \sigma_{\pi\pi}(s_{\pi\pi})H(s_{\pi\pi}, s)$$

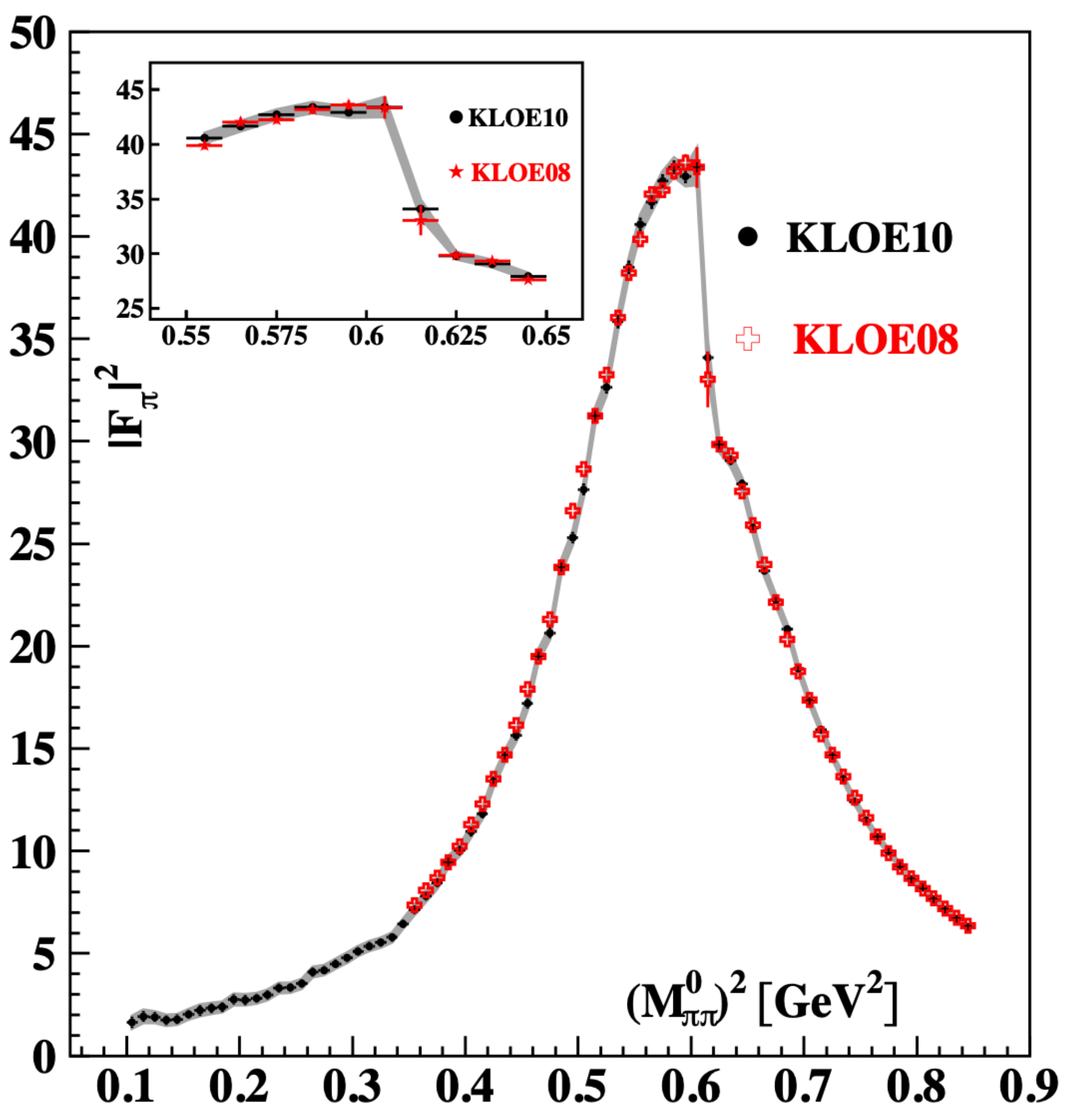
**Radiator function**

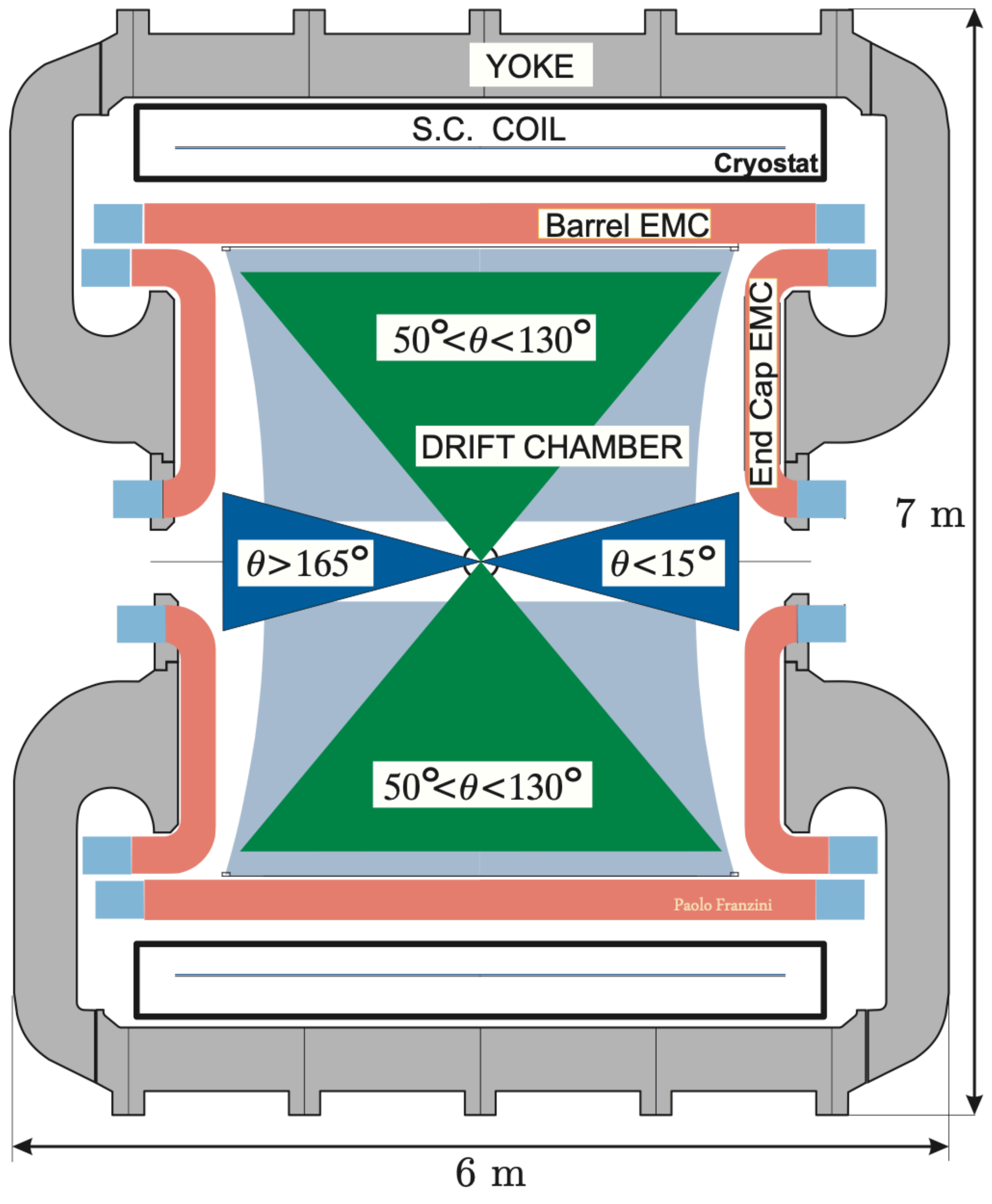


# Large Angle (KLOE10) measurement

**Large Angle KLOE10 analysis - arXiv:1006.5313 [hep-ex]**

- This analysis allows us to extend the $M^2_{\pi\pi}$ region down towards the threshold for the dipion production
  - 75 points between $0.1 < M^2_{\pi\pi} < 0.85\ GeV^2$
  - based on 232.6 $\text{pb}^{-1}$ data taken in 2006 with $\sqrt{s} = 1\ GeV$
  - **selection cuts:**
    - **2 pion tracks at large angles** $50^\circ < \theta_\pi < 130^\circ$
    - **large angle cuts:**
      - **at least 1 photon at large angles** $50^\circ < \theta_\gamma < 130^\circ$
      - photon detection possible
      - disadvantages of large angle cuts e.g. more $\phi \to \pi^+\pi^-\pi^0$ background and higher FSR contribution overcome by use of 2006 dataset
  - **normalisation to Bhabha and PHOKHARA radiator**




In order to measure $\sigma_{\pi\pi}(s_{\pi\pi})$ while operating at fixed $\sqrt{s}$ **Initial State Radiation** is used:

$$s\frac{d\sigma(e^+e^- \to \pi\pi\gamma)}{ds_{\pi\pi}}\bigg|_{ISR} = \sigma_{\pi\pi}(s_{\pi\pi})H(s_{\pi\pi}, s)$$

**Radiator function**

- Observed Spectrum for $\pi\pi\gamma(\gamma)$ events
- (Level 3 Trigger)
- Offline filter corr.
- Background subtr.
- Trigger corr.
- $\pi/e$ likelihood + TCA corr.
- Unfolding ($M^2_{Rec} \to M^2_{True}$)
- $f_0+\rho\pi$ corr.
- Tracking corr. data/MC
- Photon corr. data/MC
- Global MC efficiency
- Unshifting ($M^2_{\pi\pi} \to M^2_{\gamma*}$)
- Luminosity corr.
- Division by Radiator H
- Corr. for vac. pol.
- $\sigma_{\pi\pi}$ KLOE10

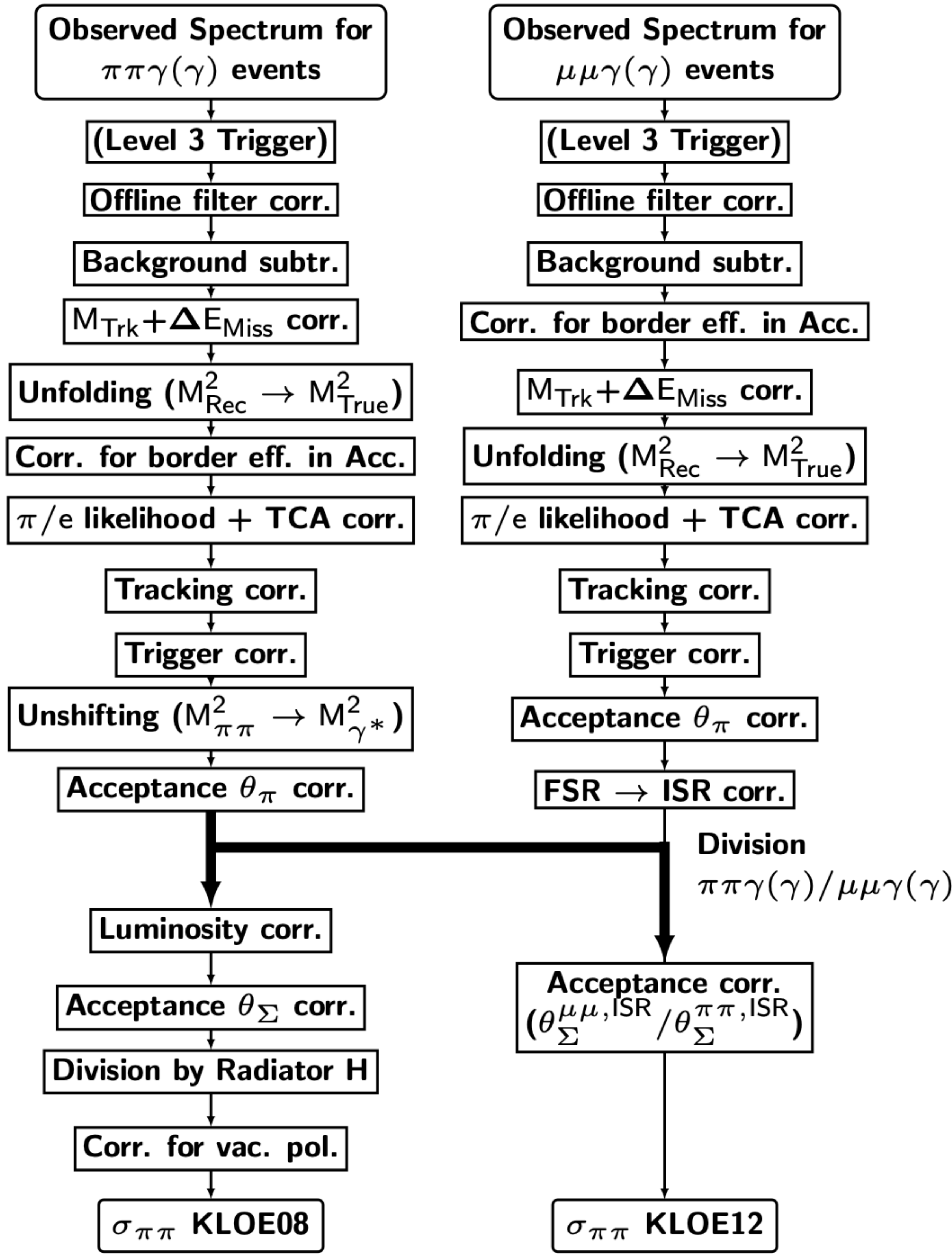
# Small Angle (KLOE12) measurement

**Small Angle KLOE12 analysis - arXiv:1212.4524 [hep-ex]**

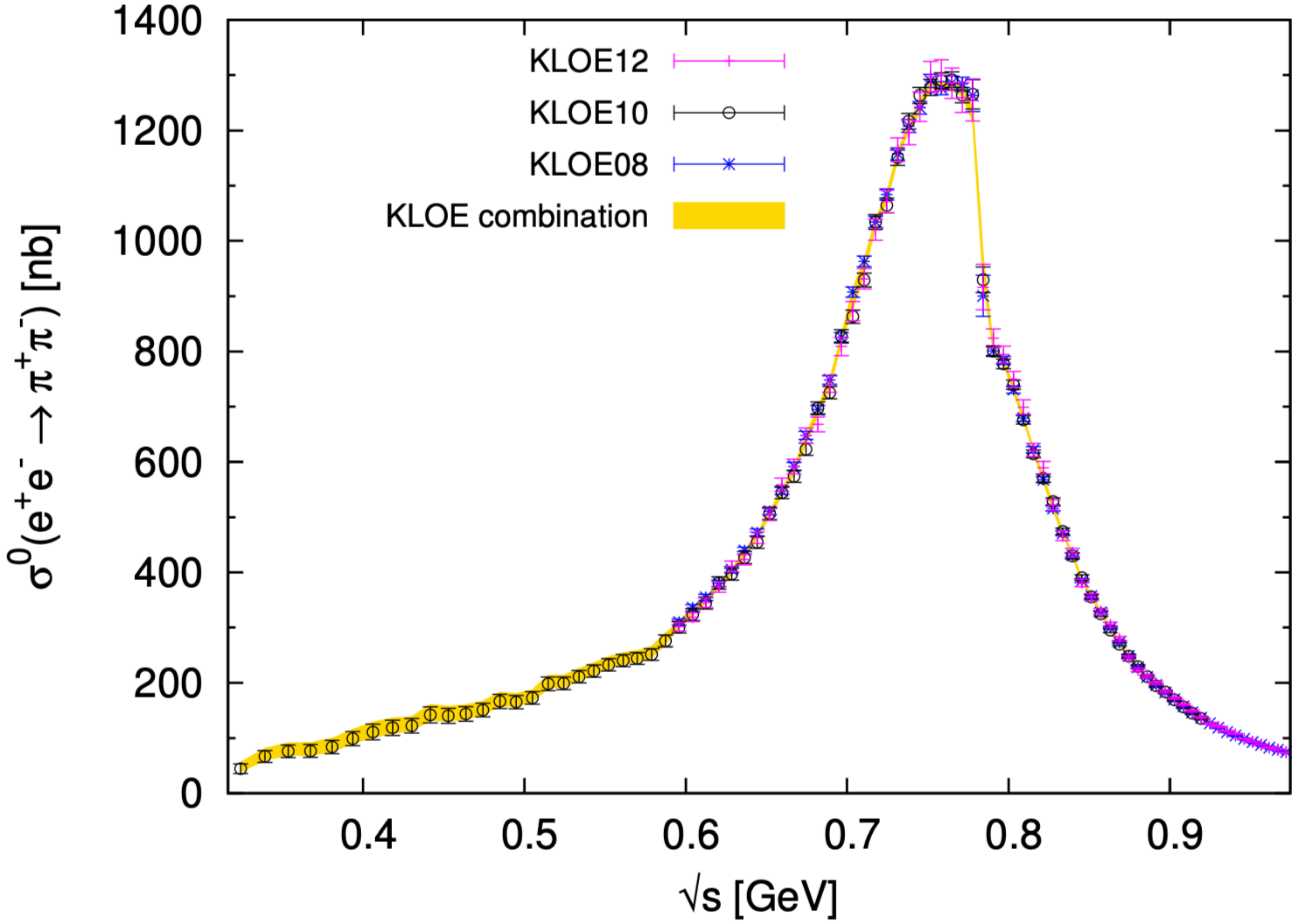
**KLOE08 + different normalisation:**

- **normalisation to $\mu\mu\gamma$ events**
- this is another method of extracting the cross section:
- $$\sigma_{\pi\pi(\gamma)}(s_{\pi\pi}) = \sigma_{\mu\mu(\gamma)}(s_{\mu\mu})\frac{d\sigma_{\pi\pi\gamma}/ds^*_\gamma}{d\sigma_{\mu\mu\gamma}/ds^*_\gamma}$$
- it is possible to **cancel out the luminosity dependence and radiator function** by normalising to $\mu\mu\gamma$
- this significantly **decreased the theoretical systematics but increased the background subtraction systematics**

| Syst Errors (%) | $a_\mu^{\pi\pi}$ absolute | $a_\mu^{\pi\pi}$ ratio |
|---|---|---|
| Background Filter (FILFO) | negligible | negligible |
| Background Subtraction | 0.3 | 0.6 |
| Trackmass | 0.2 | 0.2 |
| Particle ID | negligible | negligible |
| Tracking | 0.3 | 0.1 |
| Trigger | 0.1 | 0.1 |
| Unfolding | negligible | negligible |
| Acceptance ($\theta_{\pi\pi}$) | 0.2 | negligible |
| Acceptance ($\theta_\pi$) | negligible | negligible |
| Software Trigger (L3) | 0.1 | 0.1 |
| Luminosity | 0.3 ($0.1_{th} \oplus 0.3_{exp}$) | - |
| $\sqrt{s}$ dep. of $H$ | 0.2 | - |
| Total exp. systematics | 0.6 | 0.7 |
| Vacuum Polarisation | 0.1 | - |
| FSR treatment | 0.3 | 0.2 |
| Rad. function $H$ | 0.5 | - |
| Total theory systematics | 0.6 | 0.2 |
| Total systematic error | 0.9 | 0.7 |



# A recap of KLOE measurements




**KLOE12 analysis**

- 60 points between 0.35 and 0.95 $GeV^2$
- based on 240.0 $pb^{-1}$data taken in 2002
- **selection match KLOE08 small angle analysis**
- **normalisation to $\mu\mu\gamma$ events**

**KLOE08 analysis**

- 60 points between 0.35 and 0.95 $GeV^2$
- based on 240.0 $pb^{-1}$data taken in 2002
- **Selection cuts:**
  - **2 pion (muon) tracks at large angles**
    $50^\circ < \theta_{\pi,\mu} < 130^\circ$
  - **small angle cuts:**
    - **photons at small angles $\theta_{miss} < 15^\circ$ or $\theta_{miss} > 165^\circ$**
    - photon momentum from kinematics: $\vec{p}\text{miss} = -(\vec{p}_+ + \vec{p}_-)$
    - high statistics for ISR events
    - low FSR contribution
    - suppression of $\phi \to \pi^+\pi^-\pi^0$ background
    - threshold region not accessible
- normalisation to Bhabha and PHOKHARA radiator

**KLOE10 analysis**

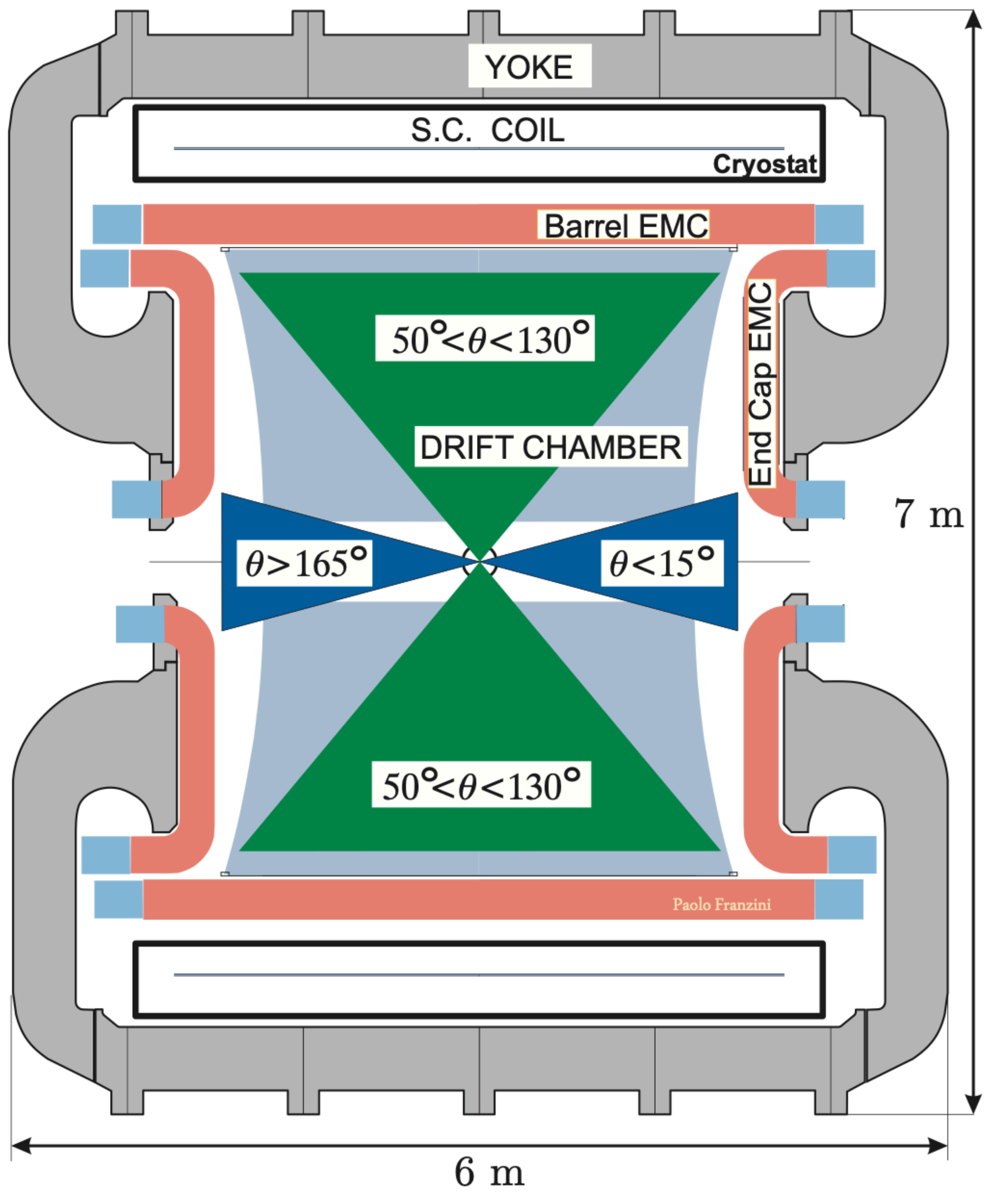
- 75 points between 0.1 and 0.85 $GeV^2$
- based on 232.6 $pb^{-1}$data taken in 2006 with $\sqrt{s} = 1\,GeV$
- **Selection cuts:**
  - **2 pion (muon) tracks at large angles**
    $50^\circ < \theta_{\pi,\mu} < 130^\circ$
  - **large angle cuts:**
    - **at least 1 photon at large angles**
      $50^\circ < \theta_\gamma < 130^\circ$
    - photon detection possible
    - disadvantages of Large angle cuts e.g. more $\phi \to \pi^+\pi^-\pi^0$ background and higher FSR contribution overcome by use of 2006 dataset.
- normalisation to Bhabha and PHOKHARA radiator

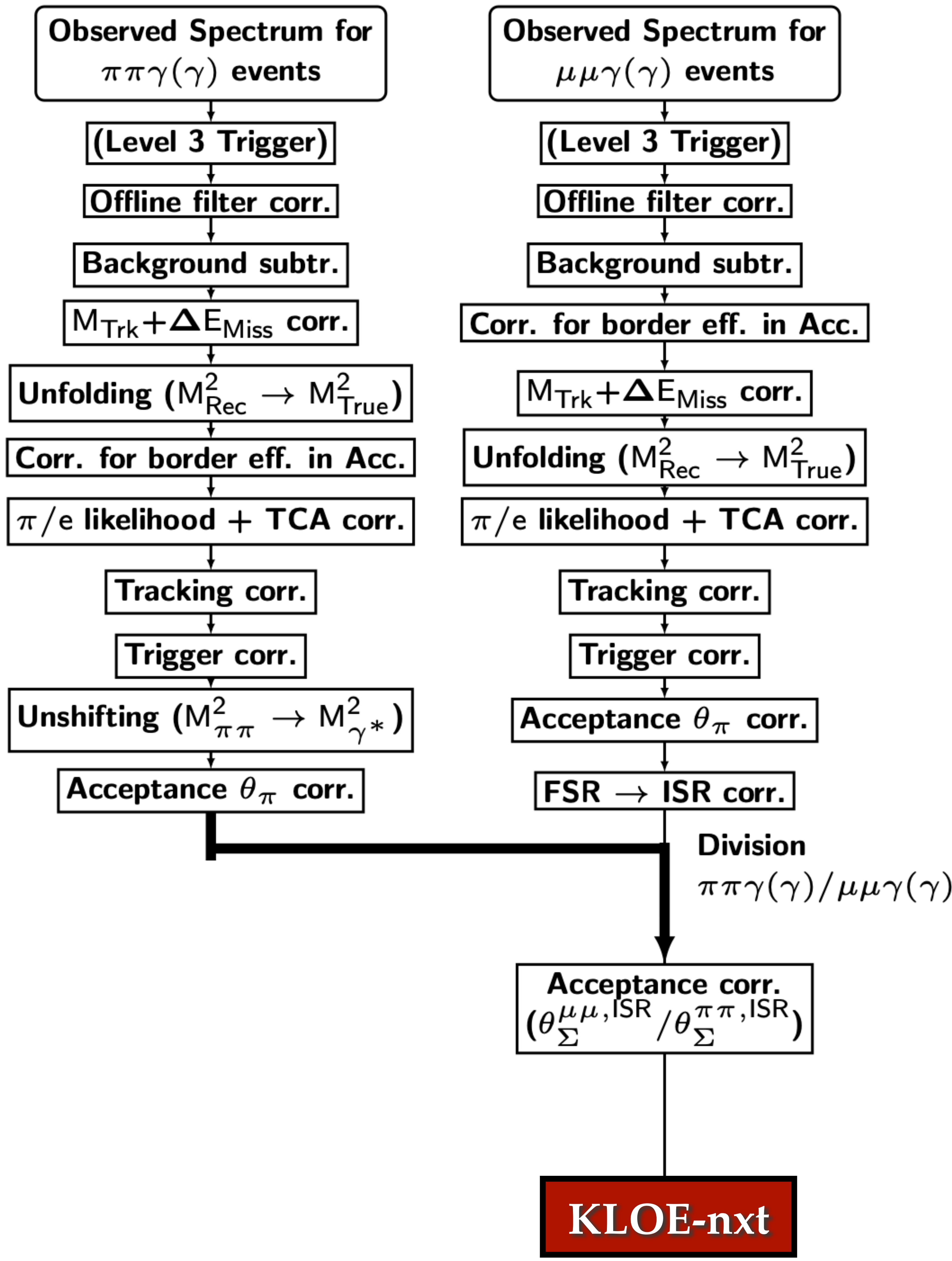
# The new (KLOE-nxt) measurement

**KLOE-nxt analysis**

- 60 points between $0.35 < M^2_{\pi\pi} < 0.95\ GeV^2$
- based on $1.7\ fb^{-1}$ data taken in 2004/2005
- **Selection cuts:**
  - **2 pion (muon) tracks at large angles $50^{\circ} < \theta_{\pi,\mu} < 130^{\circ}$**
  - **small angle cuts:**
    - **photons at small angles $\theta_{miss} < 15^{\circ}$ or $\theta_{miss} > 165^{\circ}$**
    - photon momentum from kinematics:

      $\vec{p}_{\mathrm{miss}} = -(\vec{p}_+ + \vec{p}_-)$
- normalisation to $\mu\mu\gamma$
- **The above will make the basis of the KLOE-nxt analysis however the group is prepared to make modifications if desired**
- Theory group working on NNLO Monte Carlo generator for low energy $e^+e^-$ data.



# The new (KLOE-nxt) measurement

**KLOE-nxt analysis**

- Analysis group is tackling different aspects using new techniques with the intention of reducing the larger systematic uncertainties.

**KLOE12**: $0.3\%_{stat} \oplus 0.2\%_{th} \oplus 0.7\%_{syst} \Rightarrow \sim 0.8\%_{tot}$

**KLOE-nxt(goal)**: $0.1\%_{stat} \oplus 0.2\%_{th} \oplus 0.3\%_{syst} \Rightarrow \sim 0.4\%_{tot}$

- There will be a factor 7 statistical improvement making the statistical uncertainty negligible wrt systematics.
- There will be dedicated work on the background subtraction procedure to achieve a **x3 reduction of the background subtraction uncertainty**.
- The analysis will be conducted blindly.

| Syst Errors (%) | KLOE12 $a_\mu^{\pi\pi}$ ratio | KLOE-nxt (expected) $a_\mu^{\pi\pi}$ ratio |
|---|---|---|
| Background Filter (FILFO) | negligible | negligible |
| Background Subtraction | 0.6 | 0.2 |
| Trackmass | 0.2 | 0.2 |
| Particle ID | negligible | negligible |
| Tracking | 0.1 | 0.1 |
| Trigger | 0.1 | 0.1 |
| Unfolding | negligible | negligible |
| Acceptance ($\theta_{\pi\pi}$) | negligible | negligible |
| Acceptance ($\theta_\pi$) | negligible | negligible |
| Software Trigger (L3) | 0.1 | 0.1 |
| Luminosity | - | - |
| $\sqrt{s}$ dep. of $H$ | - | - |
| Total exp. systematics | 0.7 | 0.3 |
| Vacuum Polarisation | - | - |
| FSR treatment | 0.2 | 0.2 |
| Rad. function $H$ | - | - |
| Total theory systematics | 0.2 | 0.2 |
| Total systematic error | 0.7 | 0.4 |

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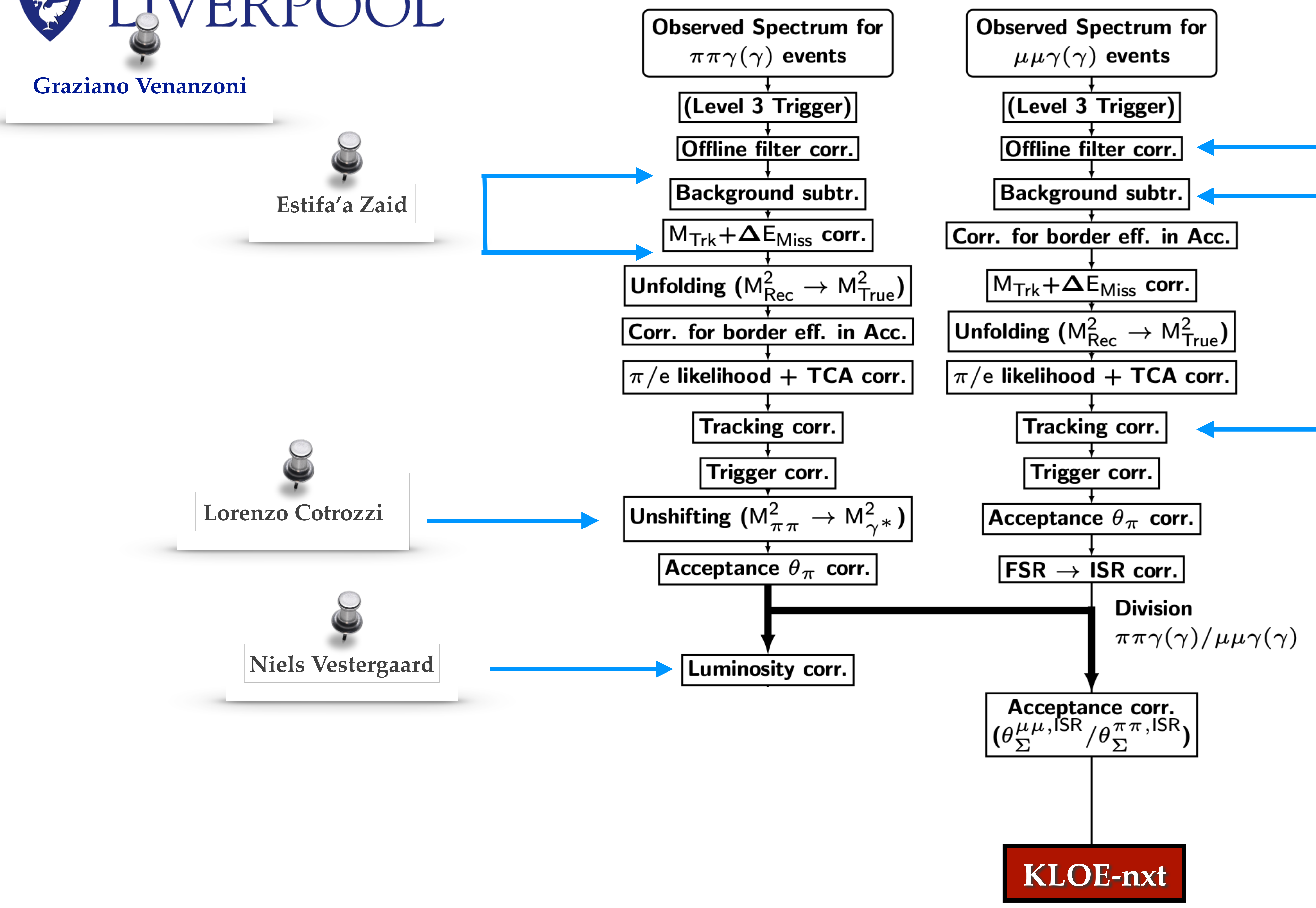
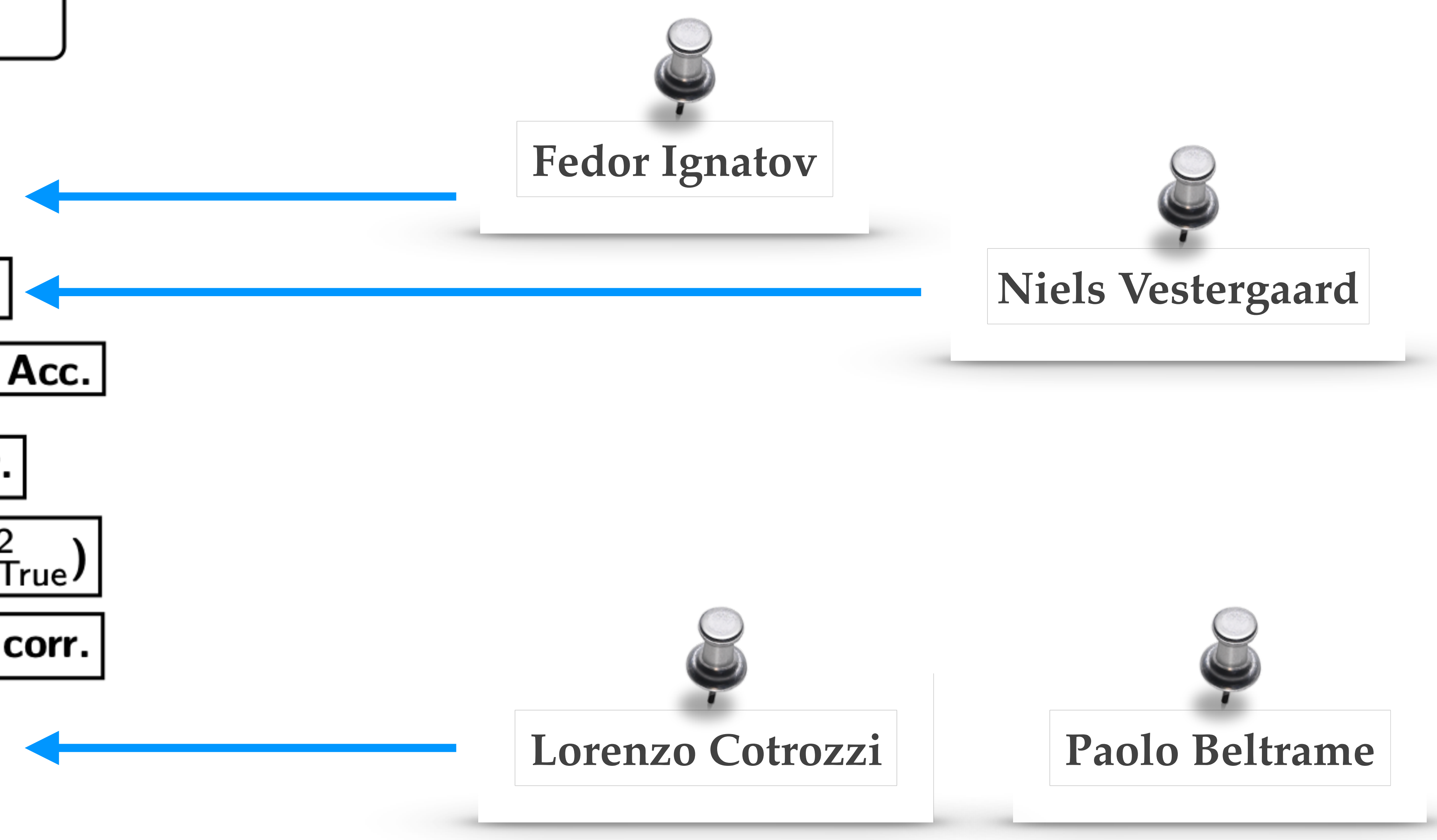
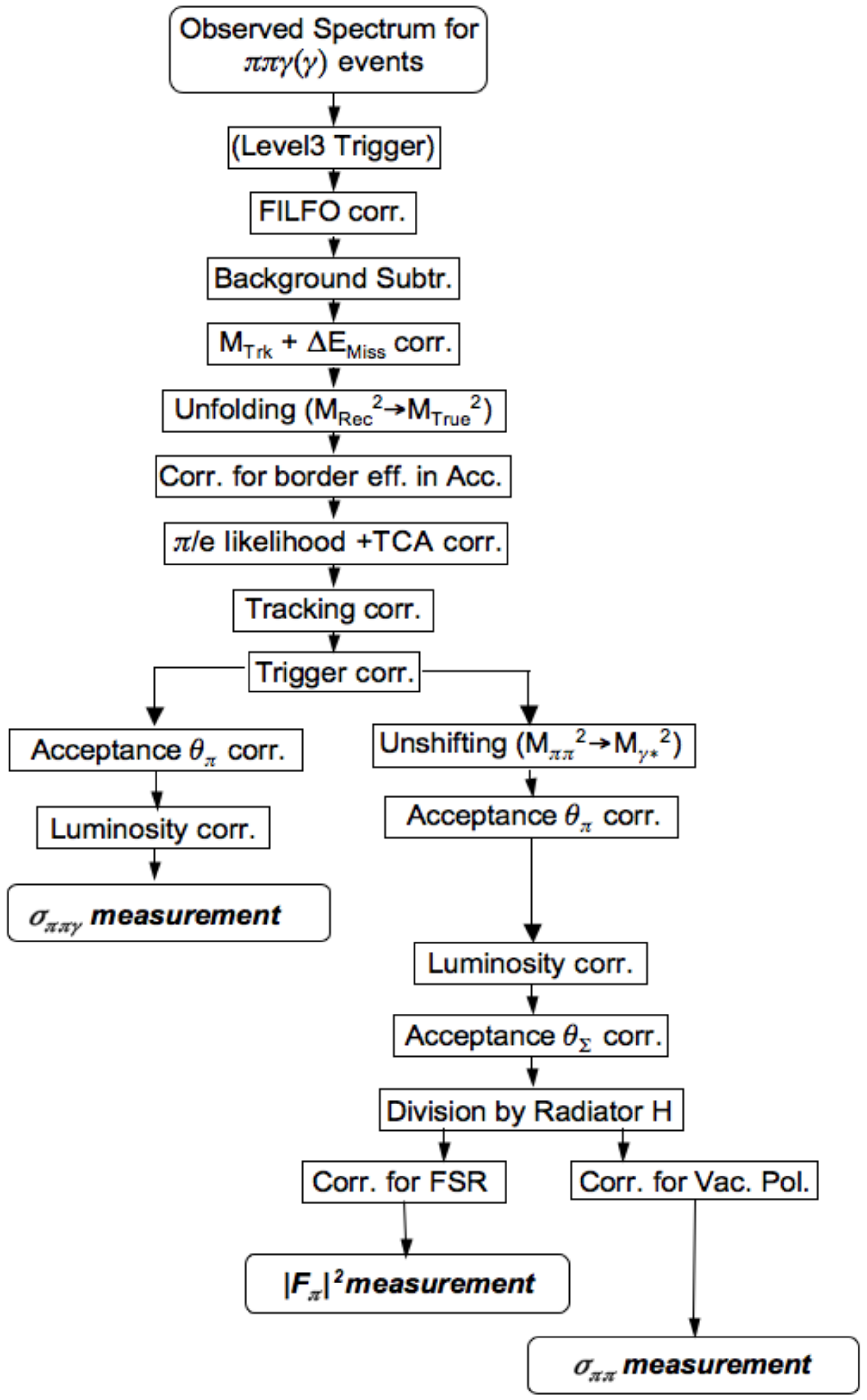



Notes:

- Jeremy Paltrinieri, William Torres, and Pau Petit are all working on radiative corrections with the ultimate goal of producing NNLO MC generators
- Liverpool is not the only institute involved, members from Pisa and Dresden heavily involved.

# Look to the future




**Planned future work:**

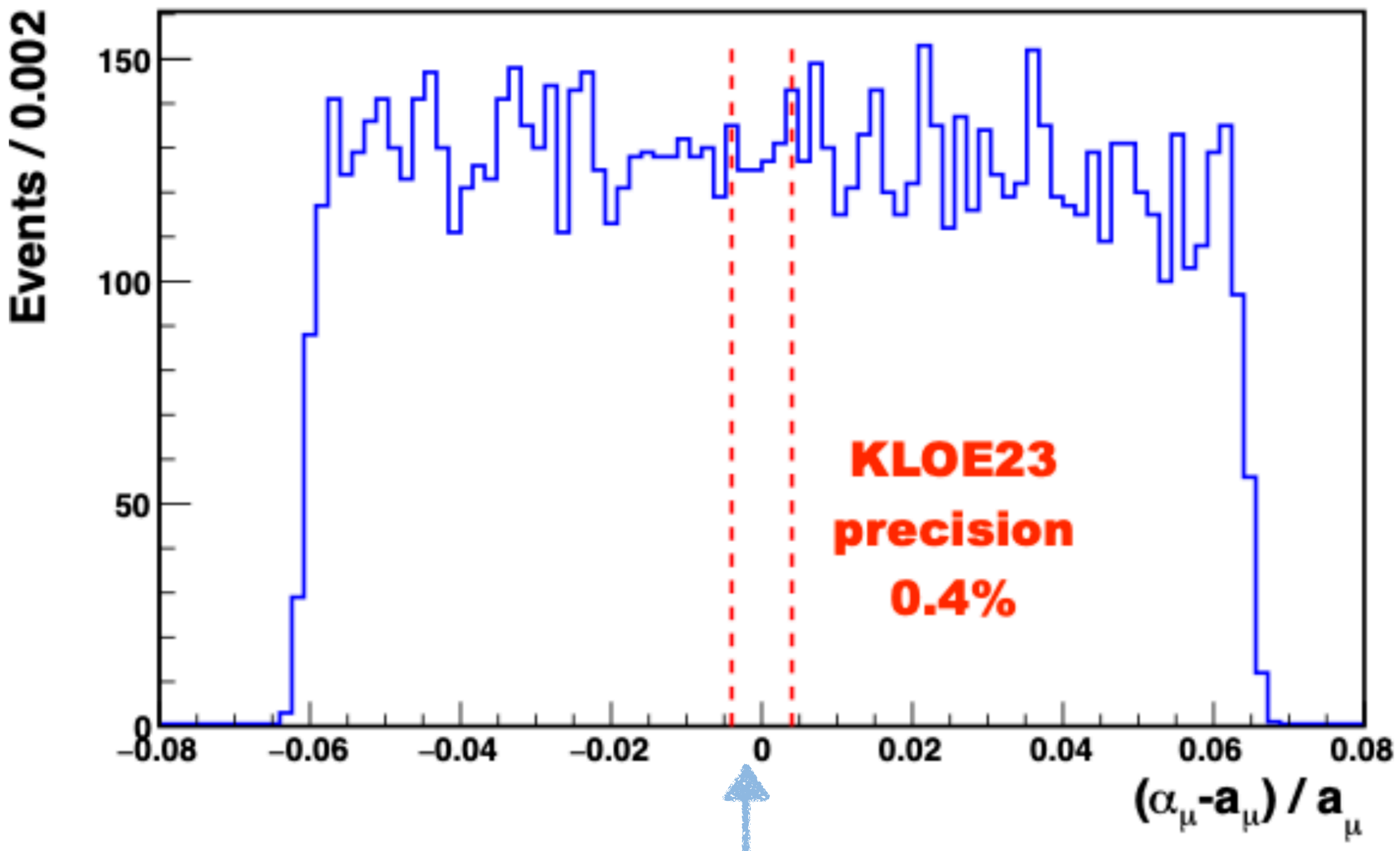
- **Work is ongoing in great detail on all aspects of the analysis** (e.g. trigger efficiencies, luminosity…) with the aim of improving systematic uncertainties and explore alternative analysis criteria
- Parallel work is being done on the **computing infrastructure** in Frascati to improve accessibility to the data
- **Theory efforts**
  - A significant effort is ongoing on radiative corrections with the ultimate goal of producing NNLO MC generators
    - STRONG2020: https://radiomontecarlow2.gitlab.io

# Thank you

# Backup

# Blinding

- The new KLOE analysis will be **conducted blindly** to ensure good practice and avoid bias throughout.
- This is not a trivial task and is the **first KLOE $a_\mu^{HLO}$ analysis to be blinded**
- The aim of blinding is to shift the result of the analysis by a small amount without jeopardising the distributions of data and Monte Carlo
- Two root-tuples will be used in this analysis; **blinded and working (unblinded) root-tuples**
- For the blinded root-tuples, proposed procedure is as follows:
  - **Removing a small, unknown (to the analysers) fraction of events from each $Q^2_{\pi\pi}$ or $Q^2_{\mu\mu}$ slice in data.**
  - This modifies the measured differential cross section and thus $a_{\pi\pi} \propto \int ds \ldots \sigma_{\pi\pi}(s)$ whilst having no affect on distributions at fixed $Q^2$ bins.
- Efficiencies are calculated on the working root-tuples ($|F_\pi|^2$ not accessible here).
- **Extraction of $|F_\pi|^2$ is done only on blinded root-tuples.**




Blinded value of $a_\mu$ is ±6% with respect to true value in simulations. Blinding offset **much larger than target KLOE23 precision**!

# Blinding

## Things to note

All corrections found with working root-tuples will then be applied to blinded ones. Blinded root-tuples will only be **provided when all analysis steps are signed off**.

The blinding procedure will be done by a member of the collaboration that is external to the analysis.

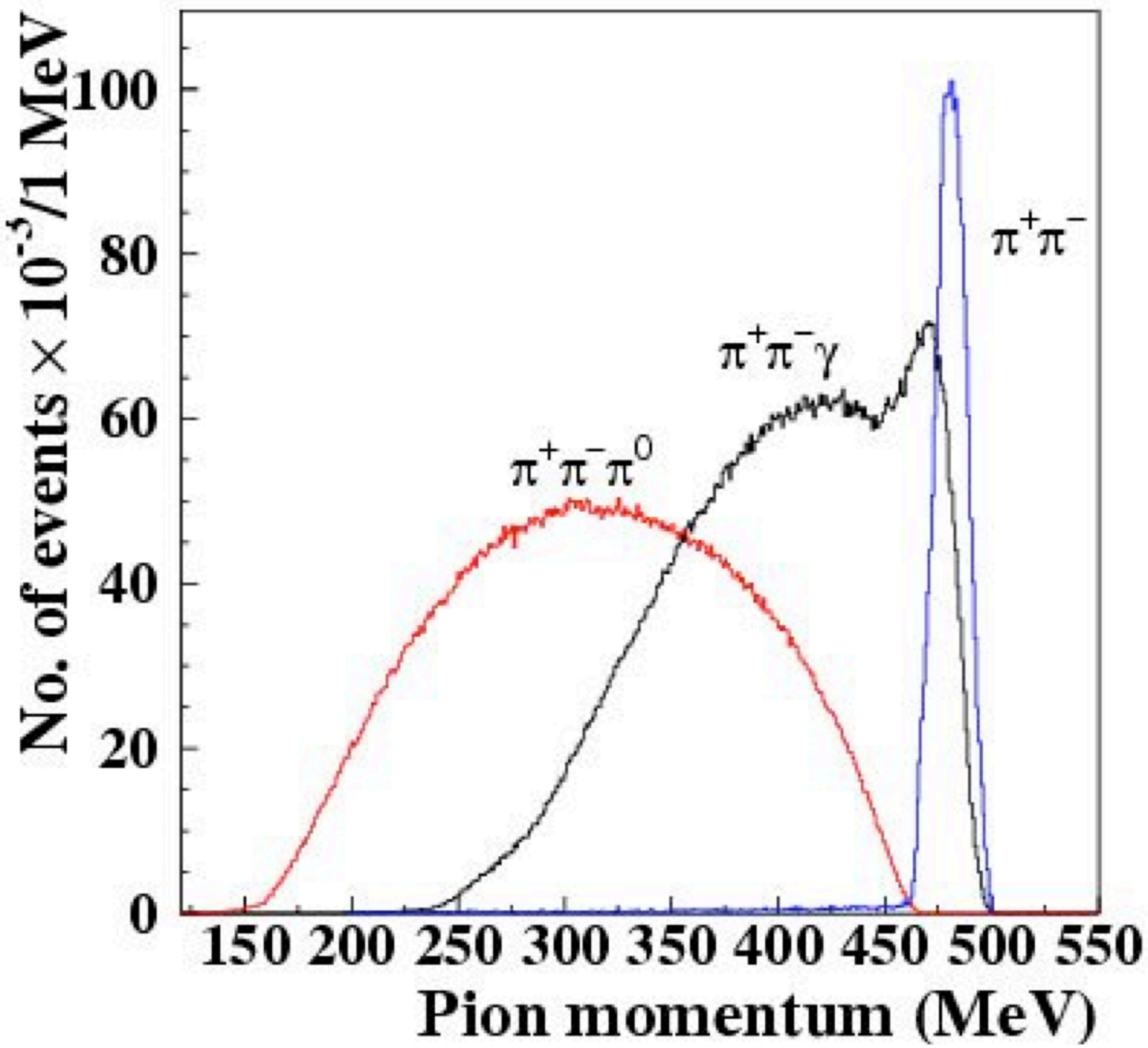
Unblinding will be performed only at the completion of the analysis and with the agreement of all the analysers involved.

This blinding is still undergoing checks to ensure procedure is sound.

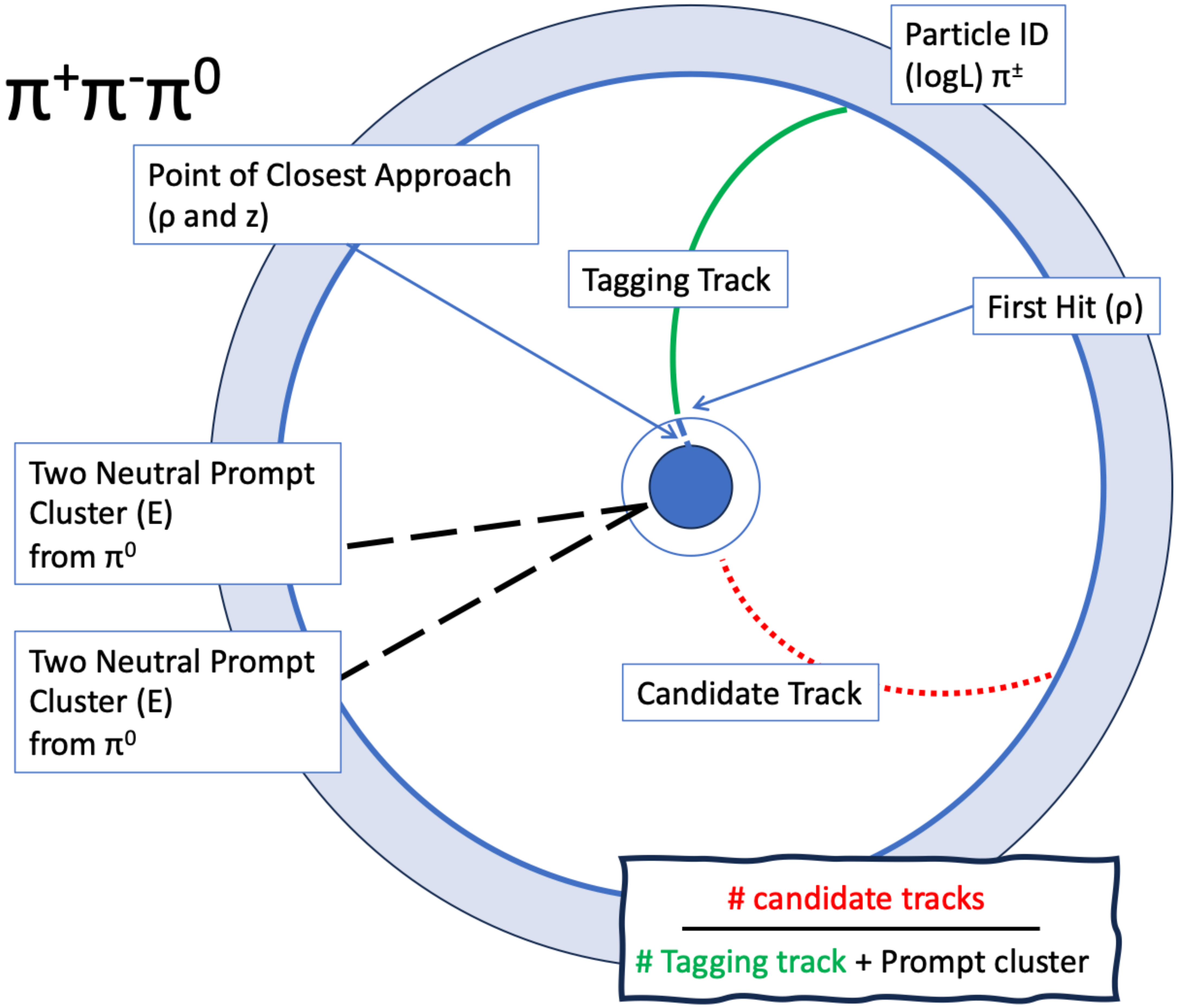
This blinding procedure like many others **assumes a level of honesty** from analysers. Analysers agree not to look at the pion form factor directly or indirectly before the unblinding.

# Tracking

- Tracking will be **conducted on the working root-tuples**
- Previous analyses have provided a foundation for selections and tracking efficiency. **In KLOE23 these will be studied and updated, with improvements made**
- Selections:
    - $\pi^+\pi^-\pi^0$
    - $\pi^+\pi^-$
    - $\pi\pi\gamma$ or $\mu\mu\gamma$
- These selections result in different momentum regions being covered
- The *old* selection procedure will be subsequently detailed…

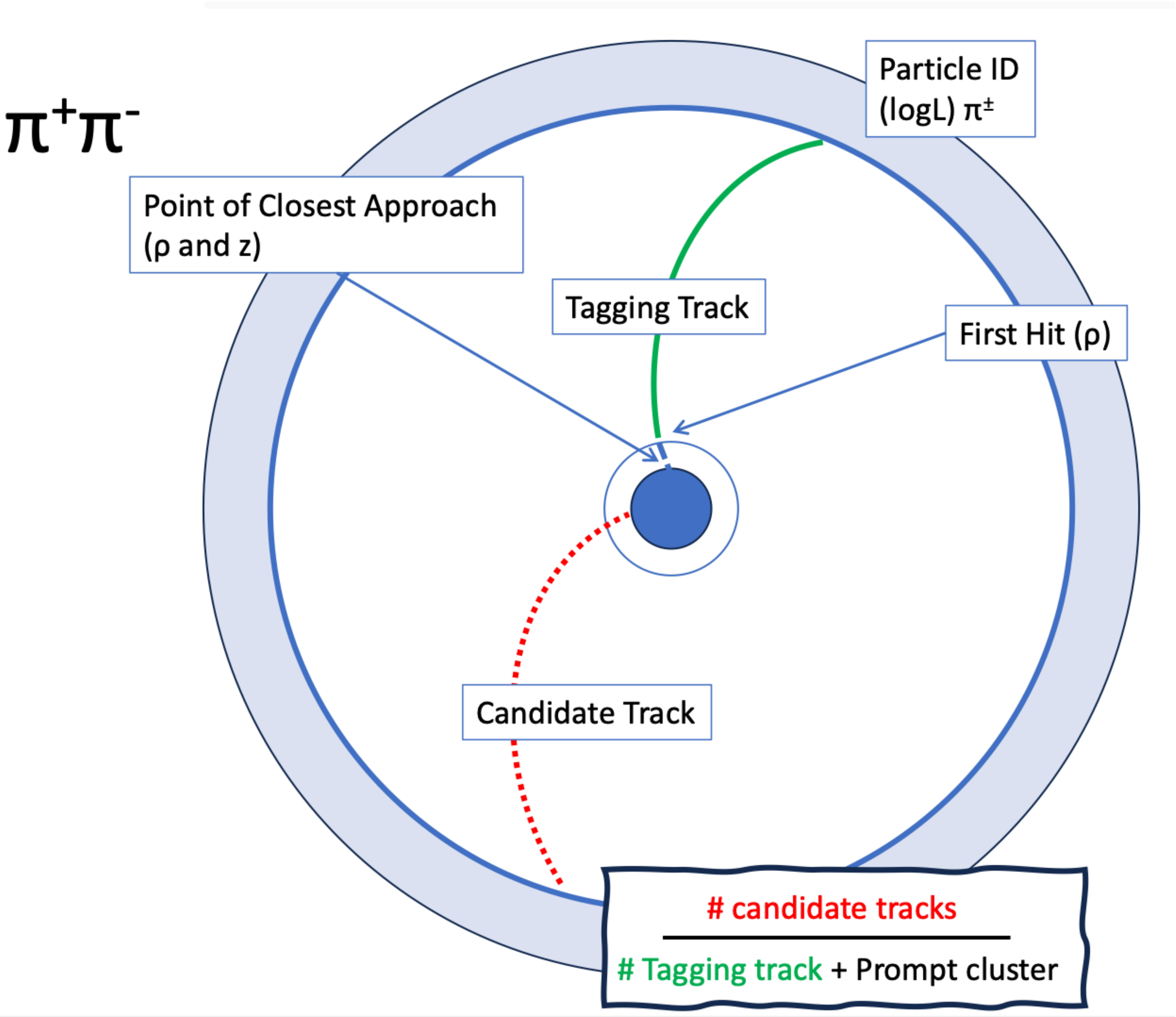


# Tracking




- **$\pi^+\pi^-\pi^0$ selections:**
  - $\sqrt{x_{fh}^2 + y_{fh}^2} < 50\text{cm}$
  - $\sqrt{x_{pca}^2 + y_{pca}^2} < 8\text{cm}$
  - $|Z_{pca}| < 7\text{cm}$
  - Must have associated cluster with particle identification LogLikelihood>1
- **Associated clusters to pions:**
  - Clusters with $E > 30\text{MeV}$
  - $R > 60\text{cm}$
  - $|m_{\gamma\gamma} - m_{\pi^0}| < 20\text{MeV}$
  - Neutral, i.e. not associated to any tracks
- **Tag and probe:**
  - Given the tagging track, $\pi^+(\pi^-)$, and two photons search for candidate track $\pi^-(\pi^+)$
- *Care is taken to not bias the sample through tracking selection (for example the tagging track is expected to satisfy the trigger)*

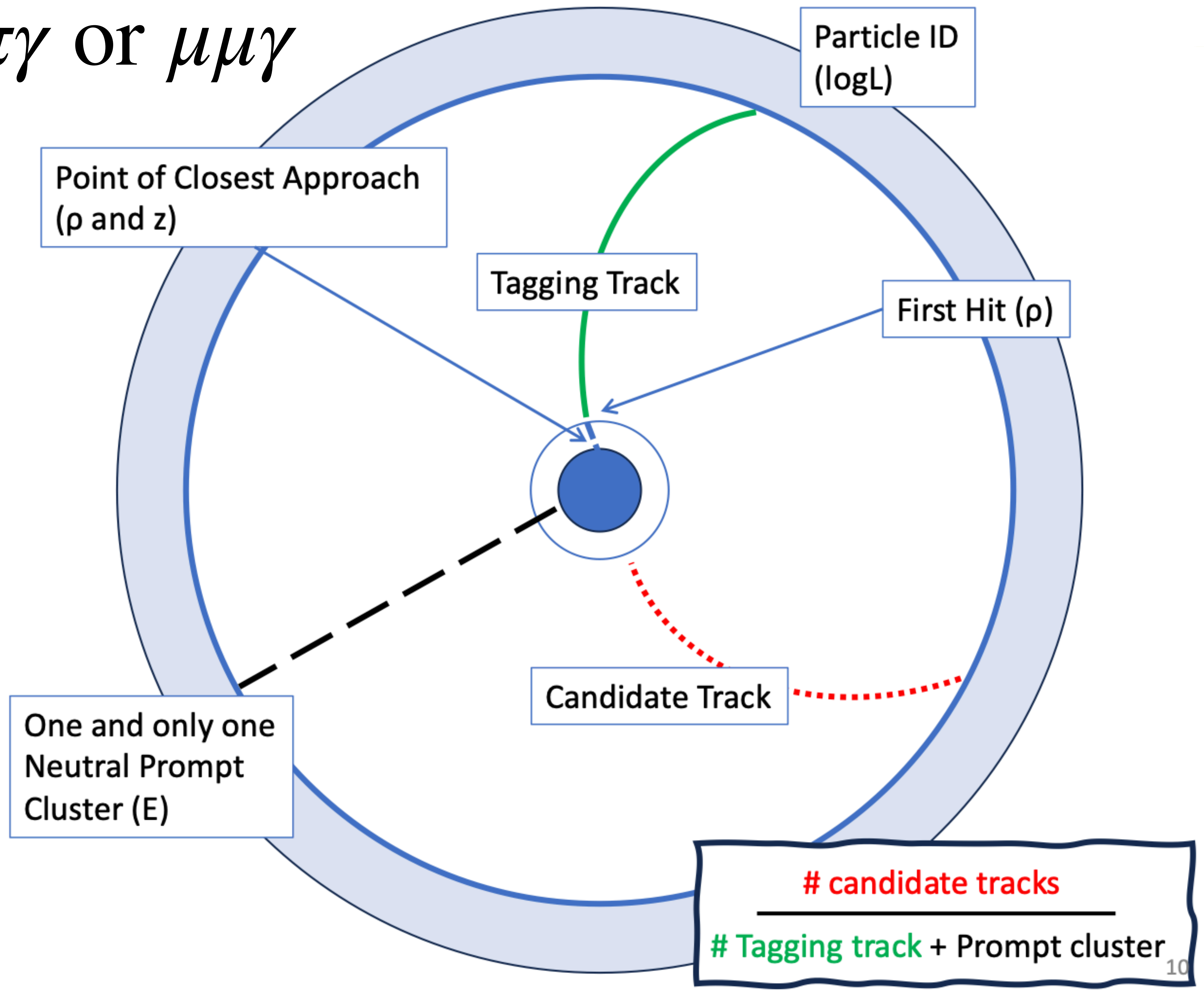
# Tracking




- **$\pi^+\pi^-$ selections:**
  - $\sqrt{x_{fh}^2 + y_{fh}^2} < 50\text{cm}$
  - $\sqrt{x_{pca}^2 + y_{pca}^2} < 8\text{cm}$
  - $|Z_{pca}| < 7\text{cm}$
  - Must have associated cluster with particle identification LogLikelihood>1
- **Associated clusters to pions:**
  - Clusters with $E > 50\text{MeV}$
  - Clusters are in the barrel and within $5ns < t < 8ns$
- **Tag and probe:**
  - Given the tagging track, $\pi^+(\pi^-)$, search for candidate track $\pi^-(\pi^+)$

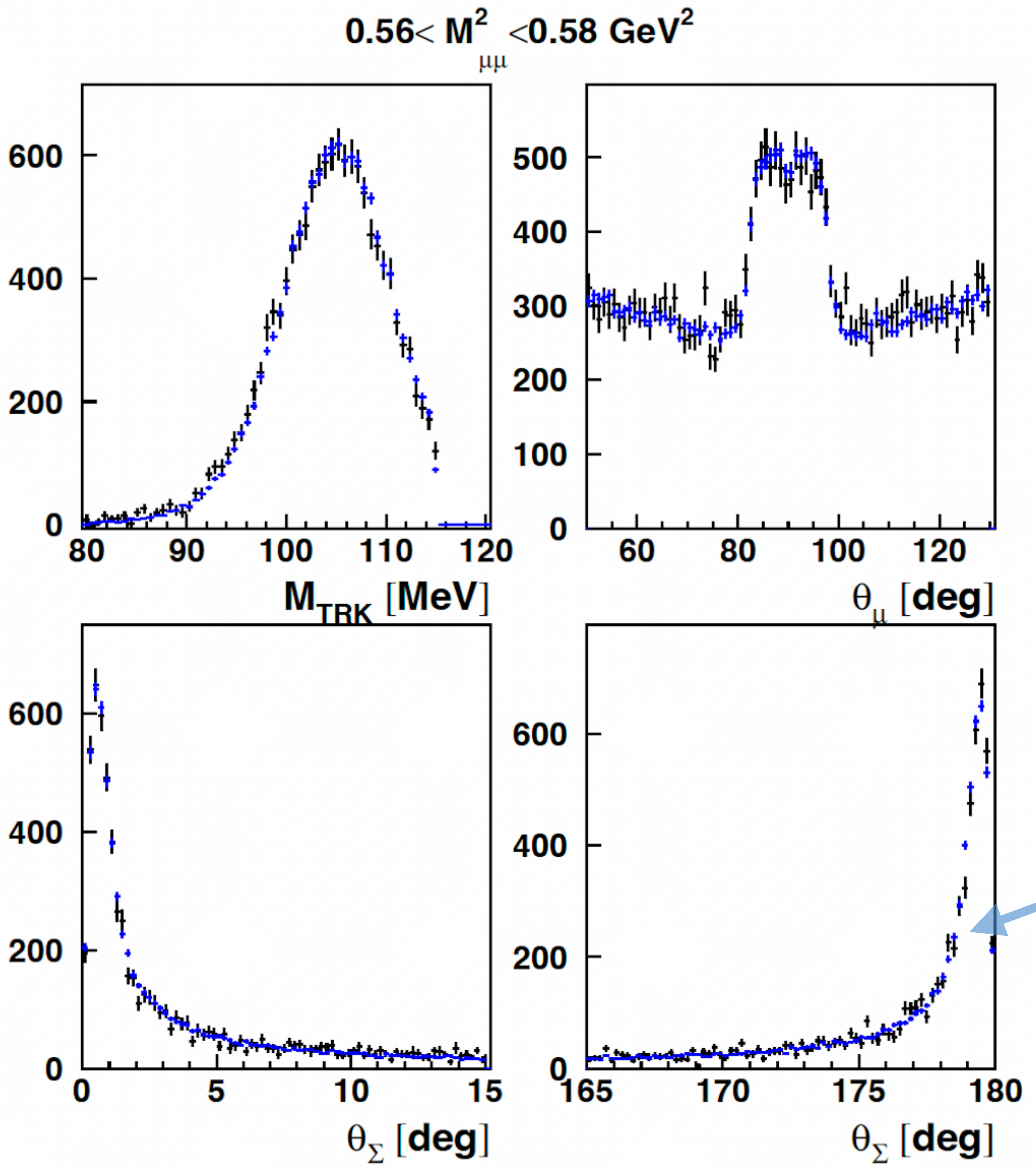
# Tracking

$\pi\pi\gamma$ or $\mu\mu\gamma$




- **$\pi\pi\gamma$ or $\mu\mu\gamma$ selections:**
  - $\sqrt{x_{fh}^2 + y_{fh}^2} < 50\text{cm}$
  - $\sqrt{x_{pca}^2 + y_{pca}^2} < 8\text{cm}$
  - $|Z_{pca}| < 7\text{cm}$
  - Must have associated cluster with particle identification LogLikelihood>1
- **Associated clusters to pions:**
  - Prompt cluster with $E > 50\text{MeV}$
  - Neutral, i.e. not associated to any tracks
- **Tag and probe:**
  - Given the tagging track, $\mu^+(\mu^-)$, search for candidate track $\mu^-(\mu^+)$

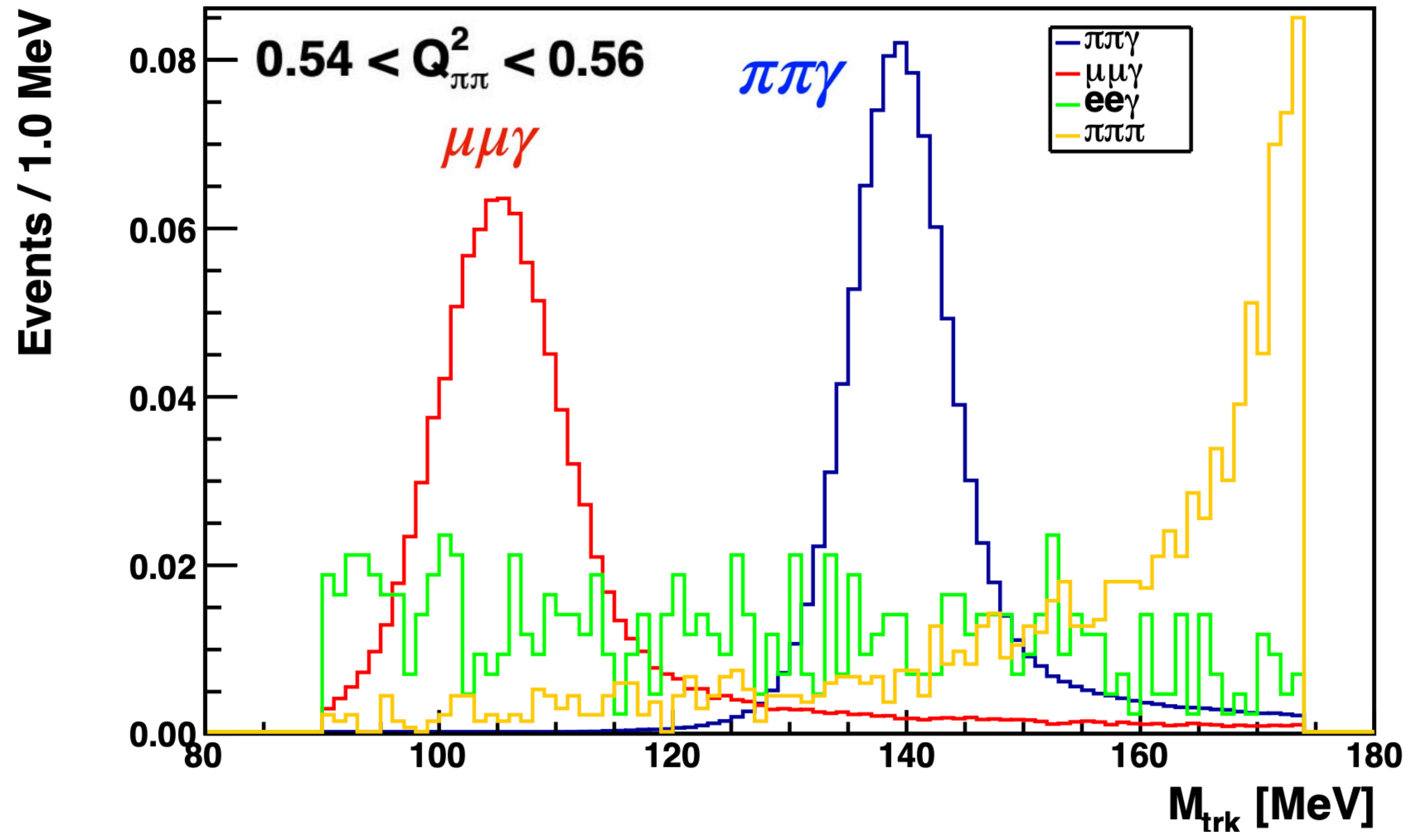
# Data MC Comparisons

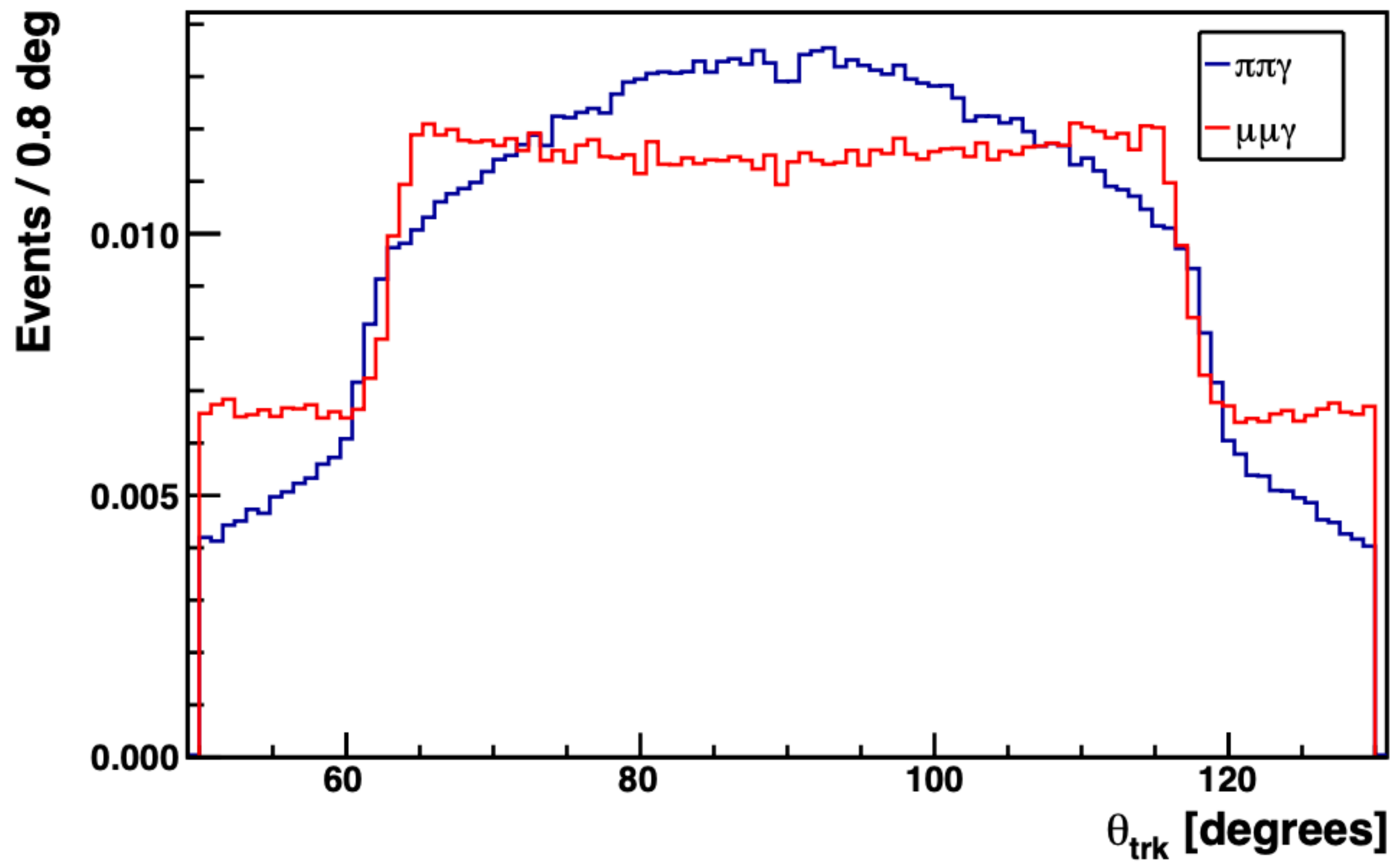



- **Aim:**
  - Comprehensively **improve Monte Carlo simulation** of data
- Ongoing work uses $\pi^+\pi^-\pi^0$, $\pi\pi\gamma$, $\mu\mu\gamma$, $\pi^+\pi^-$
- **Distribution comparisons** will be done for momentum and position variables as well as other track and cluster variables
- *Plot from KLOE12 analysis: Track mass, and polar angle θ for μ+μ−γ events. Data* ***black*** *and MC* ***blue****. The comparison is absolute*

# Background Subtraction

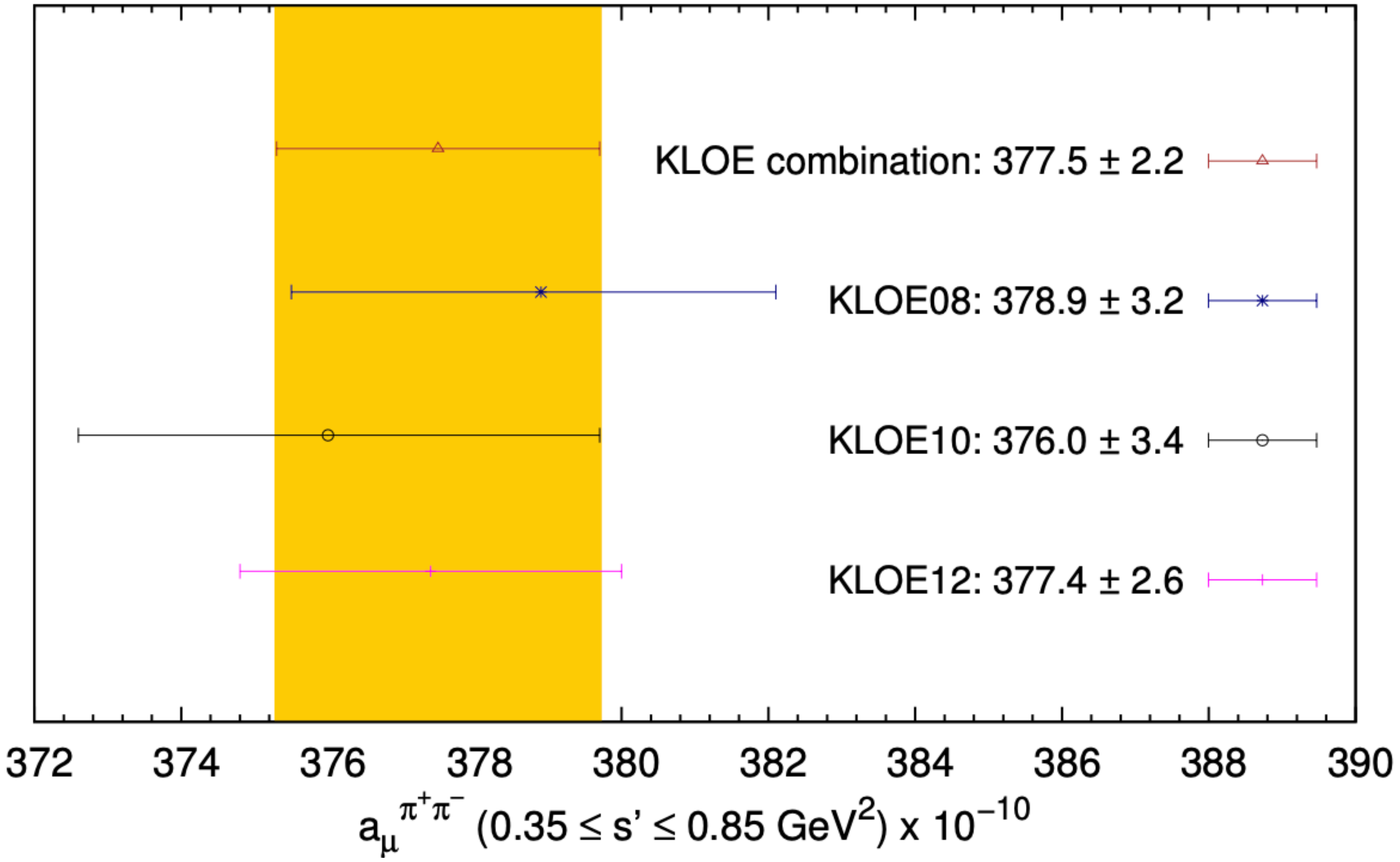
- **Background sources**
  - $e^+e^- \to \pi^+\pi^-\pi^0$, $e^+e^- \to \mu^+\mu^-\gamma$, $e^+e^- \to e^+e^-\gamma$
  - The objective is to estimate the total fraction $f$ of background events in individual slices of $Q^2_{\pi\pi}$: $f^i_B = f^i_{\mu\mu\gamma} + f^i_{ee\gamma} + f^i_{\pi\pi\pi}$
  - The number of events in each $Q^2_{\pi\pi}$ slice is scaled by $(1 - f^i_B)$
  - **Background subtraction procedure is the dominant of the KLOE12 systematics (accounting for ~85% of the total error)**
- **Progress**
  - Implementation and correctness of old procedure checked by reproducing result from previous analysis using new code
  - Previous analyses use $M_{trk}$ as the main discriminating variable for background subtraction
  - **Background fit results should be independent of variable chosen to fit on**
  - In order to improve the procedure other variables are being investigated as alternative or in addition to $M_{trk}$ e.g. polar angle wrt the beam axis $\theta_{trk}$
  - This will provide additional consistency and reduce the systematic uncertainties of the background subtraction



# Overview

- **In this talk:**
  - Current landscape of the muon anomaly $a_\mu$
  - DA$\phi$NE and the KLOE detector
  - KLOE08, KLOE10, KLOE12 analyses and results
  - New KLOE analysis (KLOE23) and its goals
  - Current work on:
    - Tracking
    - Blinding
    - Background Subtraction
    - Monte Carlo simulation
  - Look to future work to be done to produce an analysis result

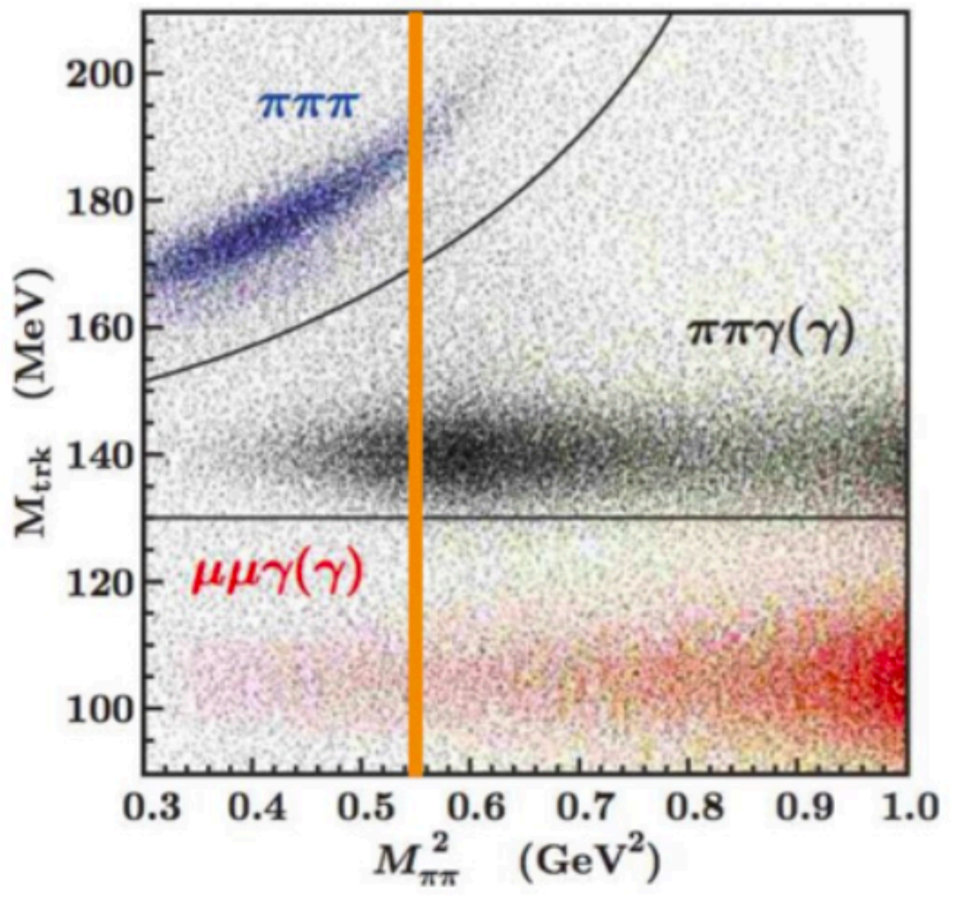


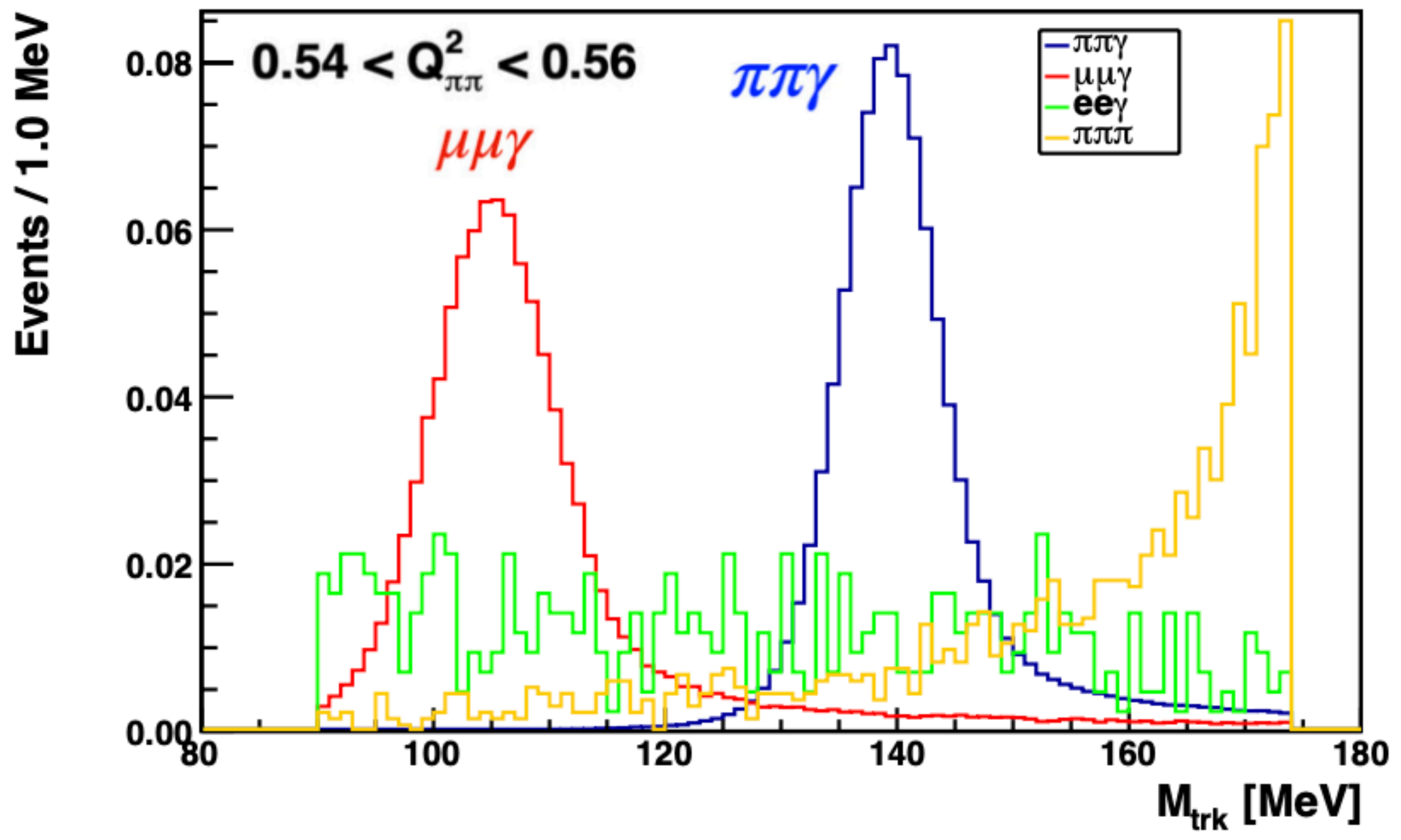
# Background Subtraction

In the KLOE $\sigma(e^+e^- \to \pi^+\pi^-)$ analyses after the angular cuts a final selection ("signal cut") is performed on the **trackmass** variable $M_{trk}$ $\longrightarrow$ used to define the signal region for $\pi^+\pi^-\gamma$ and $\mu^+\mu^-\gamma$.

$$M_{trk} \ : \quad \left(\sqrt{s} - \sqrt{|\vec{p}_+|^2 + M_{trk}^2} - \sqrt{|\vec{p}_-|^2 + M_{trk}^2}\right)^2 - (\vec{p}_+ + \vec{p}_-)^2 \equiv 0$$

$$e^+e^- \to X^+X^-\gamma \Longrightarrow M_{trk} = \hat{m}_X$$




- $80 < M_{trk} < 115$ MeV to select $\mu^+\mu^-\gamma$
- $M_{trk} > 130$ MeV to select $\pi^+\pi^-\gamma$

*Slides from L.Punzi*

# Background Subtraction for $\pi^+\pi^-\gamma$ Analysis

Three main backgrounds survive the cuts in addition to the signal ($\pi^+\pi^-\gamma$) :

$$e^+e^- \to \mu^+\mu^-\gamma(\gamma) \qquad e^+e^- \to e^+e^-\gamma(\gamma) \qquad e^+e^- \to \pi^+\pi^-\pi^0$$

The objective is estimating the total fraction $f_B^i$ of background events in each bin $i$ of $Q^2_{\pi\pi}$:

$$f_B^i = f^i_{\mu\mu\gamma} + f^i_{ee\gamma} + f^i_{\pi\pi\pi}$$

- Data $M_{trk}$ distribution is fitted in each bin $i$ with MC $M_{trk}$ distributions to find the fractions $F^i_\alpha$ of each channel $\alpha$.
- Fits are performed on the **entire range** of $M_{trk}$ (no signal cut) to increase sensitivity.
- Fractions in the **signal region** of $M_{trk}$ ($f^i_\alpha$) are calculated using the weights $w^i_\alpha$:

$$w^i_\alpha \equiv F^i_\alpha \frac{N^i_{dat}}{N^i_{mc,\alpha}} \quad \Longrightarrow \quad f^i_\alpha = w^i_\alpha \frac{n^i_{mc,\alpha}}{n^i_{dat}} = F^i_\alpha \frac{N^i_{dat}}{N^i_{mc,\alpha}} \frac{n^i_{mc,\alpha}}{n^i_{dat}}$$

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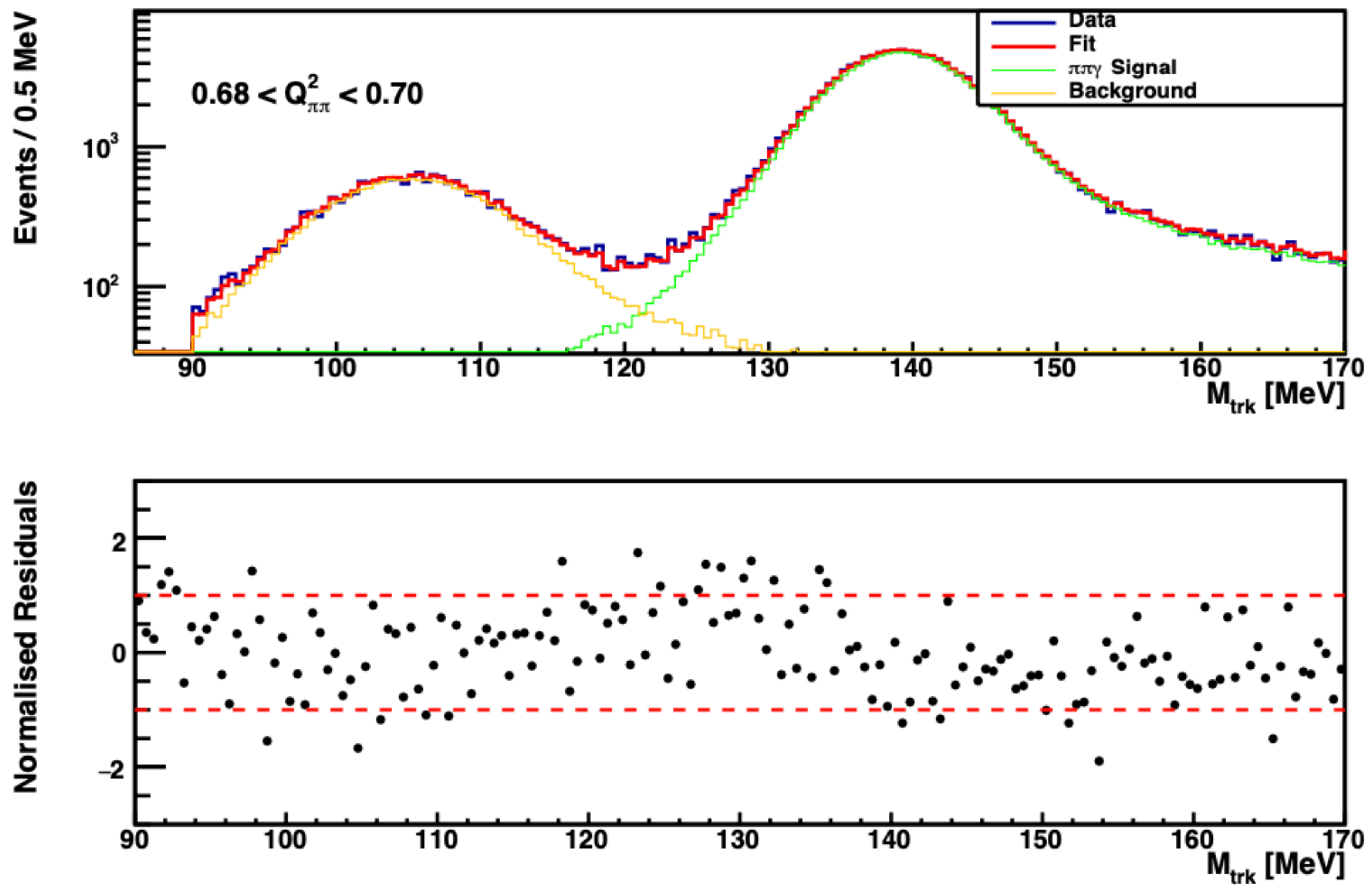
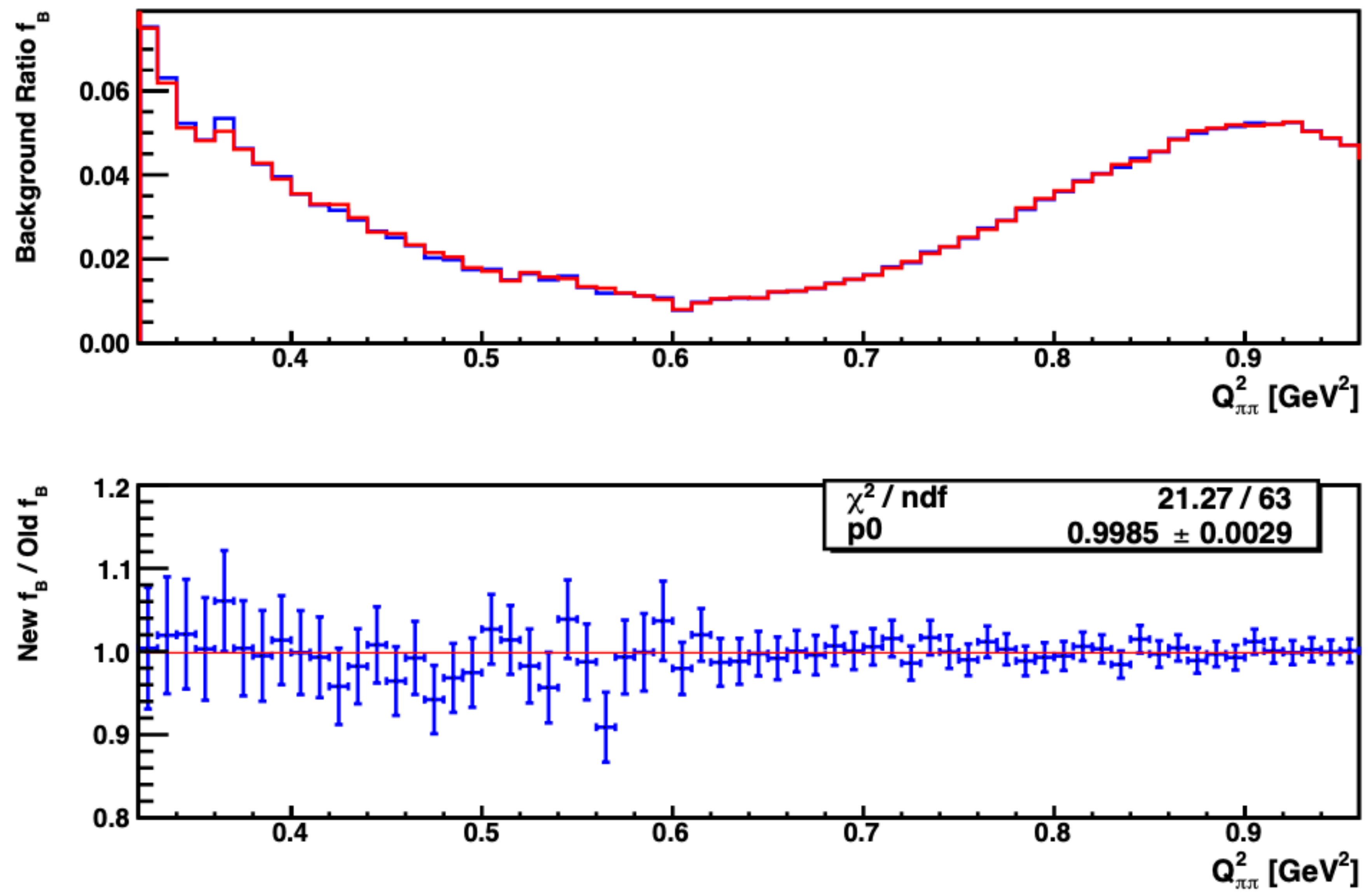
# Reproducing the KLOE08 Background Fit on $M_{trk}$

The KLOE08 background fit using $M_{trk}$ ($\pi^+\pi^-\gamma$ analysis) was successfully **reproduced using newer software** (`C++` instead of `Fortran+Perl`).




Fit on $M_{trk}$ in a bin of $Q^2_{\pi\pi}$.




Comparison of old and new results for $f_B^i$.

$$f_B^i = f_{\mu\mu\gamma}^i + f_{ee\gamma}^i + f_{\pi\pi\pi}^i \text{ in bin } i \text{ of } Q^2_{\pi\pi}.$$

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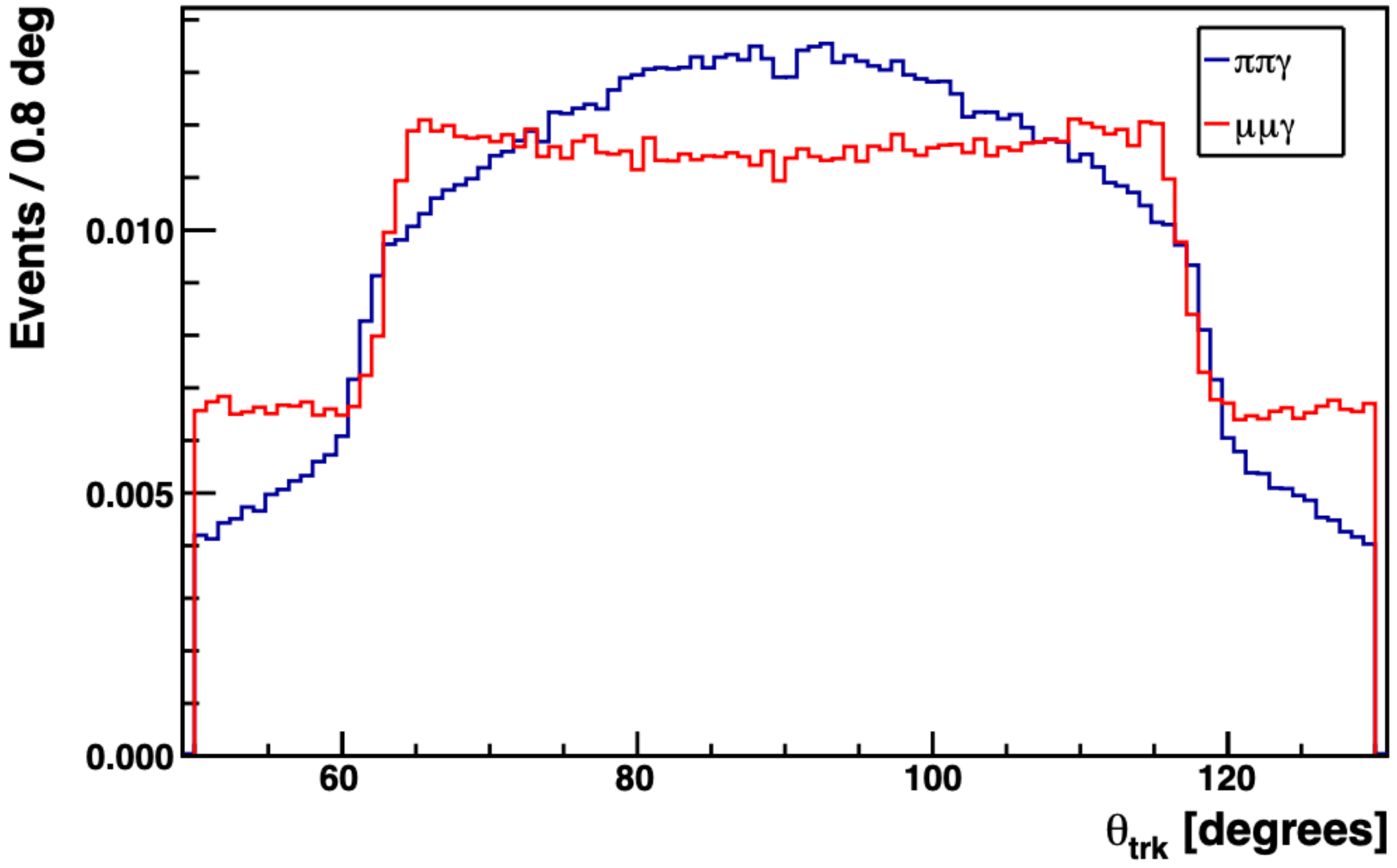
# New Fit Variable : $\theta_{trk}$

- Background fit can in principle be performed on **any variable** $\longrightarrow$ $M_{trk}$ was chosen for its good separation between $\pi^+\pi^-\gamma$ and $\mu^+\mu^-\gamma$.
- Considering new fit variables can increase **confidence** in result and possibly increase **precision**.
- New variable: polar angle of charged particles $\theta_{trk}$ has been studied as a fit variable.




- Different distribution due to different spin of $\pi$ and $\mu$.
- Less separation compared to $M_{trk}$.

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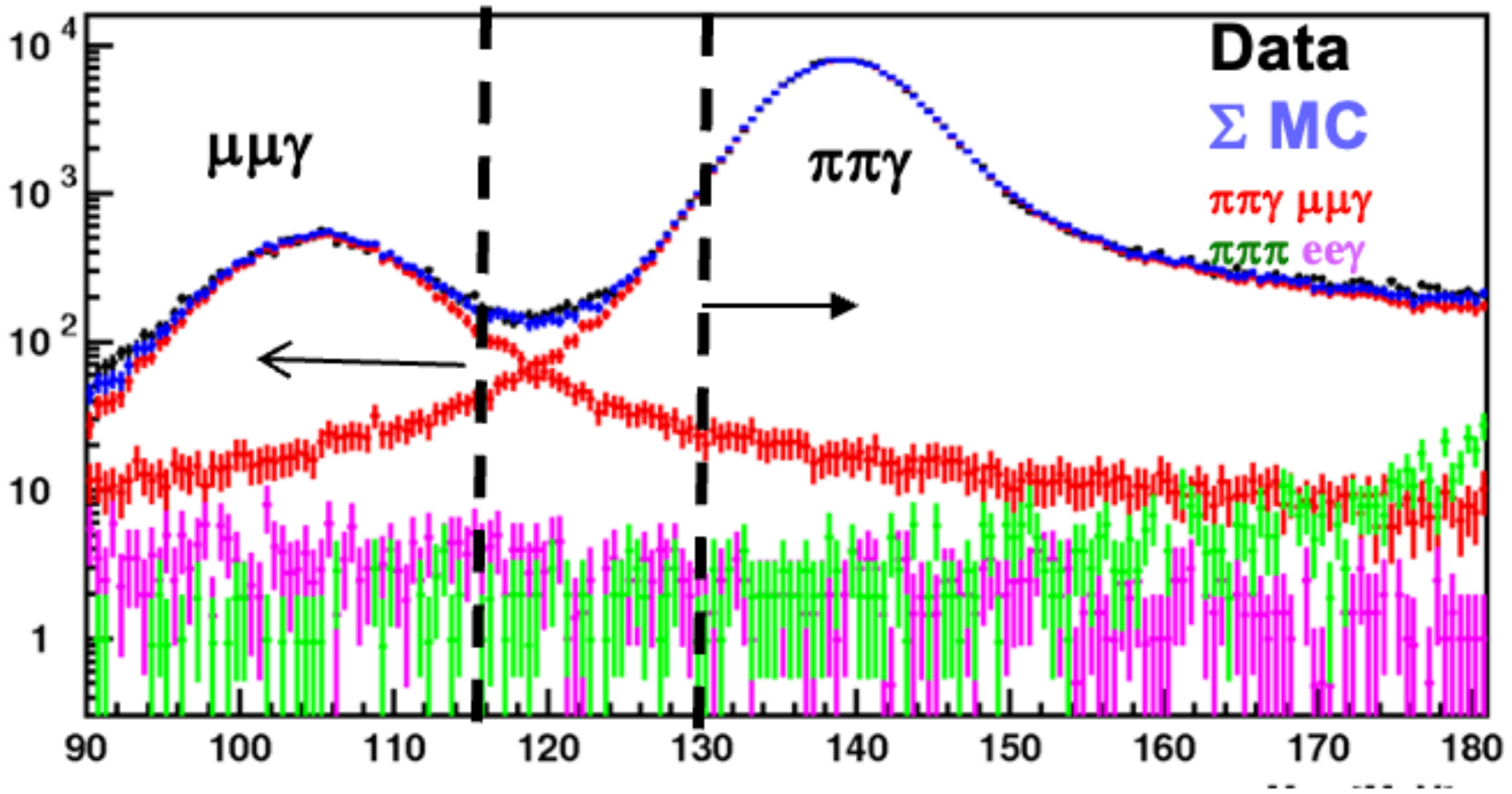
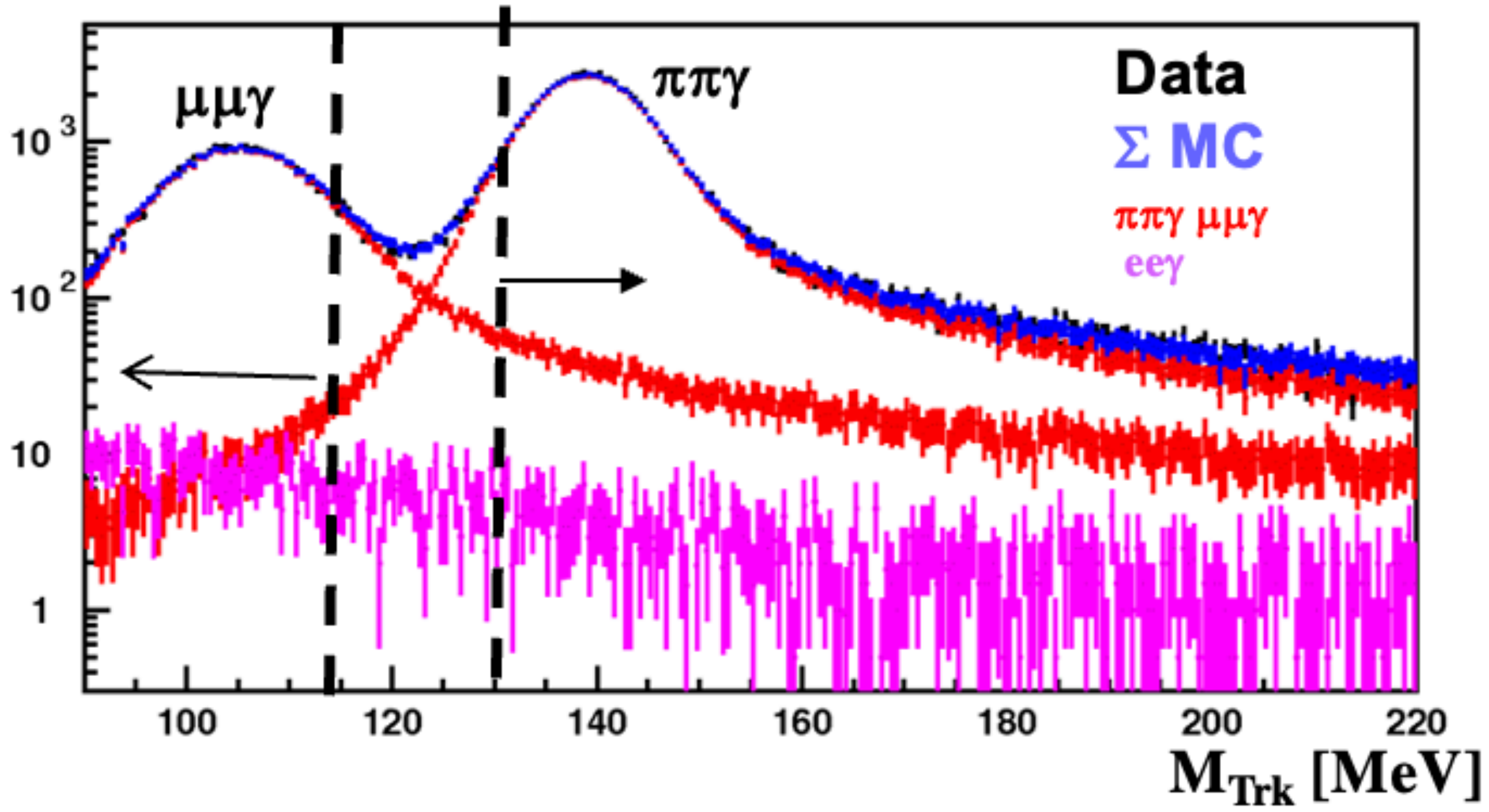
# Background:

Main backgrounds estimated from MC shapes fitted to data distribution in $M_{Trk}$ ($\pi\pi\gamma/\mu\mu\gamma$, $\pi\pi\pi$, $ee\gamma$)

$0.60 < M_{\pi\pi}^2 < 0.62$ GeV$^2$, $\chi^2$/ndof = 158/180

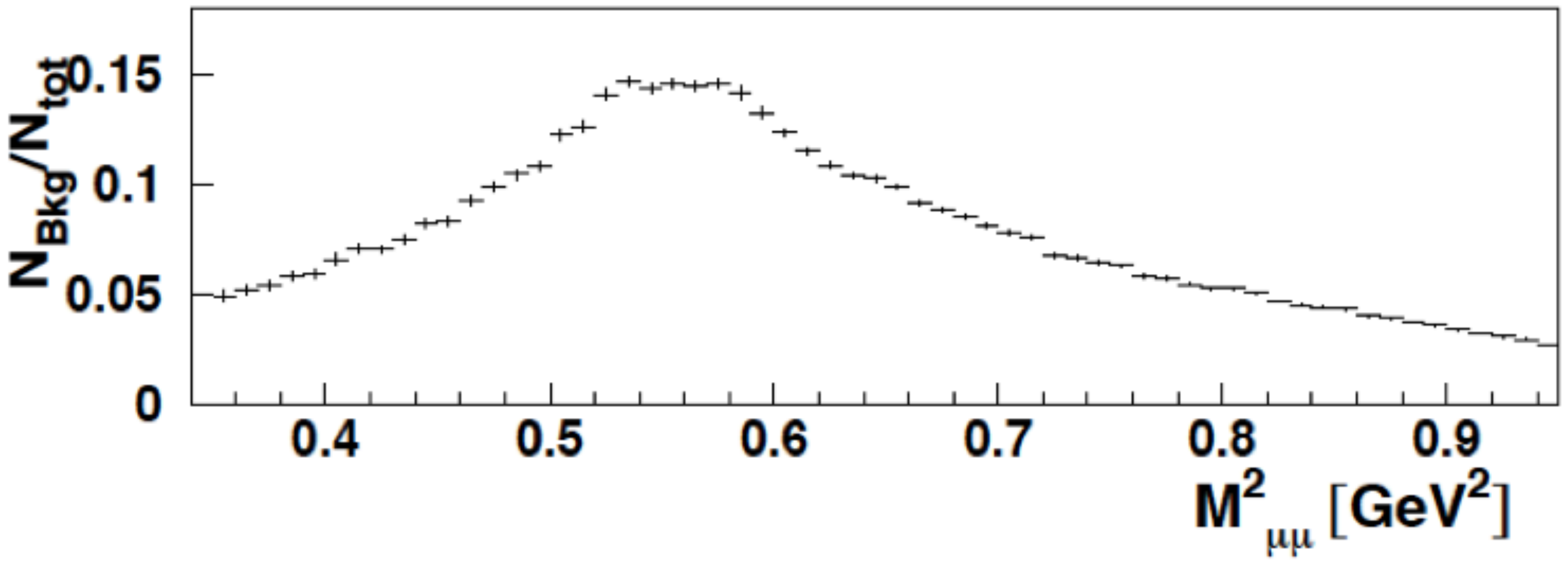



$0.84 < M_{\pi\pi}^2 < 0.86$ GeV$^2$ $\chi^2$/ndof = 179/258

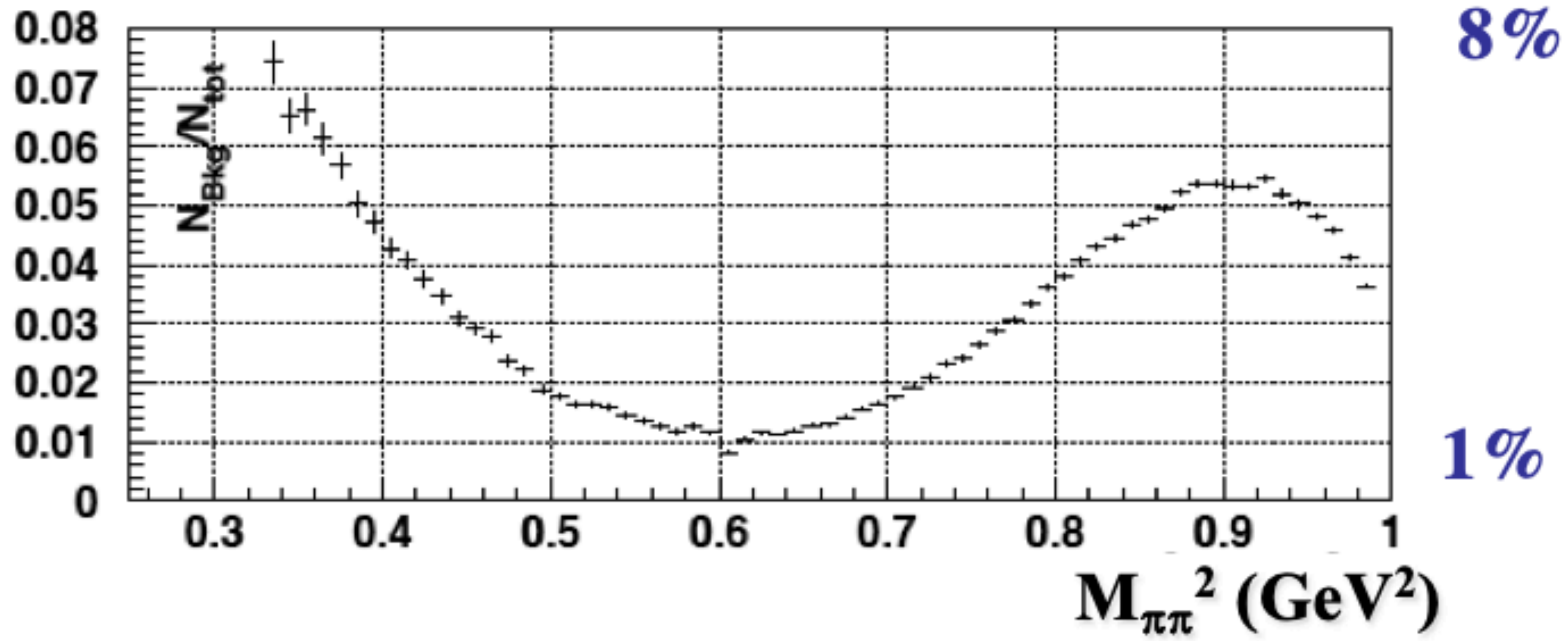



G. Venanzoni - CSN1- 4/12/12

## Tot % bckg to $\mu\mu\gamma$




## Tot % bckg to $\pi\pi\gamma$




- Systematic error on $\mu\mu\gamma$ due to background~1% in the $\rho$ peak

# $\pi/\mu$ separation: control of $\pi\pi\gamma$ $M_{TRK}$ tail

- A careful work has been done to achieve a control of ~1% in the muon selection, especially ~0.6 GeV$^2$ ($\rho$ peak) where $\pi/\mu \sim 10$.
- $\pi\pi\gamma$ % background to $\mu\mu\gamma$ signal ($M_{TRK}$<115 MeV) is ~15% at $\rho$ peak
- ➔ $\pi\pi\gamma$ $M_{TRK}$ tail in the $\mu\mu\gamma$ region must be well under control.
- $\pi\pi\gamma$ $M_{TRK}$ tail tuned using $\phi \to \pi^+\pi^-\pi^0$ control sample.
- Excellent agreement on $M_{TRK}$ ($\pi\pi\gamma$ and $\mu\mu\gamma$) distributions