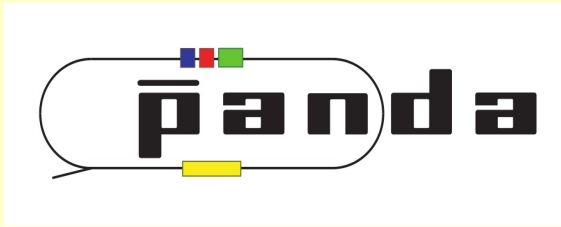


March 11th 2014



Update on simulations concerning time-like form factors from

$$\bar{p} p \rightarrow \mu^+ \mu^-$$

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Motivation

- The differential cross section¹ for the muonic channel $\bar{p} p \rightarrow \mu^+ \mu^-$ gives access to the moduli of the **time-like electromagnetic form factors**

G_E and G_M :

$$\frac{d\sigma}{d \cos \theta_{CM}}(s, \theta) = \frac{\alpha^2 \pi}{2 \cdot s} \cdot \frac{p_l^-}{\bar{p}} \cdot |G_M|^2 \left[\frac{4M_p^2}{s} (1 - \beta^2 \cos^2 \theta_{CM}) \cdot R^2 + \left(1 + \frac{4m_l^2}{s} + \beta^2 \cos^2 \theta_{CM} \right) \right]$$

- Extract $|G_E|$ and $|G_M|$
- Strong hadronic background, mainly $\bar{p} p \rightarrow \pi^+ \pi^-$

$$R = \frac{|G_E|}{|G_M|}$$

$$\frac{\sigma(\mu^+ \mu^-)}{\sigma(\pi^+ \pi^-)} \propto 10^{-6}$$

1) first derived by A.Zichichi et al., Nuovo Cimento XXIV,170 (1962)

Simulation & Analysis

- **Simulations** for both **signal and background** (10^6 events) at beam momentum of 1.5 GeV/c
 - PandaRoot trunk version (linked to external packages apr13)

Event generators:

PndLepLepGenerator $\bar{p} p \rightarrow \mu^+ \mu^-$

PndPiPiGenerator $\bar{p} p \rightarrow \pi^+ \pi^-$

(Manuel Zambrana, HIM)

- **Analysis:** Available PID and different cuts to achieve good **background suppression**

Simulation & Analysis

Analysis: for both signal & main background channel

Muon mass hypothesis → *Fill lists with positive / negative candidates*

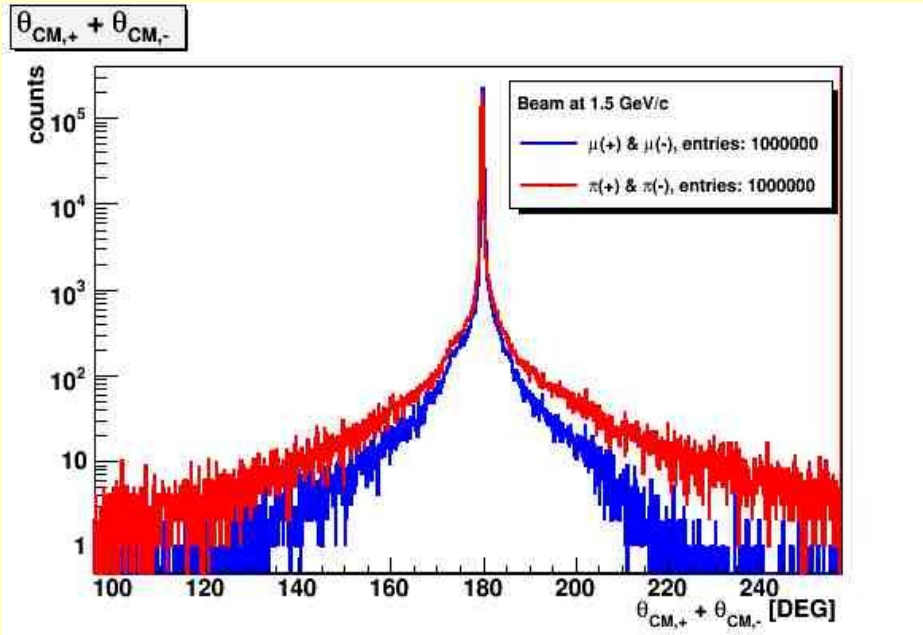
→ *combination to pairs*

PID	$P(\mu^-)_{STT}; P(\mu^-)_{EMC}$	> 0.05
	$P(\mu^+)_{STT}; P(\mu^+)_{EMC}$	> 0.05
	$P(\mu^+)_{EMC+MDT+STT}; P(\mu^-)_{EMC+MDT+STT}$	> 0.999999
Additional Cuts:	Invariant mass [GeV/c]] 2.23 , 2.27 [
	$\theta^+_{CM} + \theta^-_{CM}$ [DEG]] 179.9 , 181.5 [
	$ \varphi^+_{lab} - \varphi^-_{lab} $ [DEG]] 179.0 , 181.0 [
	Number of Hits MDT] 7 , 21 [
	Path length inside iron [cm]	> 32.0
	Deposited energy in 5x5 cluster EMC [GeV]	> 0.15
	Deposited energy in 3x3 cluster EMC [GeV]	> 0.05
	Number of fired crystals EMC	< 5

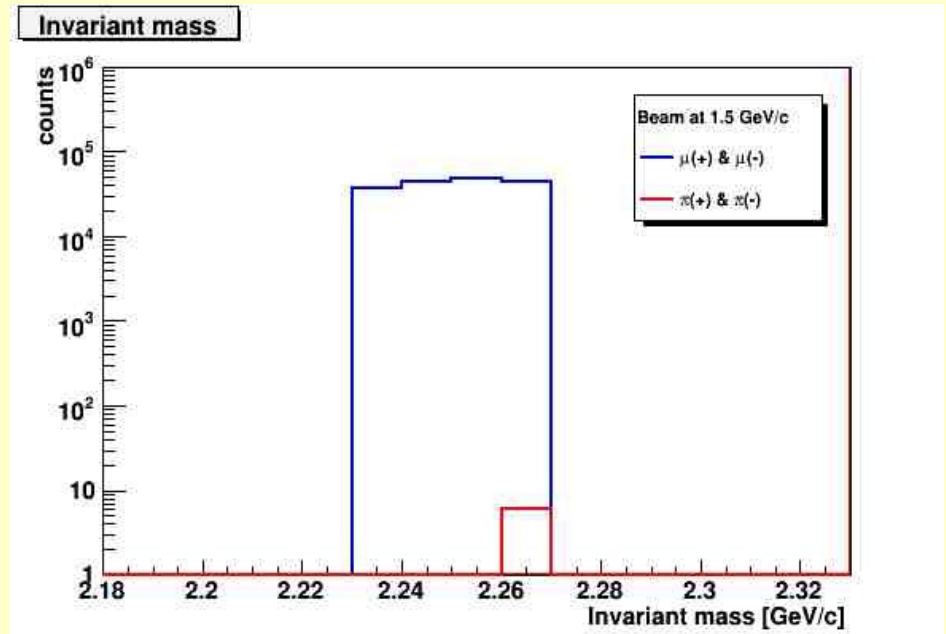
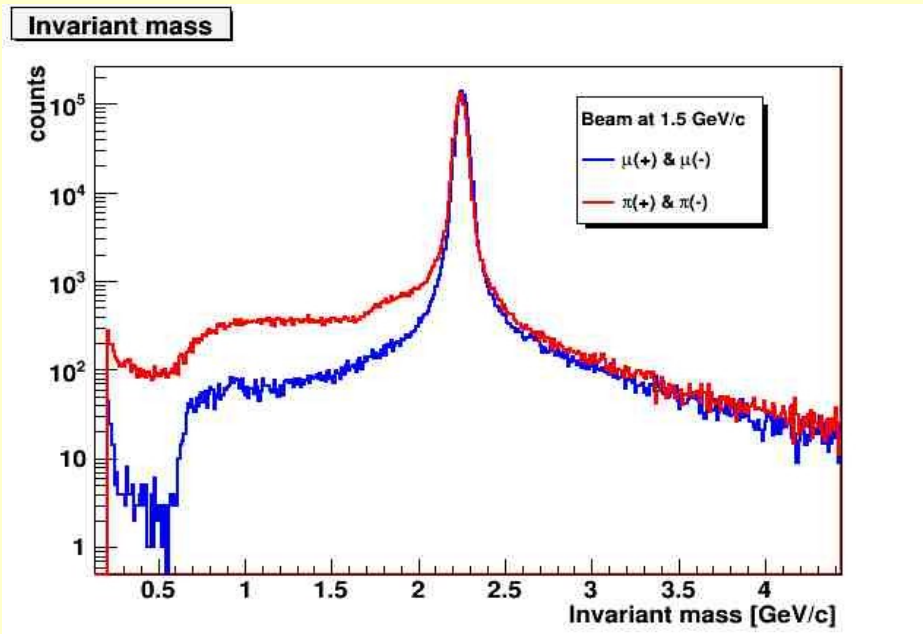
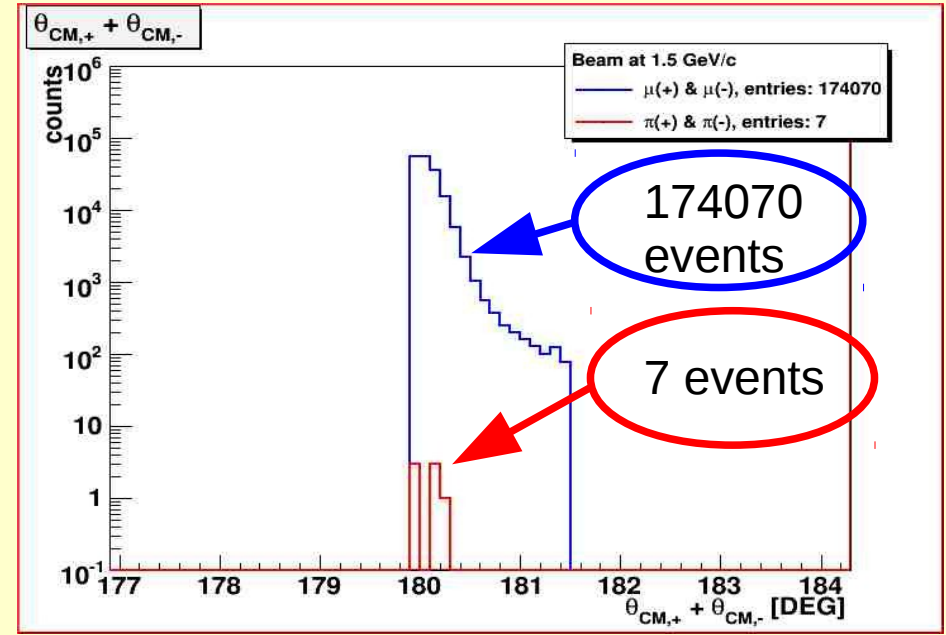
Analysis

- MDT
- STT
- EMC

No PID & No ADDITIONAL CUTS

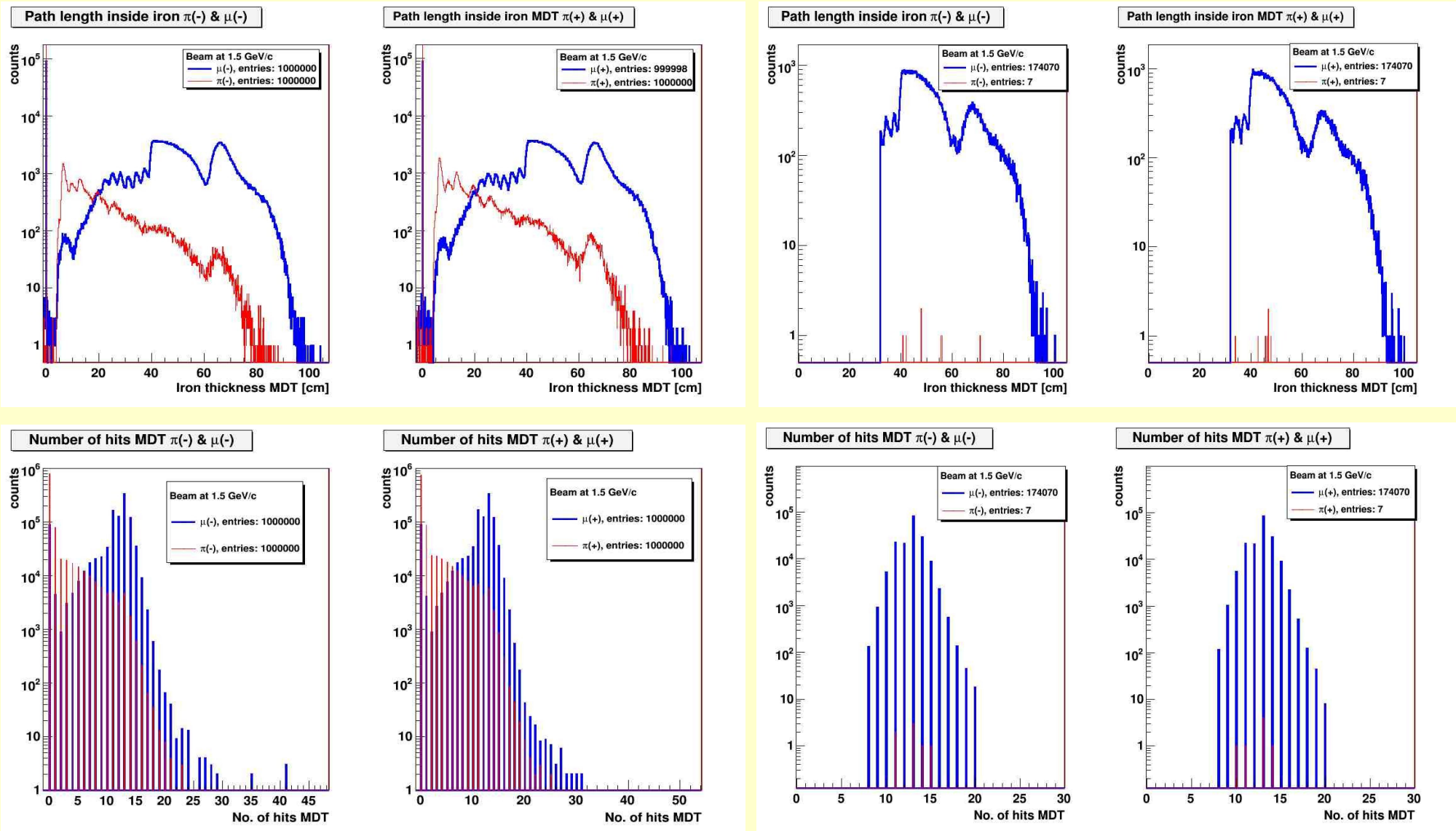


After PID & ADDITIONAL CUTS



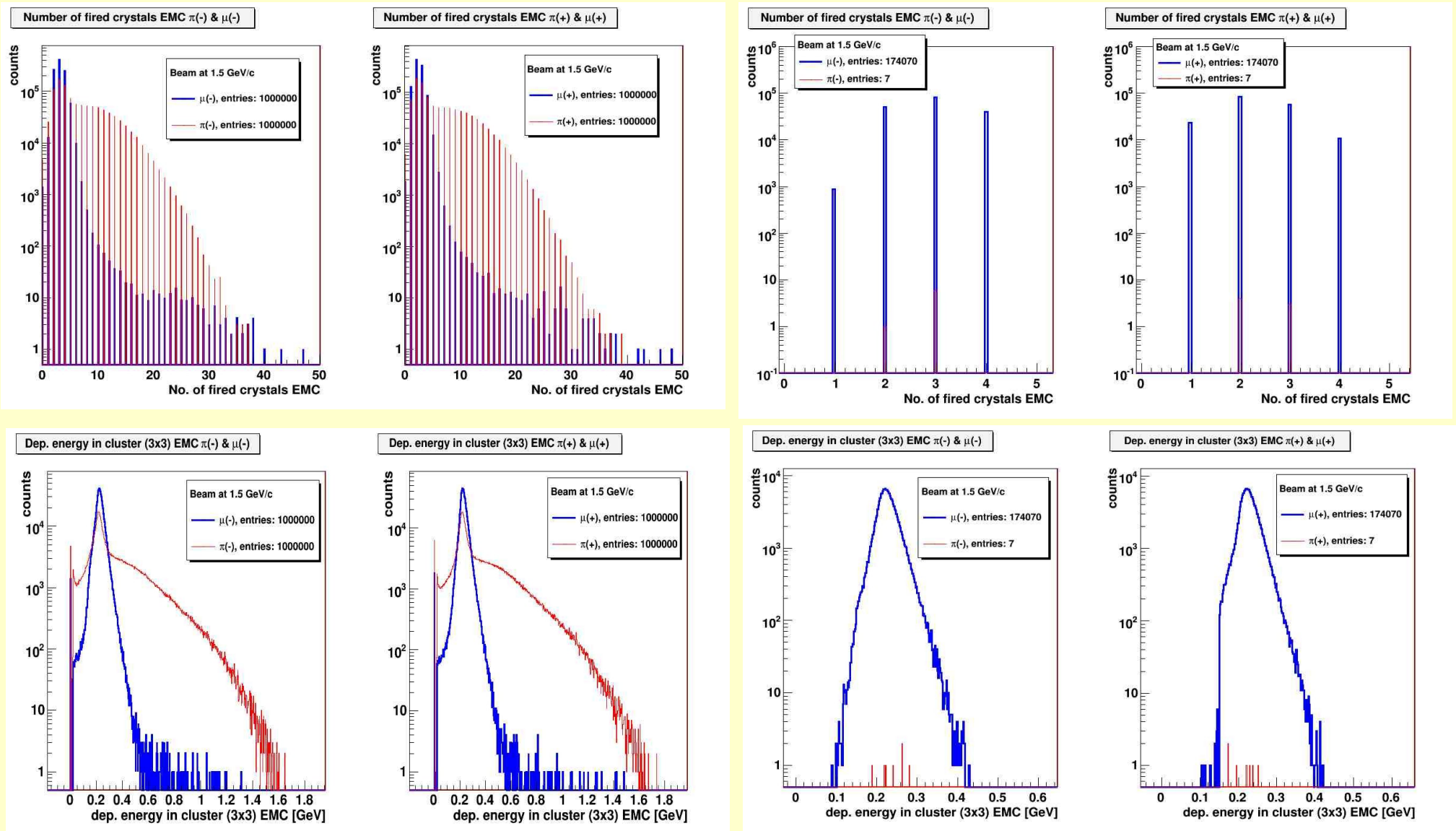
NO PID & NO ADDITIONAL CUTS

PID & ADDITIONAL CUTS



NO PID & NO ADDITIONAL CUTS

PID & ADDITIONAL CUTS



Preliminary results of test sample

1.5 GeV/c beam momentum	#No. of signal events	#No. of background events
Monte Carlo Simulation	10^6	10^6
After PID	660918 ($\sim 66.092\%$)	389 ($\sim 3.89 \cdot 10^{-2}\%$)
After PID + additional cuts	174070 ($\sim 17.407\%$)	7 ($\sim 7.00 \cdot 10^{-4}\%$)
After PID + additional cuts NO EMC USED	221808 ($\sim 22.181\%$)	38 ($\sim 3.8 \cdot 10^{-3}\%$)

Background: 7 events out of 10^6 MC-generated events survive PID & additional cuts in our test sample

→ upper limit (at 95% CL): 13 events

Summary & Outlook

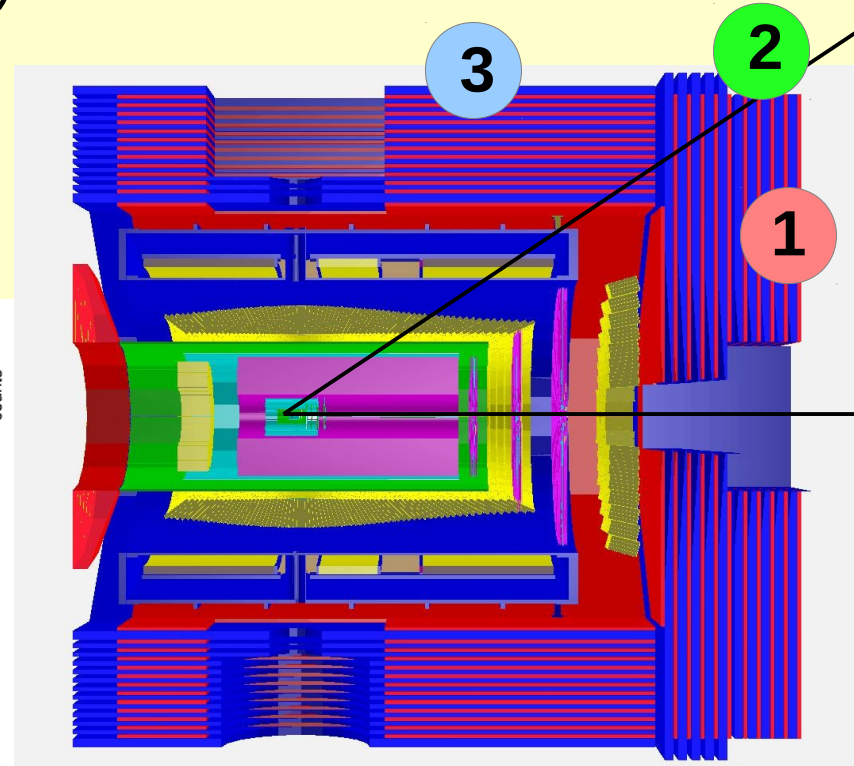
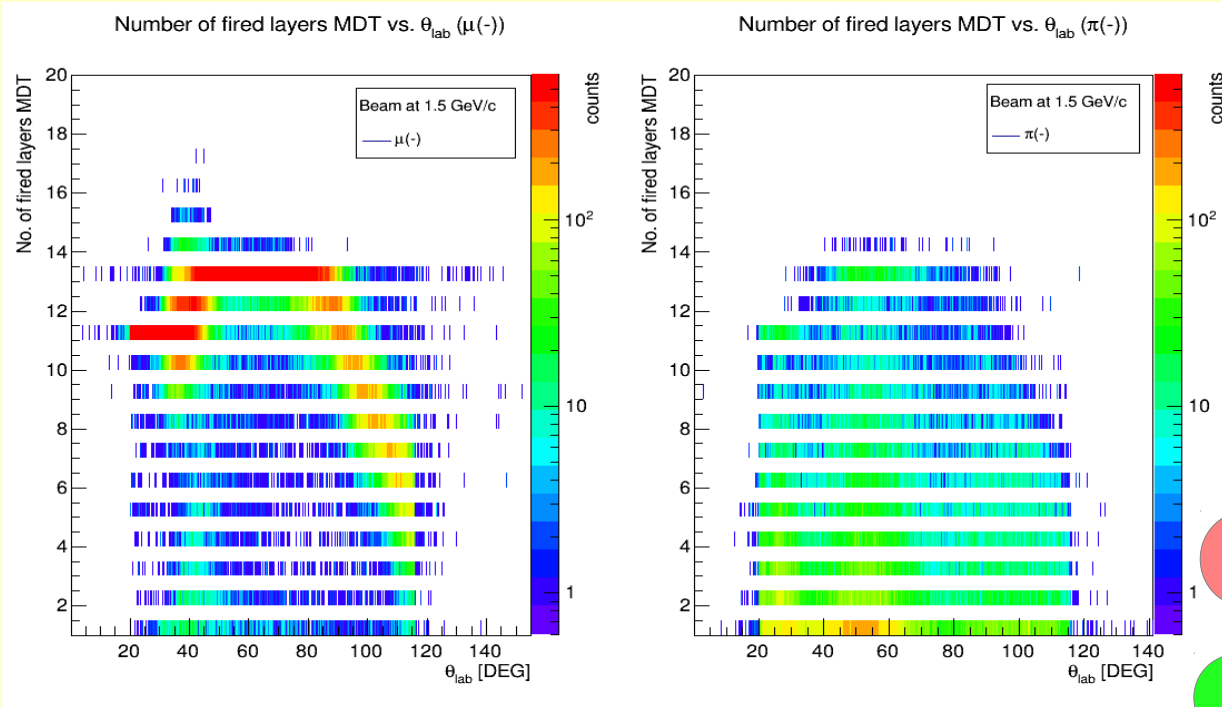
- **Simulation & Analysis: 10^6 Monte-Carlo generated events** for both **signal and main background process** at **1.5 GeV/c** beam momentum
 - After PID & additional cuts still surviving background events in test sample
- Separate studies using **kinematical fitting (4-Constraint fitting)** in progress
- **Cut optimization** using Monte-Carlo Generator in progress
- Usage of **multivariate data analysis** (TMVA Toolkit in ROOT): Artificial neural networks etc. for muon pion separation
- **Background simulation study of 10^8 events** in progress

Backup Slides

Muon Range System

1.5 GeV/c beam momentum

No PID & No ADDITIONAL CUTS



1

Endcap & Muon-Filter:
11 detection layers of Mdt

2

$\sim 40^\circ$ polar production angle:
overlap region Barrel & Endcap:
“Hybrid tracking”

3

Barrel: 13 detection layers

4

Forward Range System (FRS)
(not shown): 16 detection layers

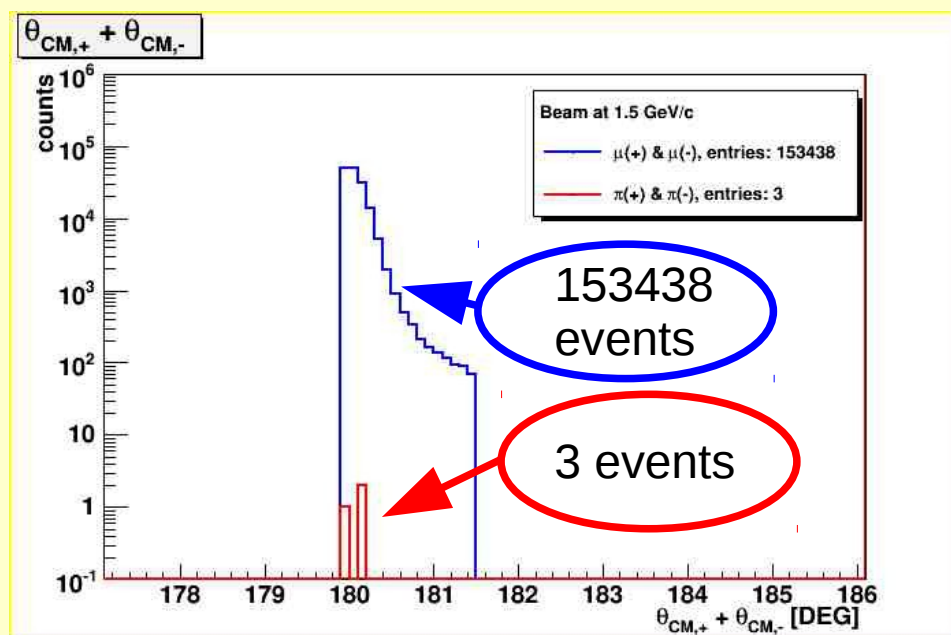
Muon mass hypothesis

10^6 events

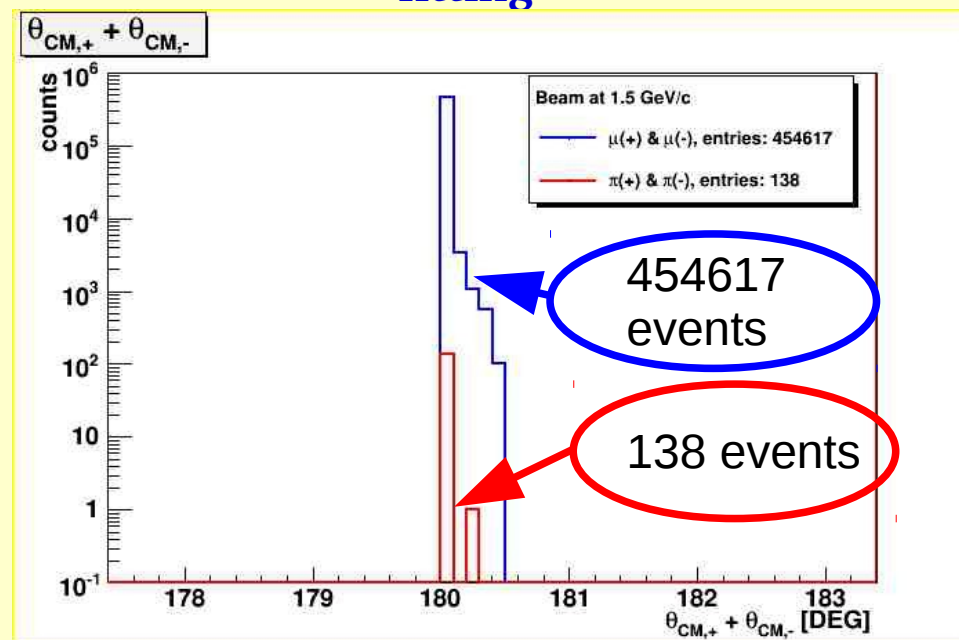
PRELIMINARY Analysis

RHO Classes: Usage of Combinatorics & Kinematical Fitting (4-Constraint)

After PID & ADDITIONAL CUTS*
Combinatorics & **NO** kinematical fits



After PID & ADDITIONAL CUTS*
Combinatorics & **4-Constraint fitting**



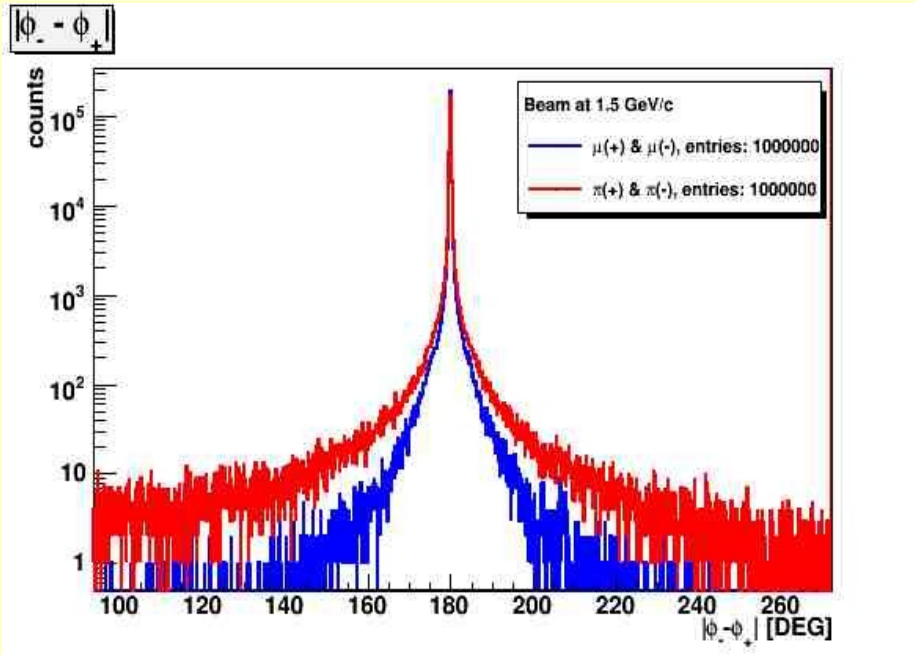
- MDT
- STT
- EMC

Kinematical fitting leads to **increasing numbers** of surviving signal & background events for the same **PID & additional cuts**.
→ Cut optimization needed (in progress)

Analysis

- MDT
- STT
- EMC

NO PID & NO ADDITIONAL CUTS



PID & ADDITIONAL CUTS

