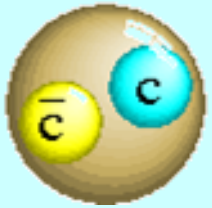
Physics with antiprotons at Panda:
software development @ DFG

Stefano Spataro

New Charmonium resonances



X(3872), Belle 09'2003, 1^{++}, χ_{c1}' or D^0D^* molecule

- decays into $J/\psi\pi^+\pi^-$, $J/\psi\pi^+\pi^-\pi^0$, $J/\psi\gamma$, D^0D^*

Y(3940), Belle 09'2004, JP^+, 2^3P_1??

- decays into $J/\psi\omega$

Y(4260), BaBar 06'2005, 1^{--}, 2^3D_1 (BaBar) or 4^3S_1 (CLEO) or Hybrid

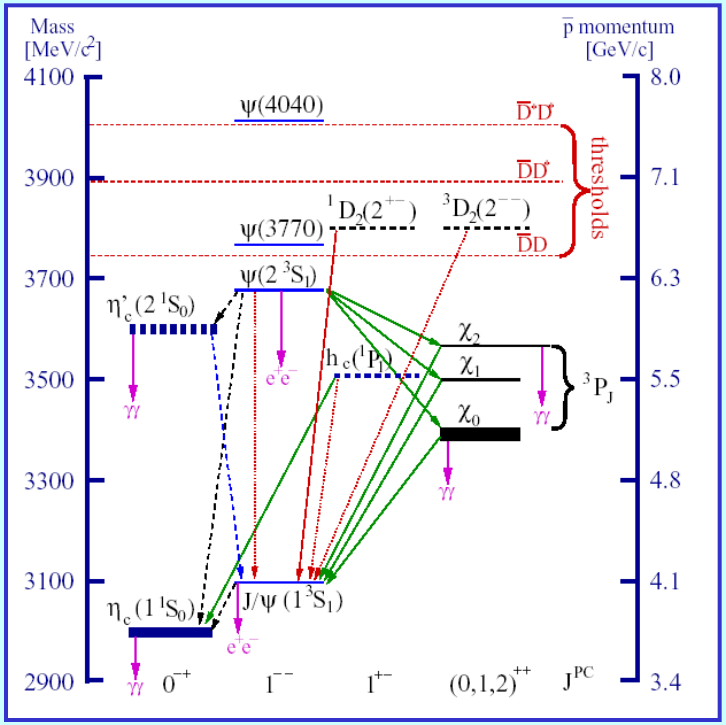
- decays into e^+e^-, $J/\psi\pi^+\pi^-$, $J/\psi\pi^0\pi^0$, $J/\psi K^+K^-$

X(3940), Belle 07'2005, 0^{-+}, η_c''

- decays into D^0D^*

Z(3930), Belle 07'2005, 2^{++}, χ_{c2}'

- decays into $\gamma\gamma$, DD



Why antiprotons?

with e^+e^- collisions
ONLY
1^- states are populated

or ISR

$$e^+e^- \rightarrow \Psi' \rightarrow \gamma \chi_{C1,2} \rightarrow \gamma\gamma J/\psi \rightarrow \gamma\gamma e^+e^-$$

Production

$$Br(e^+e^- \rightarrow \psi) \cdot Br(\psi \rightarrow \gamma\eta_c) = 2.5 \cdot 10^{-5}$$

with $\bar{p}p$ collisions
ALL POSSIBLE
states are populated

$$\bar{p}\,p \rightarrow \chi_{C1,2} \rightarrow \gamma J/\psi \rightarrow \gamma e^+e^-$$

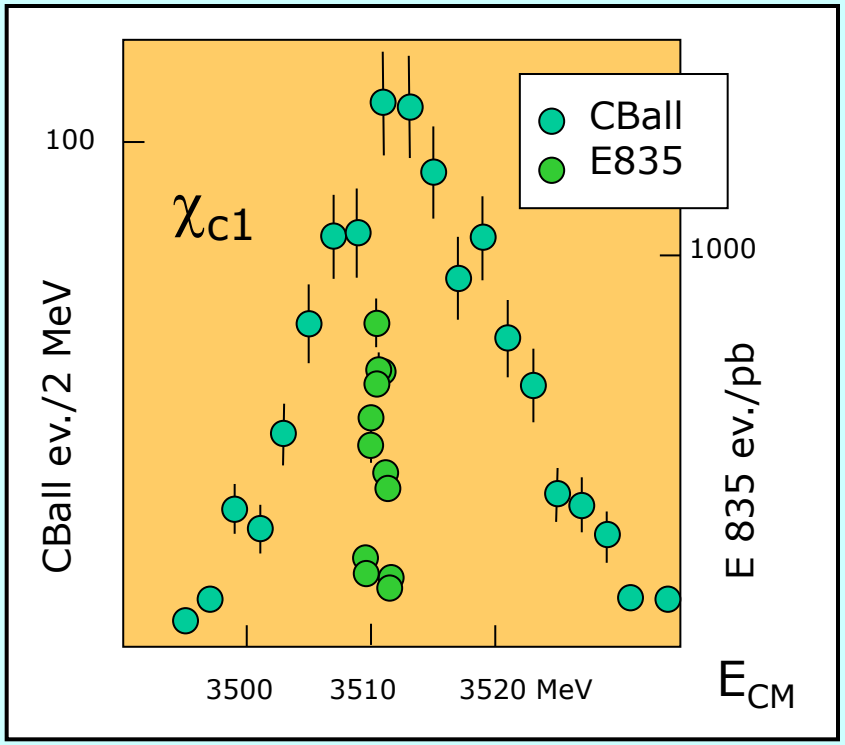
Formation

$$Br(\bar{p}p \rightarrow \eta_c) = 1.2 \cdot 10^{-3}$$

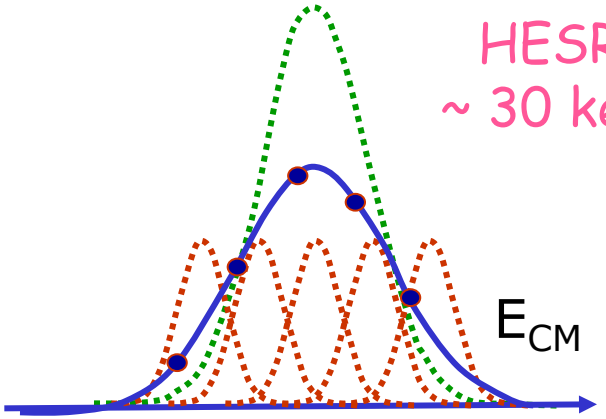
Why antiprotons?

Formation ⇒ Higher cross sections

No dependency on detector resolution

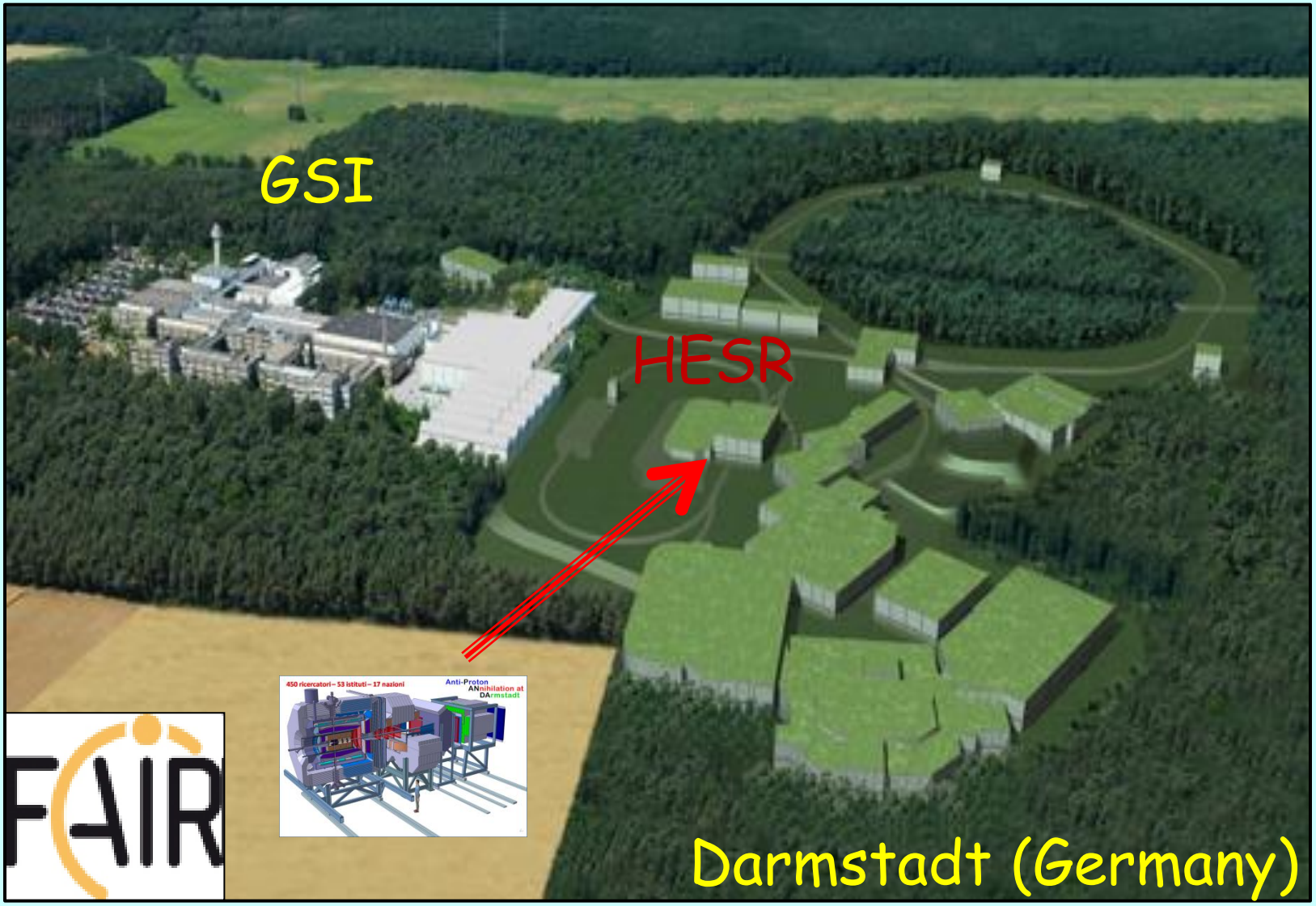


Resonance scan



beam momentum spread $\Delta p/p$ extremely important

Facility for Anti-protons and Ion Research

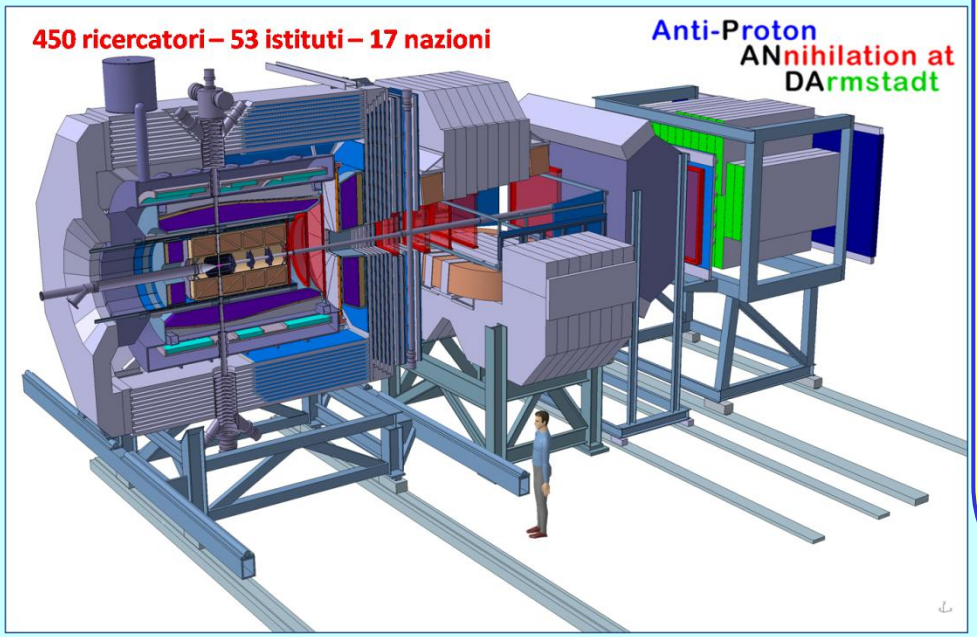


The Panda experiment

AntiProton Annihilations at Darmstadt

Multi purpose detector at FAIR

$\bar{p}p$, $\bar{p}A$ collisions
1.5⇒15 GeV/c ($\bar{p}$ momentum)



Physics program

- Charmonium ($c\bar{c}$) spectroscopy
- Open charm spectroscopy
- Search for gluonic excitations (hybrids - glueballs)
- Charmed hadrons in nuclei
- Drell-Yan
- Single and double Hypernuclei
- Other options (Parton Distrib., EM Form Factor…)

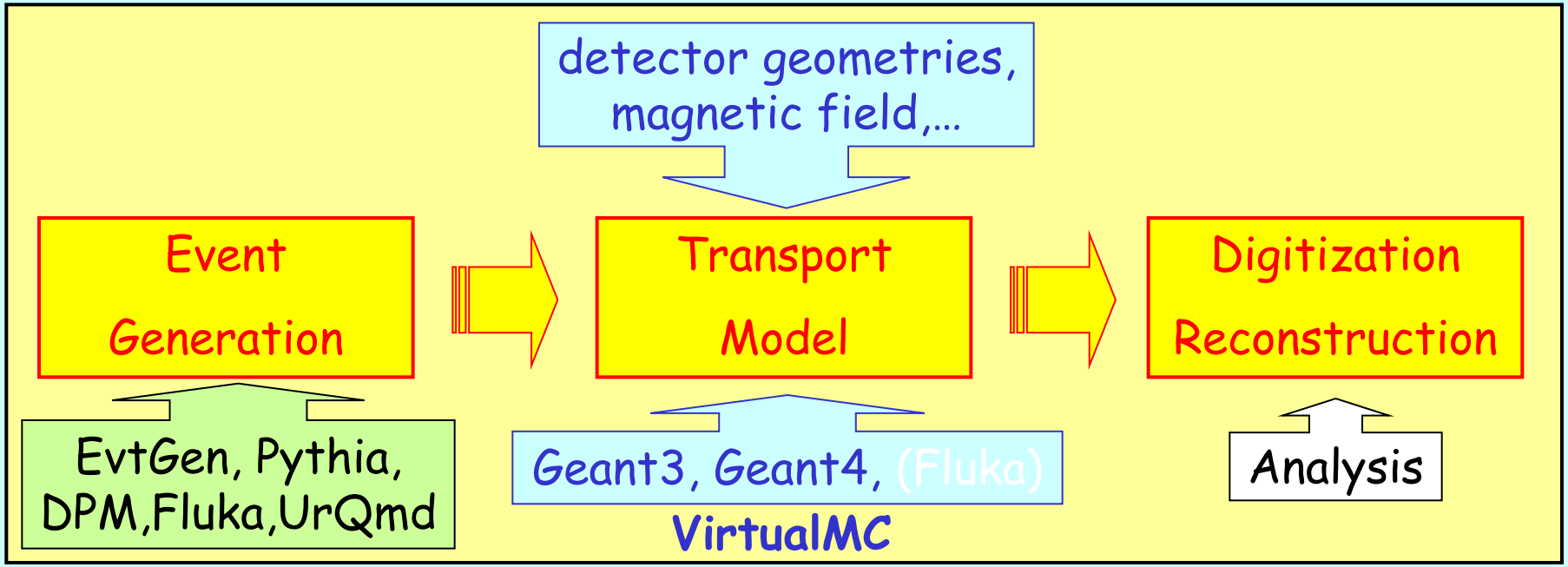
Software activities @ DFG

- Core Developments
- Global Tracking Code
- Design of a Muon tracker
- Global Particle Identification framework
- Analysis
- GRID

The PandaRoot framework

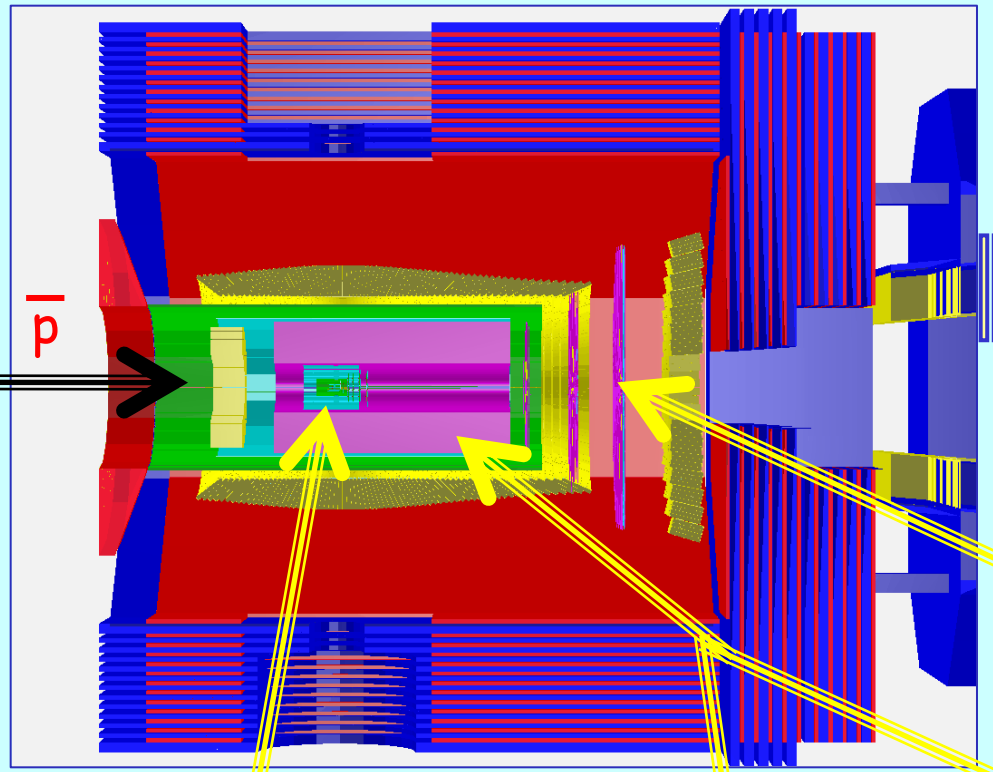
- Framework for simulation and analysis
- Based on ROOT and Virtual Monte-Carlo
- compiled and running on more than 10 Linux platforms + Mac OS X

strong collaboration
CERN/ALICE
FAIR/HADES-CBM



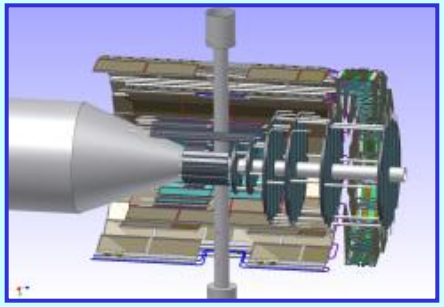
Physics with antiprotons at Panda: software development @ DFG

Global Tracking Software

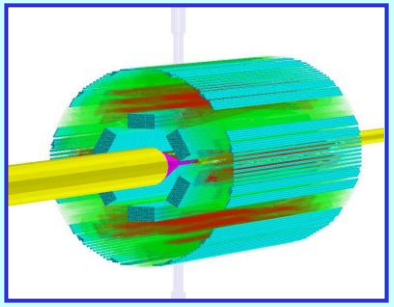


involvement

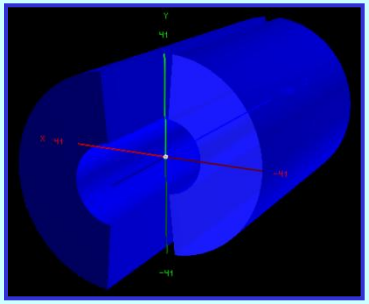
MVD: Bonn (D), DFS, Julich (D)



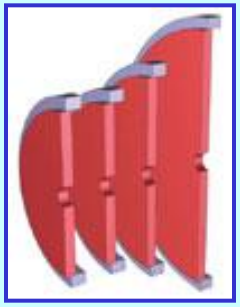
STT: Frascati, Julich (D),Pavia



TPC: Munich (DE)

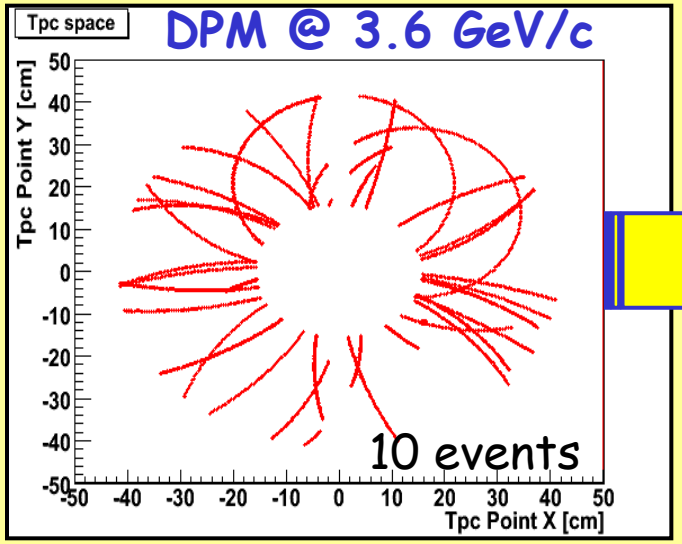


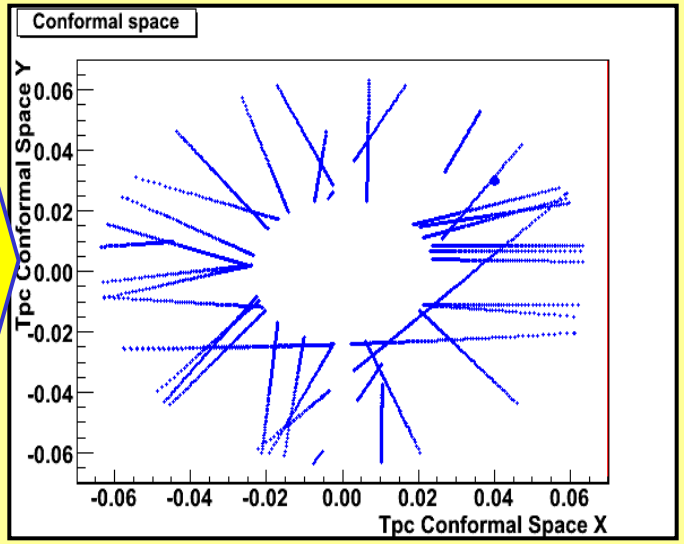
GEM: GSI (D)



Physics with antiprotons at Panda: software development @ DFG

Global Tracking (central tracker)

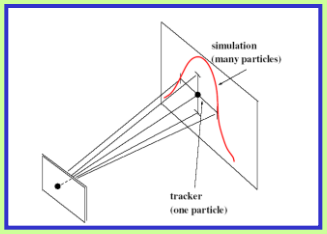




helix assumption

conformal mapping

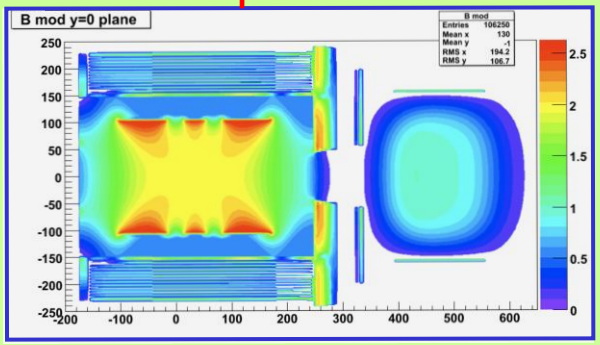
Helix fit



Kalman Filter
(genfit - Munich)

Track Follower
(GEANE – Pavia/CERN)

field map from TOSCA

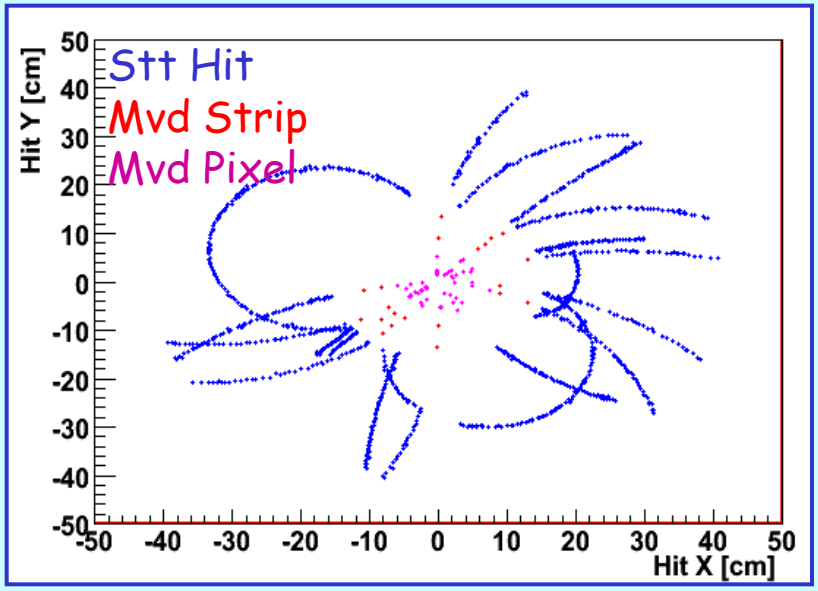


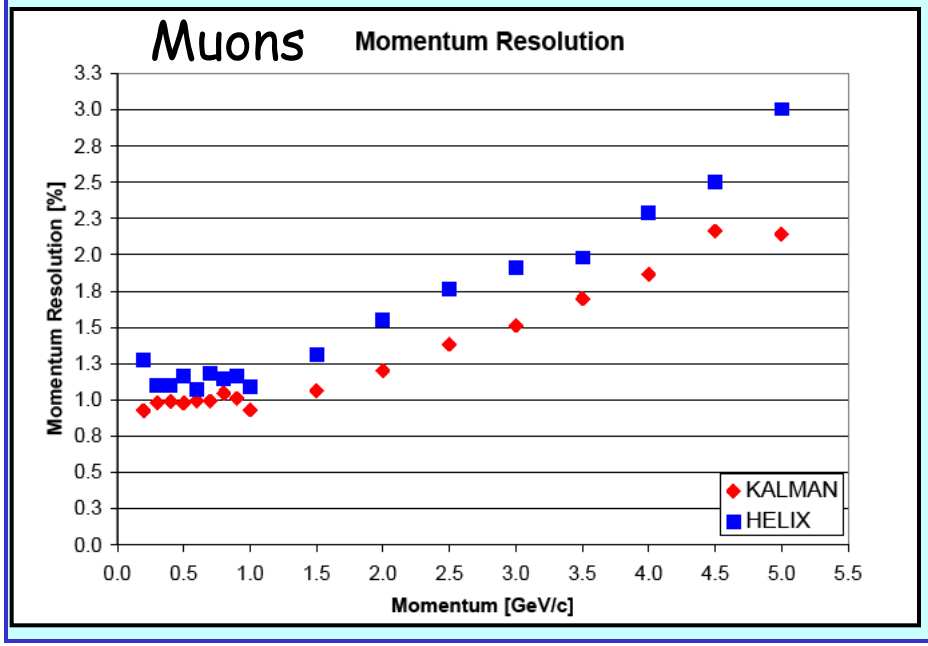
use of the same geometry for simulation and track following

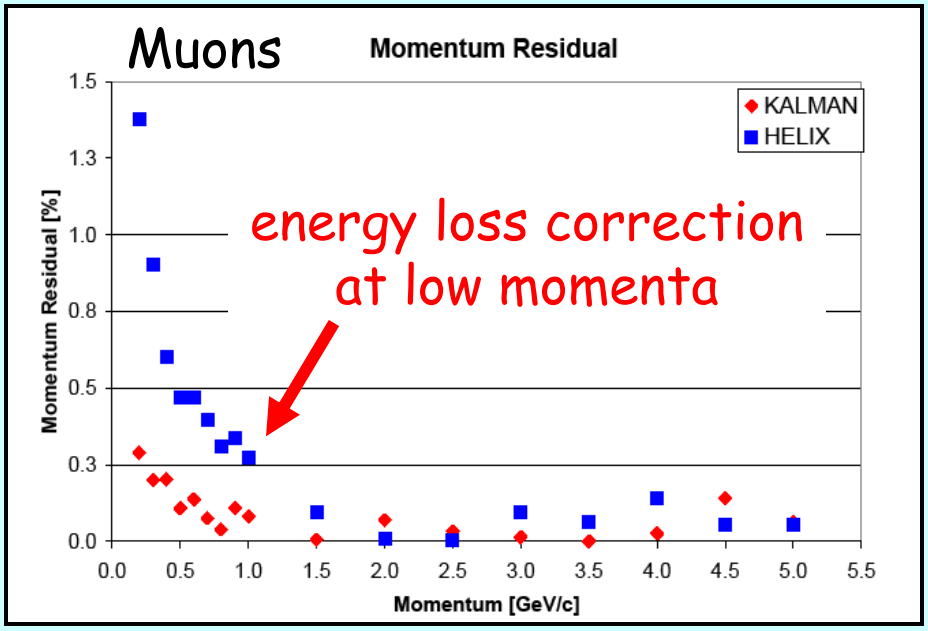
Central Tracker: Performances

DFG + Pavia + Bonn + GSI + Munich collaboration

Tracking TDR decision STT/TPC

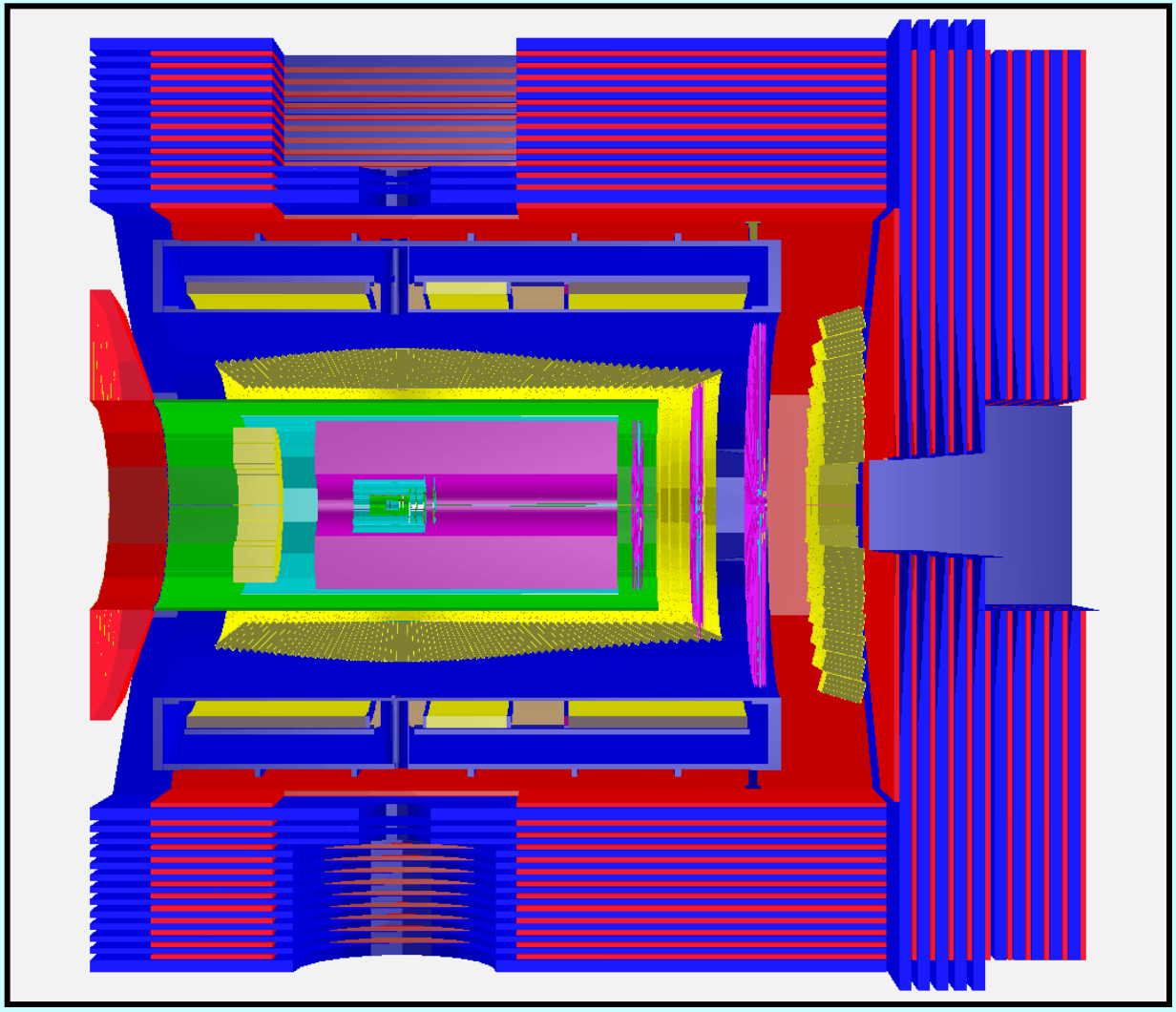






Design of Muon Tracker (MDT)

collaboration
JINR – Dubna (RU)



highest efficiency in muon identification

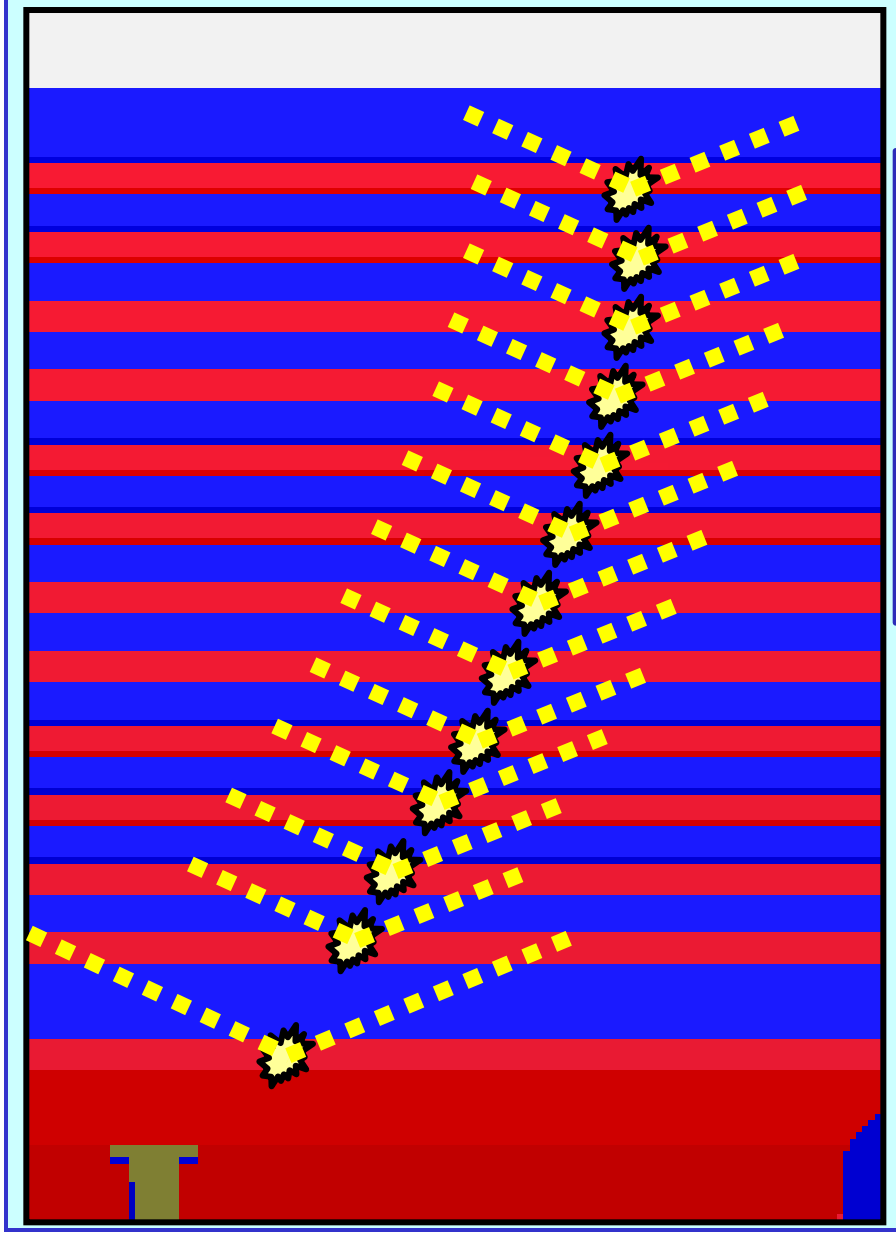
strong hadronic background

benchmark channel

Drell-Yan

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

signal-to-noise ~ 10^{-6}



Pattern Recognition

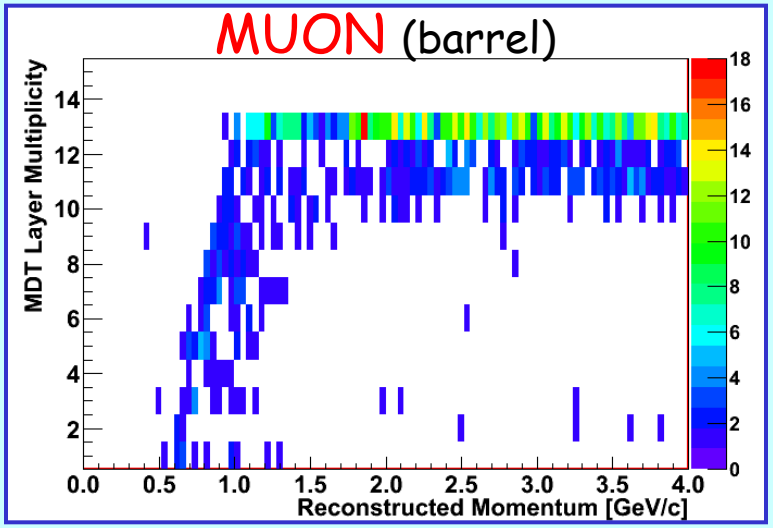
- ✓ Number of fired layers
- ✓ Maximum fired layer
- ✓ Number of hits inside search cone
- ✓ tracking χ^2
- ✓ …

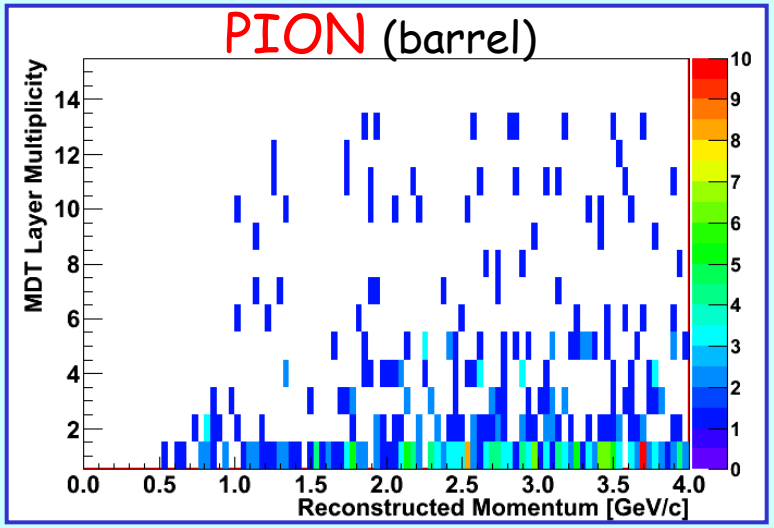
correlation to central tracker

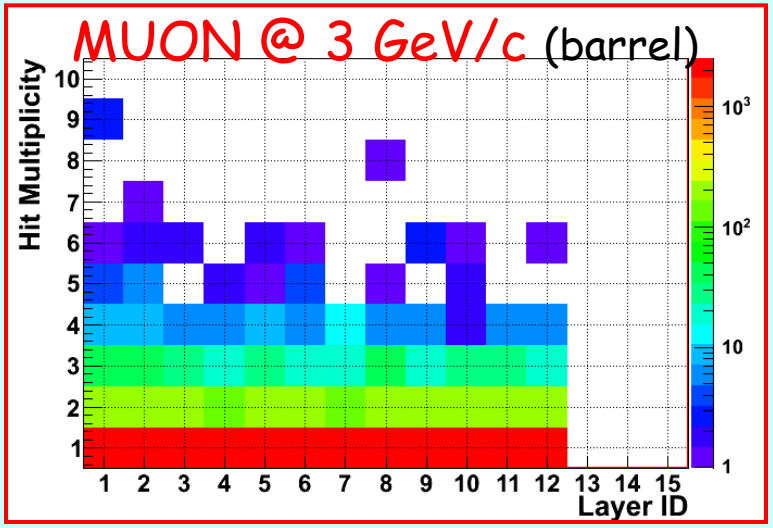
μ/π separation

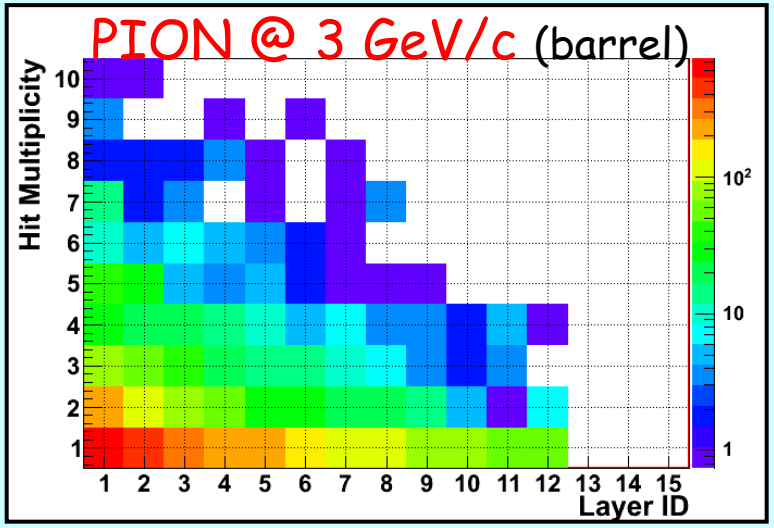
hadronic shower

Muon Detection

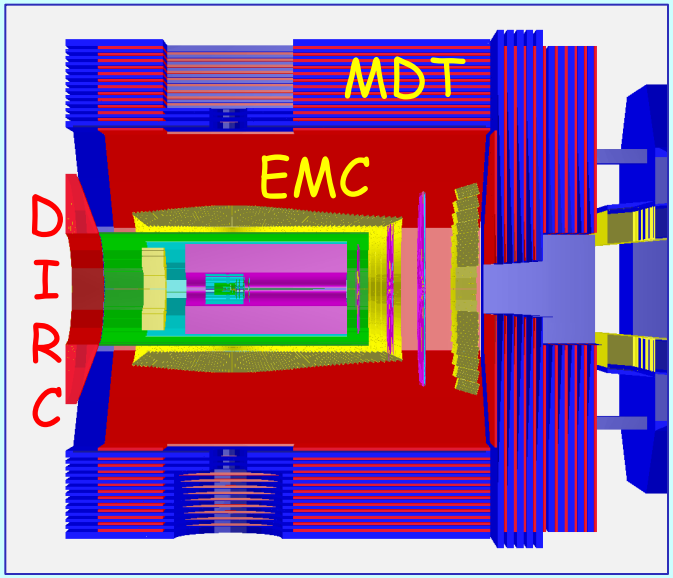








Particle Identification



different detectors for PID
covering
different momentum/angle ranges

MVD, TPC/STT, Cherenkov, EMC, MDT…

- handling of different PID signals
- combining several PID info

two approaches under study

- Bayesian method (DFG)
- Multivariate analysis TMVA (DFG+KVI)
  - ✓ Neural network
  - ✓ Genetic algorythm
  - ✓ …

PID: Bayesian Method

particle flux

Global Likelihood

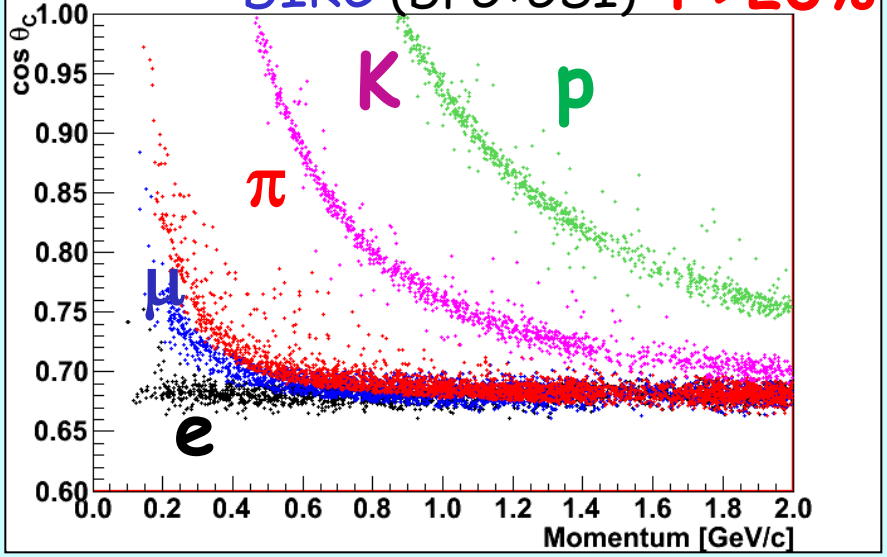
$$L(\vec{x}\,|\,h) = \prod_k p_k(\vec{x}\,|\,h)$$

algorithms

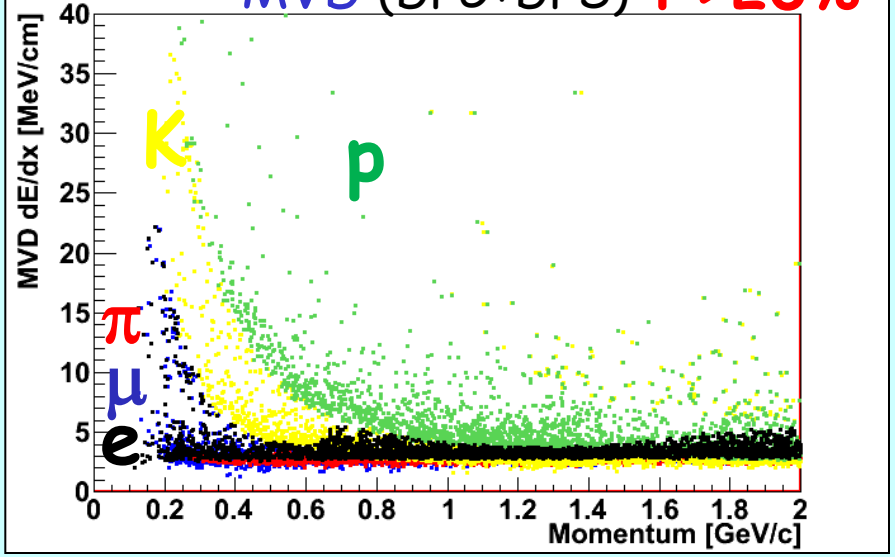
$$P(\vec{x}\,|\,h) = \frac{L(\vec{x}\,|\,h)\times P(h)}{\sum_{h=e,\mu,\pi,K,p} L(\vec{x}\,|\,h)\times P(h)}$$

probability

DIRC (DFG+GSI) P>20%

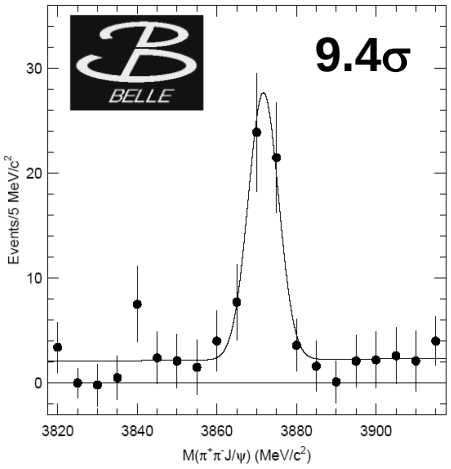


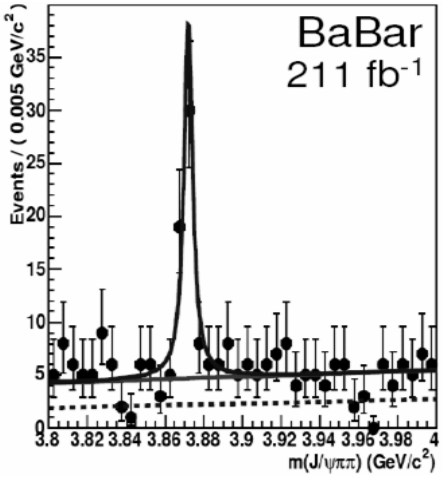
MVD (DFG+DFS) P>20%

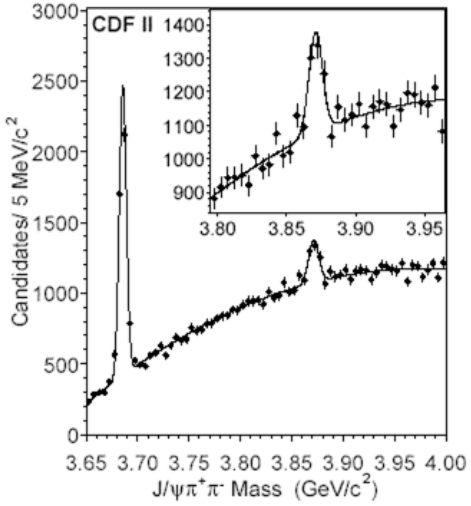


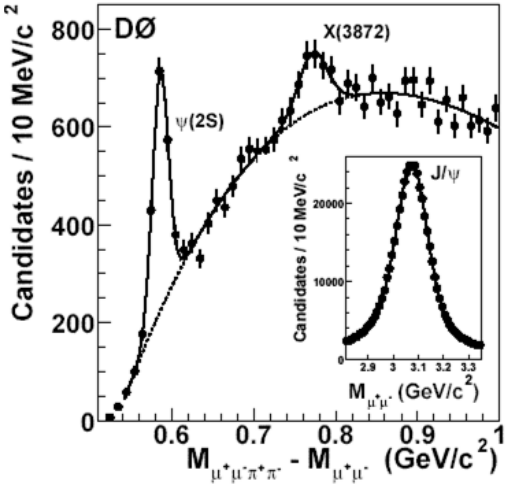
more complicated cases (EMC, MUON) → Multivariate Analysis

X(3872) a new Charmonium State









C=+1

Cannot be produced in e^+e^- formation more

Unique for PANDA

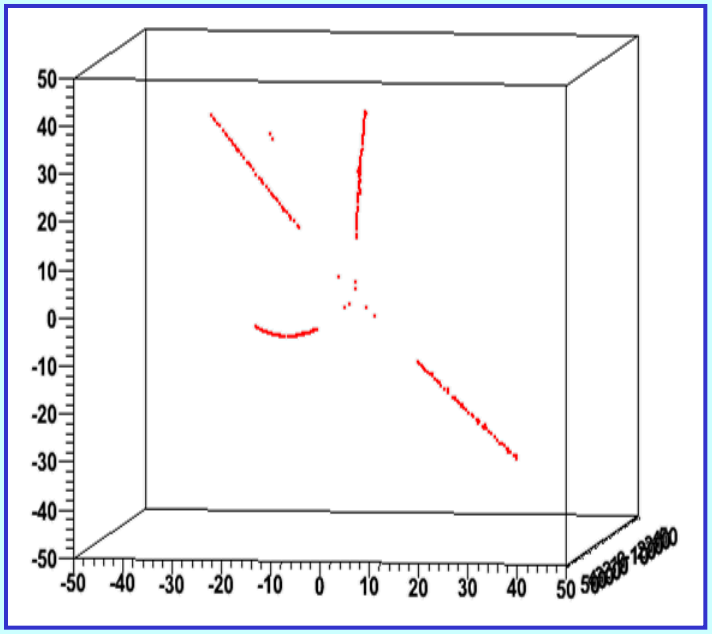
$X(3872) \rightarrow J/\psi\pi^+\pi^-$

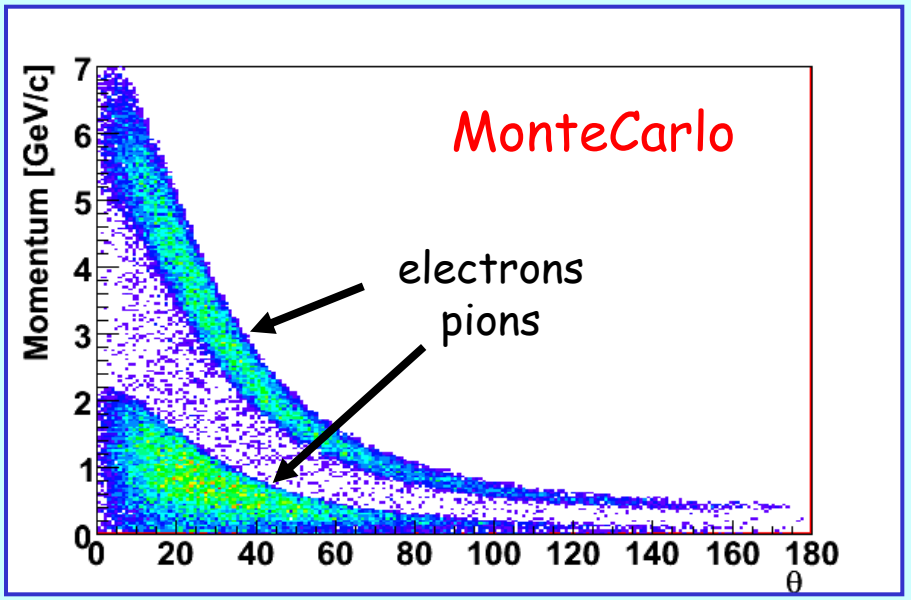
$X(3872) \rightarrow J/\psi\ \pi^+\ \pi^-$
$J/\psi \rightarrow e^+\ e^-$

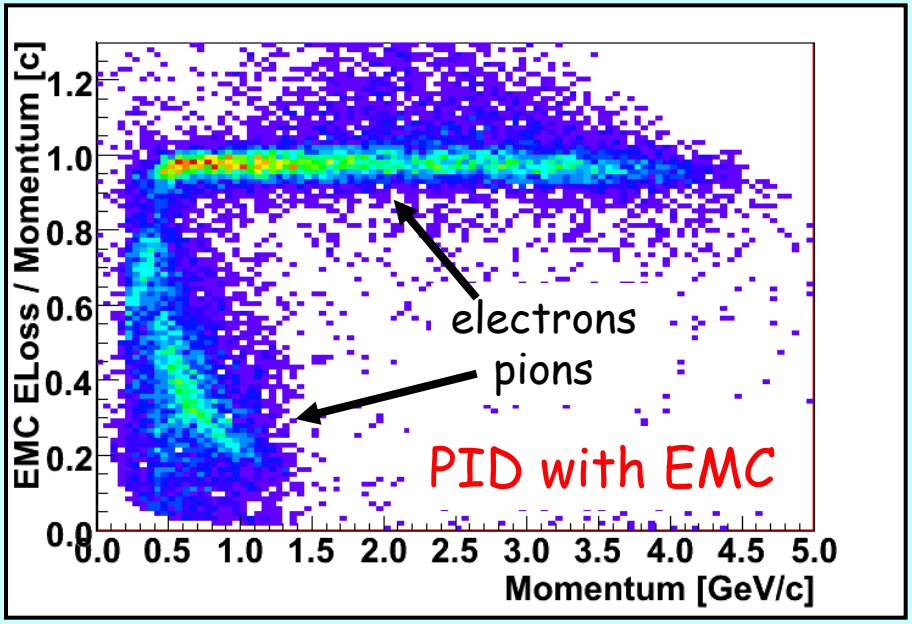
Peak cross section 50 nb (E.Braaten)

$X \rightarrow J/\psi\ \pi^+\ \pi^-$ 250 pb

$J/\psi \rightarrow e^+\ e^-$ b.r. 6%







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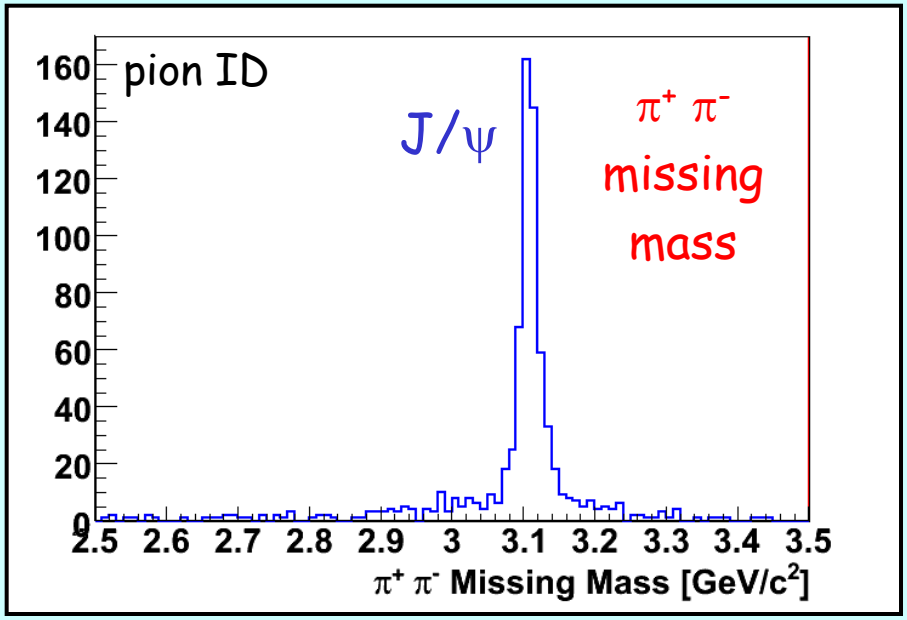
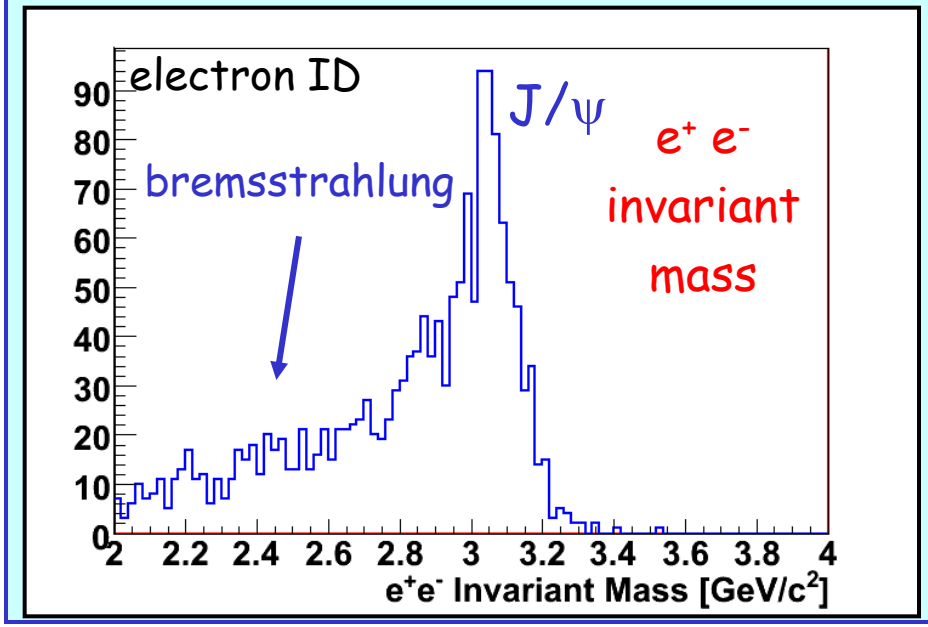
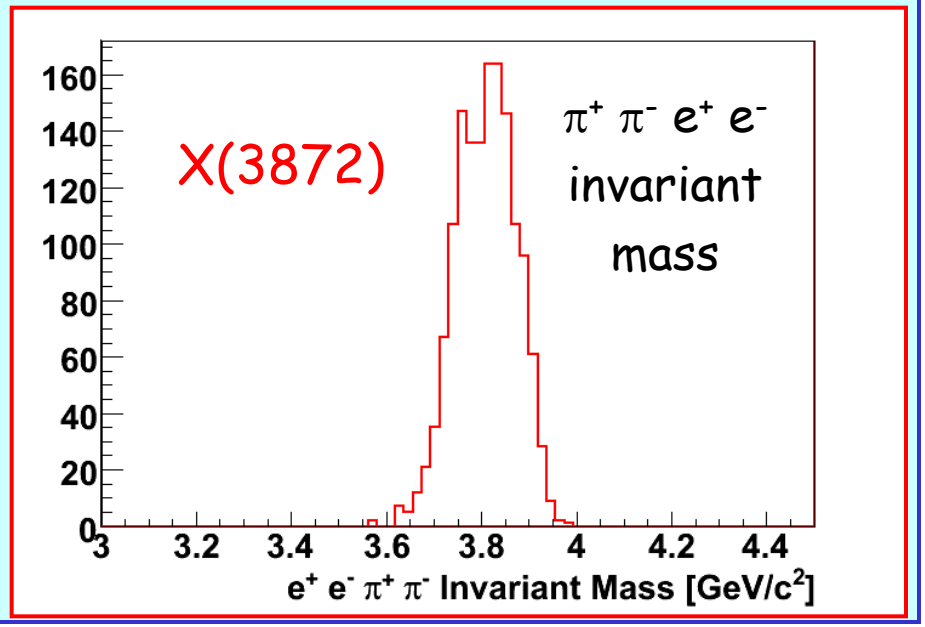


$X(3872) \rightarrow J/\psi\ \pi^+\ \pi^-$
$J/\psi \rightarrow e^+\ e^-$

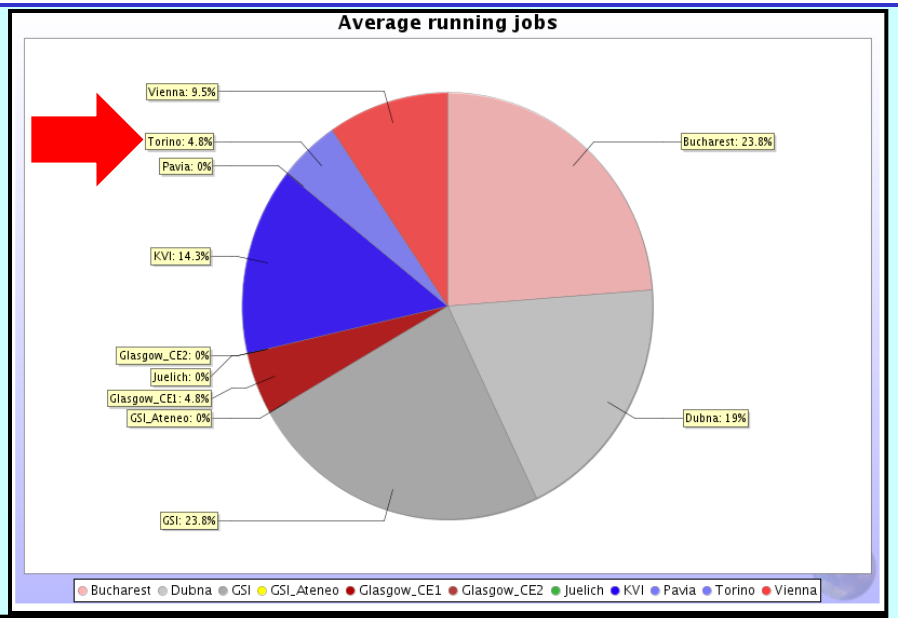




Physics with antiprotons at Panda: software development @ DFG

Grid node in Torino

Data Challenge
23-27 November 2009



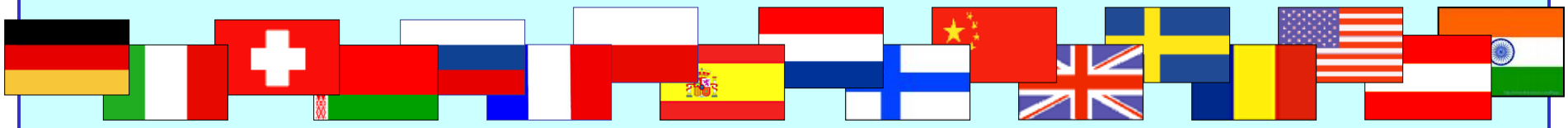
Summary

PANDA has a huge physics program

a lot of things to do for the following years

DFG strongly involved in Panda software activities:

- Core Developments
- Global Tracking
- Muon Detector Design
- Particle Identification
- Analysis
- GRID



a strong international collaboration