Update on the PANDA project

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IPN Orsay
GDR PH-QCD: Plenary meeting 25-27 november 2013

PANDA@FAIR(1)

Facility for Antiproton and Ion Research

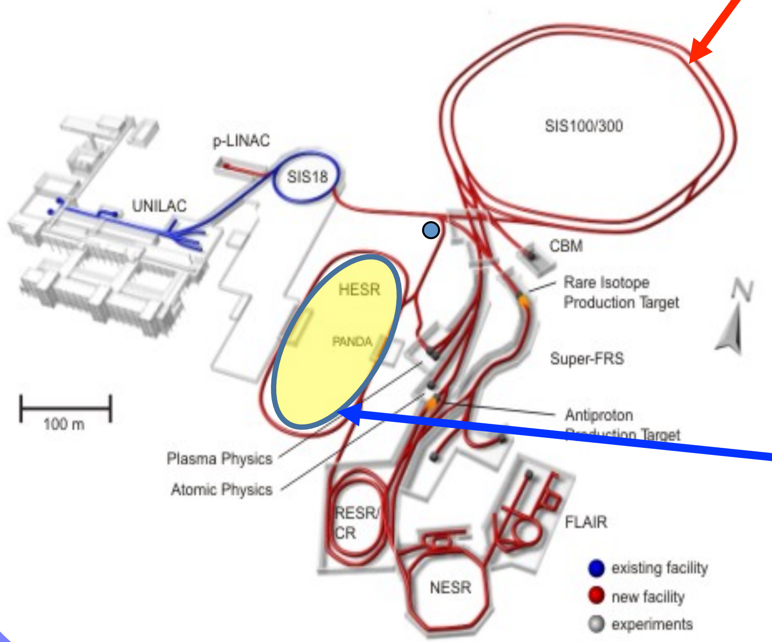
Hadron Structure and Dynamics

- **Nuclear and quark matter**
- **Super-heavy elements**
- **Nuclear Structure and Astrophysics**
- **Atomic, Plasma and Material Physics**
- **Radiobiology**

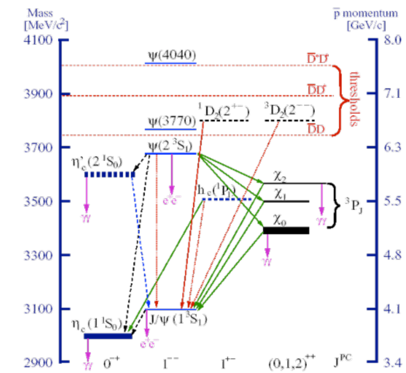
FAIR at Darmstadt/Germany

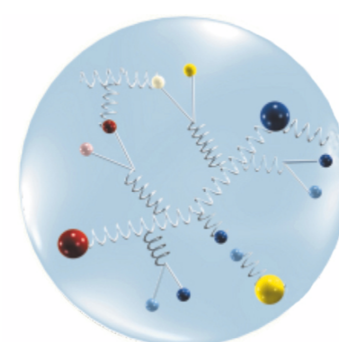
Official foundation of FAIR: 4/10/2010

First experiments: ~2018/19



Antiproton ring
High Energy Storage Ring 1.5 – 15 GeV/c
$L = 2 \times 10^{32}$ cm^{-2} s^{-1}
$\sigma_p/p = 10^{-4}$
2×10^7 int.s^{-1}





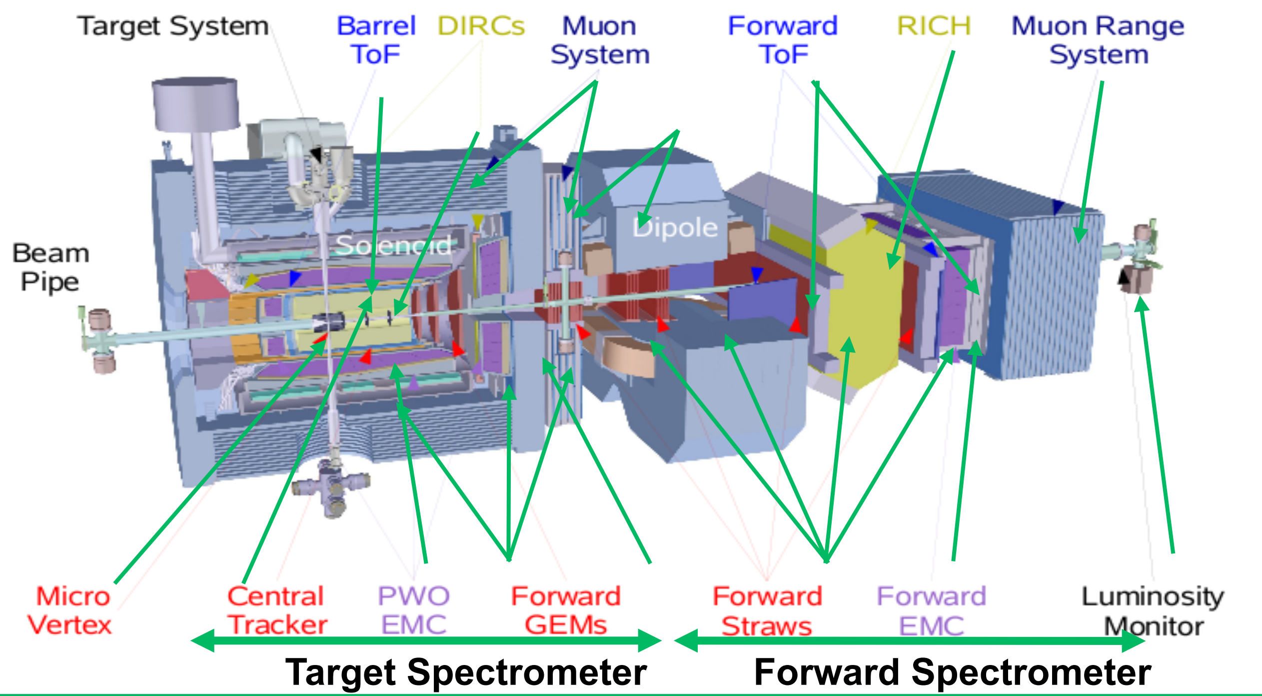
PANDA@FAIR(2)

Detector requirements:

- *nearly 4π solid angle*
- *high rate capability: 2x10^7 events/s;*
- *good momentum resolution $\Delta p/p \approx 2\%$;*
- *vertex resolution < 100 μm*
  for K0, Σ, Λ, ($D^{\pm}$,cτ ≈ 317 μm);
- *good PID (γ, e, μ, π, K, p);*
- *γ detection, few MeV < E_γ < 10 GeV.*

- ***Tracking detectors (Si-MVD, STT, GEMs) in B field (solenoid + dipole at forward angles)***
- ***Particle Identification***
  - ***dE/dx (MVD + STT)***
  - ***DIRC + RICH***
  - ***ECAL (20000 PbWO4 crystals @ -25°C) + HCAL***
  - ***Muon detector (instrumented return yoke)***

International
collaboration
520 people
67 institutes
17 countries



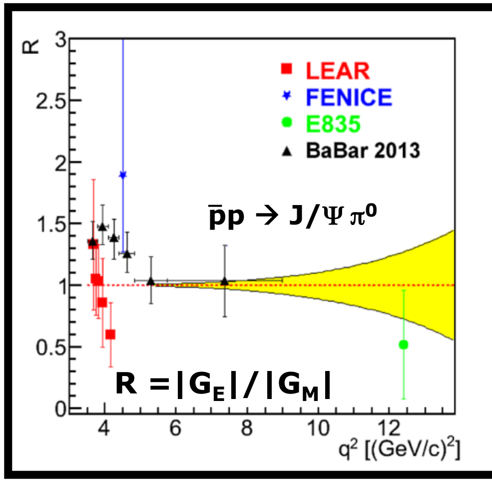
Overview of IPN activities

- **Phenomelogical activities: Modelling of reaction channels**
  - **EM channels: l^+l^-, $\pi^0\gamma$, $e^+e^-\pi^0$, $e^+e^-\eta$, J/Ψ, $J/\Psi\pi^0$**
  - **Hadronic channels: $\pi^+\pi^-$, K^-K^+, $\pi^+\pi^-\pi^0$**
- **Simulation and software activities**
  - **Reaction simulations**
  - **Particle Identification**
  - **Tracking (specific to electrons)**
  - **Event filtering**
- **R & D activities (Barrel ECAL)**

Simulation and phenomenology

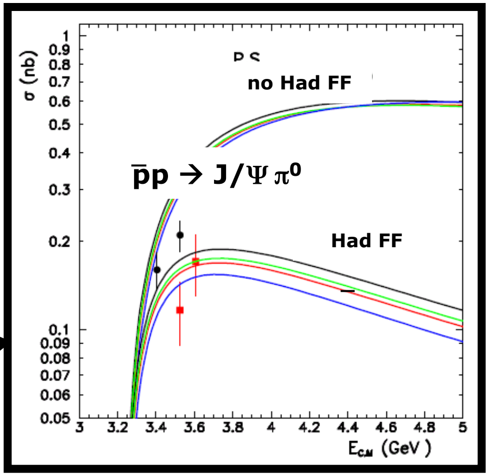
Physics channel feasibility studies

- Separate determination of FF Time-Like $|G_E|$ et $|G_M|$ of the proton via annihilation precatio bar p → $e^+ e^-$ (Sudol et al, EPJ A 44 (2010) 373)
- Feasibility studies of the pbar p → $e^+e^-\pi^0$ electromagnetic channel at PANDA (J. Boucher, Thèse Univ. Paris-Sud et Mainz, déc. 2011))
- Study of the internal stucture of the proton with the PANDA experiment at FAIR (A. Dbeyssi, Thèse Univ. Paris-Sud, sept. 2013)

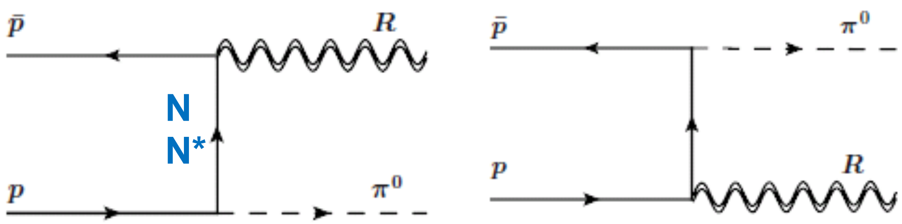


Phenomenology

- Radiative corrections (J. Van de Wiele et S. Ong; EPJ A 49 (2013) 18, E. Tomasi et al; PRC83 (2011) 04520)
- Heavy leptons lourds and Polarisation (E. Tomasi et al; NPA 894 (2012) 20 et PR C83 (2011) 025202)
- Cross-channels and Unification TL et SL (E. Tomasi et al; PLB 712 (2012) 240)
- Reaction mechanisms (E. Tomasi et al; NPA 920 (2013) 45)
- Hadronic channels (E. Tomasi et al; EPJA 46 (2011) 91, J. Van de Wiele et S. Ong; EPJA 46 (2010) 291 et EPJC (2013))

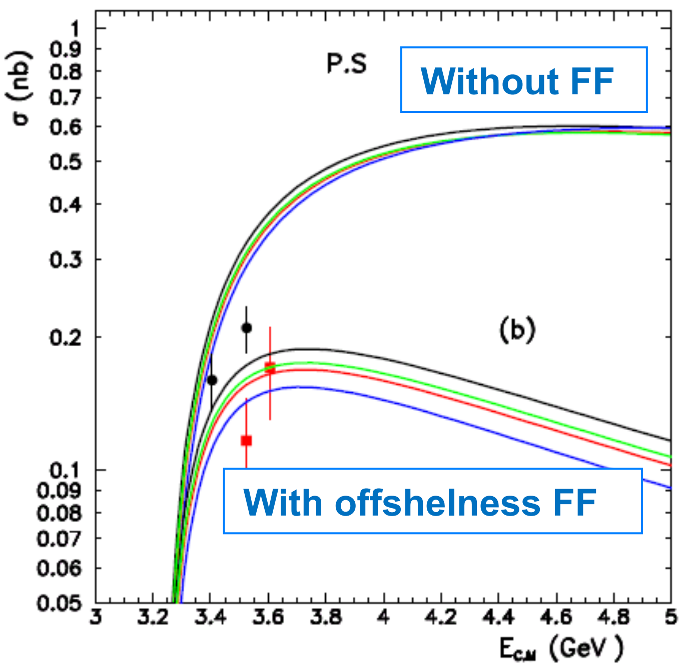


$\bar{p}p \rightarrow \pi^\circ J/\Psi \rightarrow \pi^\circ e^+e^-$ in a lagrangian based model



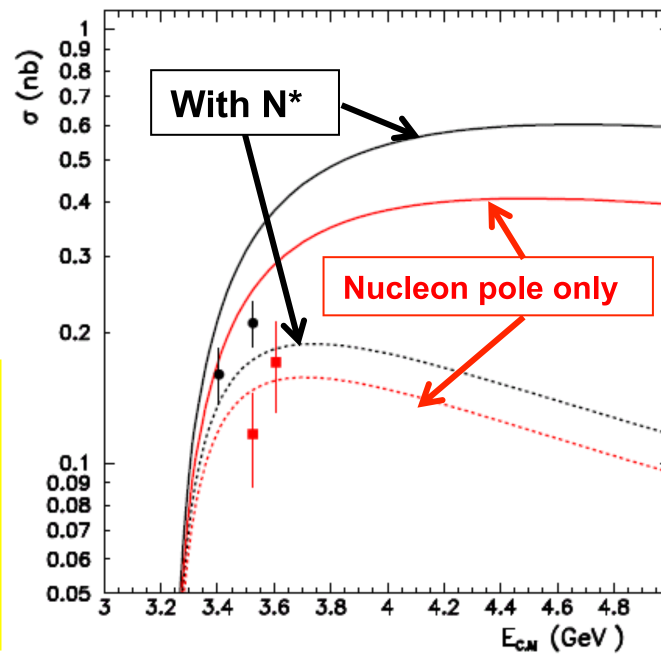
J. Van de Wiele et S. Ong
$p\,p \rightarrow \pi^0\, J/\Psi$
EPJC (2013)

First calculations with the contribution of 5 N* resonances (1440 to 1710 MeV)



Fermilab data

PANDA can improve data quality by at least 2 orders of magnitude over the full range



Full Reaction simulation

- Pbar p → e^+e^- with PANDARoot + background (A. Dbeyssi, thèse Univ. Paris-Sud , 27/09/2013) → see next presentation
- Pbar p → e+e- with new radiative correction generator (Van de Wiele and Ong)
- TDA feasibility studies (B. Ma in collaboration with K. Semenov)
  - Generator available
  - Need of background simulation

Software developments:
Filtering, Tracking, PID

Why do we need filtering?

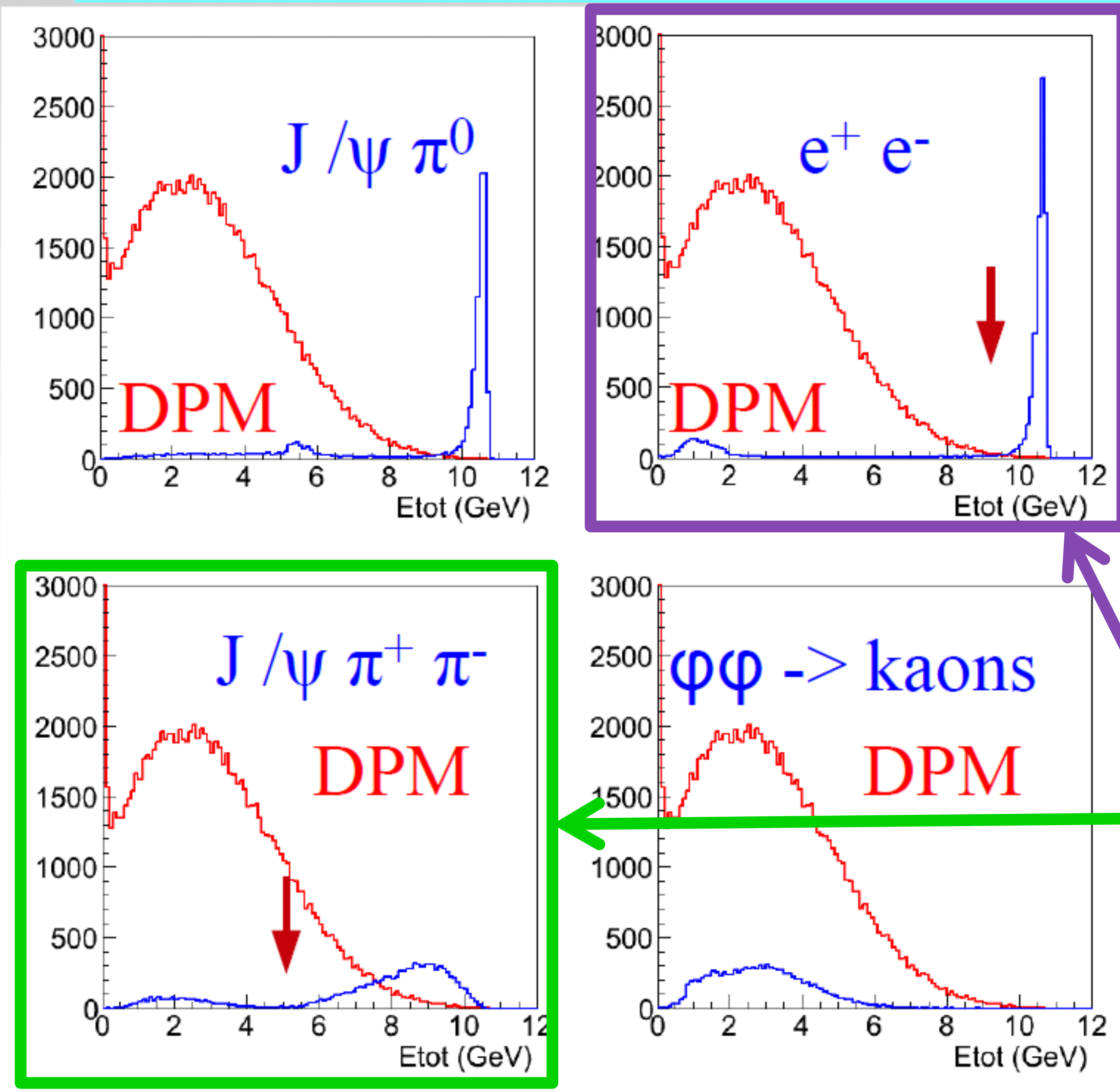
- Interaction rate: 2 10^7 per sec (→1 Eo per year of data taking)
- PANDA is a triggerless experiment

→ Need to downscale the dominant hadronic channels (multi pion production), while keeping most of the signal

- Various scenarios are being considered at different levels
- Most promising are the fastest ones
  - EMC is the only selective detector on which a fast decision can be made
  - Tracking reconstruction comes much later (needed to do PID)

- Tune effective filtering method (e.g. cluster energy)

Filtering with the total cluster energy



P_{beam} = 10 GeV/c

Four channels compared with background from DPM

DPM background left:

E_{tot} > 9 GeV/c 3%

E_{tot} > 5 GeV/c 17%

Efficiency: ≈ 80%

From R. Kunne

Electron momentum recontruction

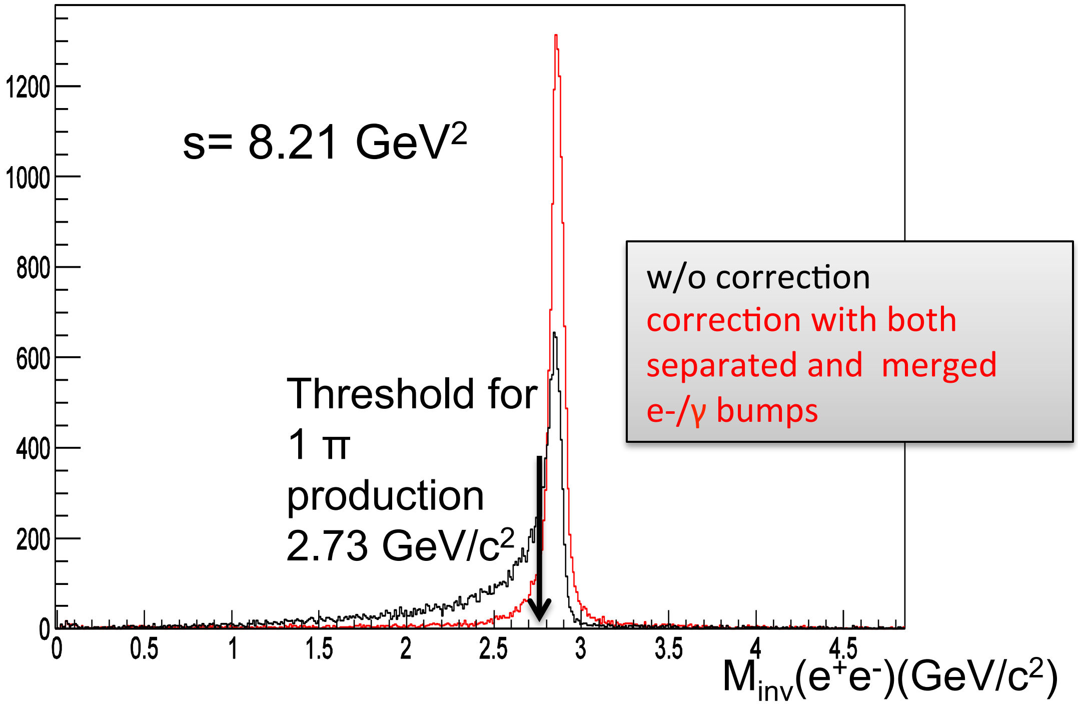
Material mostly from B. MA

- x/X0 varies between 7% and 25% in the tracking system

  → $<E_{loss}>_{\text{tracking system}}$ by Bremstrahlung ≈ 64 MeV at 1 GeV, « highly asymmetric »
- Electron after Bremsstrahlung has a different curvature: can that be detected or corrected?
- Need to control
  - What do we loose (efficiency after Kalman Filter and PID)
  - It is θ and p dependant , which would then lead to uncorrect $R=|G_E|/|G_M|$
- Existing methods: Gaussian Sum Filter and Dynamic Noise Adjustment (Atlas note ATL-COM-INDET-2008-010) Need to be tuned very precisely
- New idea: Correlate the electron track with the γ in the calorimeter

Application for nucleon form factors studies in $\bar{p}p \rightarrow e^+e^-$

Invariant mass of e^+e^- before cuts



Selection of $\bar{p}p \rightarrow e^+e^-$ channel

- PID
- Angular correlations
- Cut on $M_{inv}(e^+e^-) \sim \sqrt{s}$

Main backgrounds:

- $\bar{p}p \rightarrow \pi^+\pi^-, \pi^+\pi^-\pi^0$
- $\bar{p}p \rightarrow e^+e^-\pi^0$

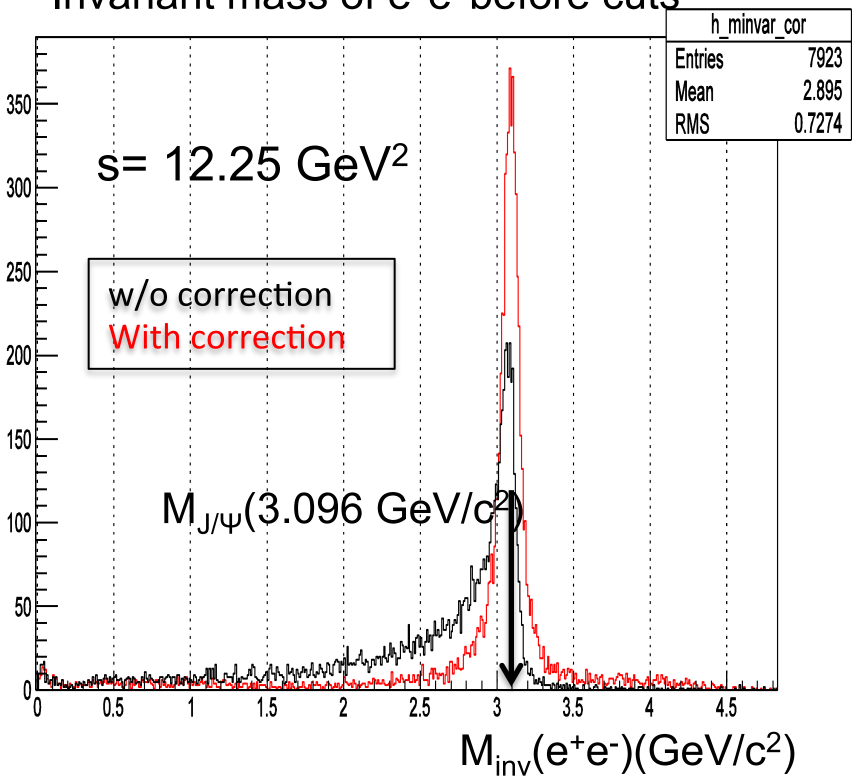
Improvement of number of events inside the cut : 51%→87%

Improving on pbar p → $J/\Psi\ \pi^0$

Application for TDAs studies in

$\bar{p}p \rightarrow J/\Psi\pi^0 \rightarrow e^+e^-\pi^0$

Invariant mass of e^+e^- before cuts



Selection of $\bar{p}p \rightarrow J/\Psi\pi^0 \rightarrow e^+e^-\pi^0$ channel:

- PID($e^+e^-2\gamma$)
- π^0 reconstruction: $M_{inv}(2\gamma) \sim M_{\pi^\circ}$
- Cut for $M_{inv}(e^+e^-) \sim M_{J/\Psi}$
- Kinematical constraints

Main backgrounds:

- $\bar{p}p \rightarrow \pi^+\pi^-\pi^0$, $\pi^+\pi^-\pi^0\pi^0$
- $\bar{p}p \rightarrow J/\Psi\pi^0\pi^0$
- Non resonant $\bar{p}p \rightarrow e^+e^-\pi^0$

Improvement of number of events inside 2σ: 38.4%→61.0%

Hadronic Shower Simulation in GEANT

PID

E. Atomssa

Why the study

- Implication of using various hadronic physics lists for Geant4 on feasibility studies
  - Eg. $\bar{p}p \to e^+e^-$ and $\bar{p}p \to \pi^0 e^+e^-$ critically dependent on PiD
  - Tail of hadronic response plays dominant role in hadron rejection
- How does Geant4 physics lists compare to those available in Geant3?
- How much variation in the response using different Geant4 models?

Available Geant 4 hadronic physics lists

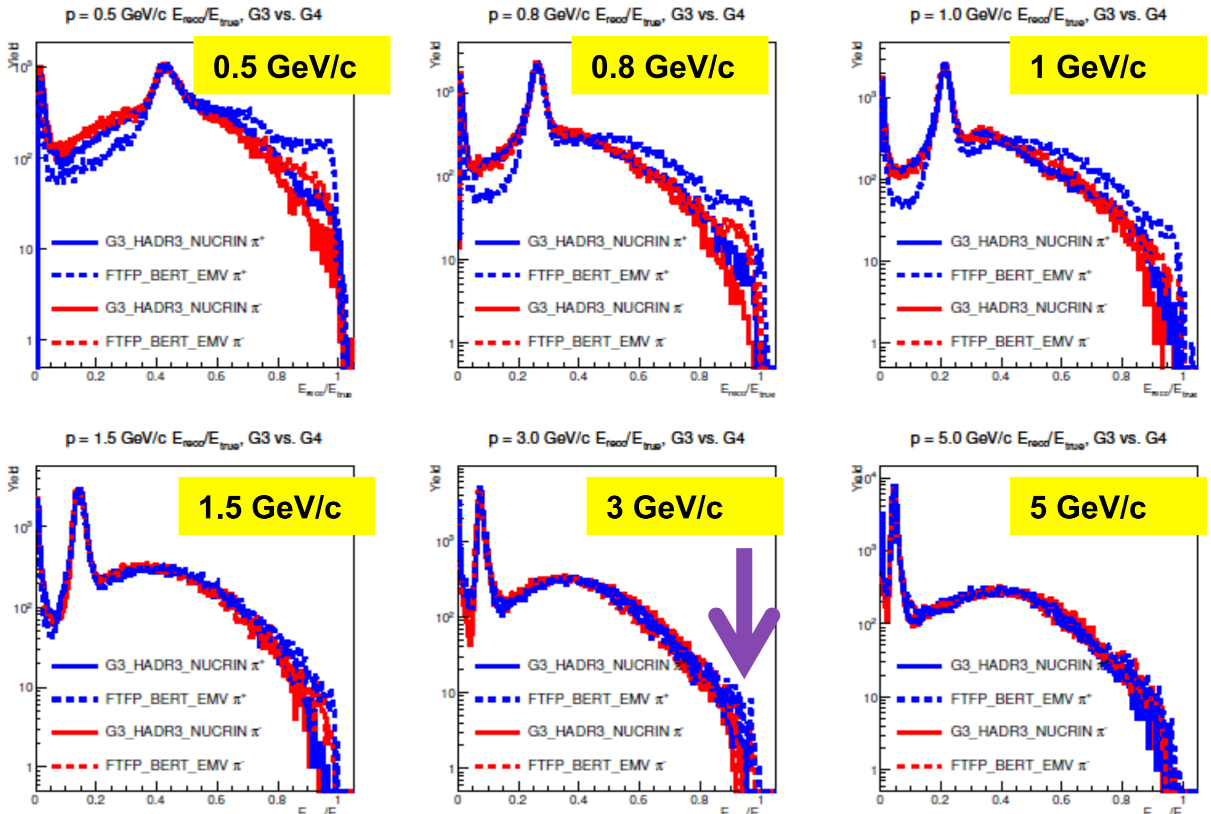
- Options depending on *hadronic interaction* and *cascade (nuclear de-excitation)* models
- High energy hadronic interaction: Quark Gluon String (QGS) and Fritiof (FTF)
- Variations based on low energy hadronic interaction and nuclear de-excitation (cascade)
  - "Precompound model": parametrization for nuclear de-xcitation modeled after GHEISHA
  - "Binary cascade" and "Bertini Cascade" altenate models with validity range limited to low energies that handle both h-N interactions and nuclear de-excitation

Geant3 vs. Geant4 (FTFP_BERT_EMV)

π^+

π^-

in PANDA ECAL



GEANT 3 continous lines

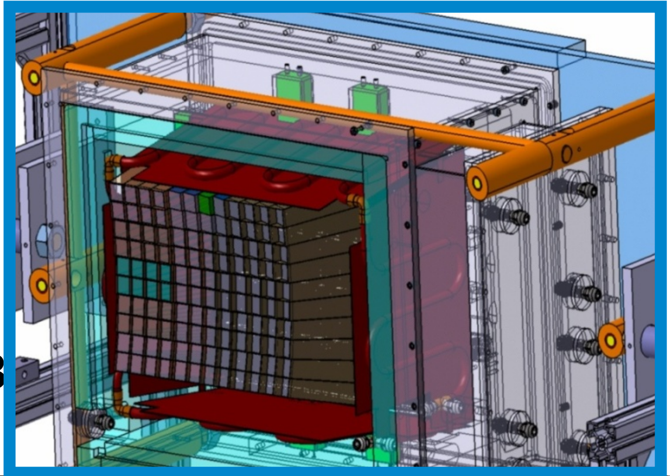
GEANT 4 dashed lines

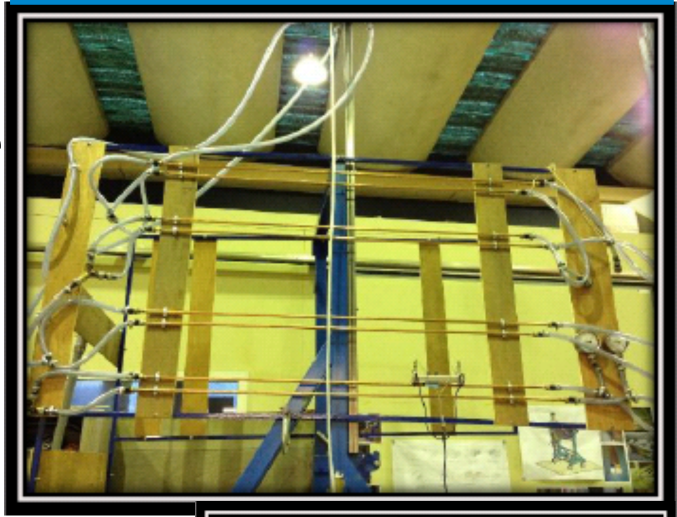
E/p (=1 for electrons)

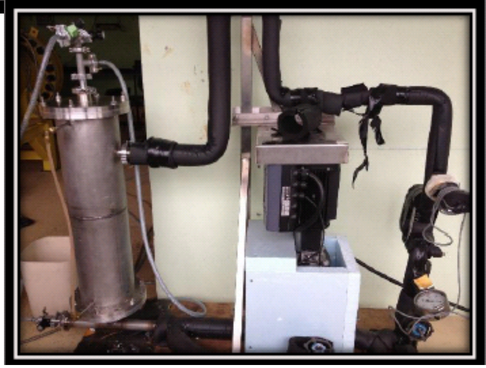
- Sample comparison between Geant3 and Geant4 at various incident energies using PANDA simulation tool
- Ratio of reconstructed cluster energy to true MC energy E_{reco}/E_{true}
- Biggest difference: deviation between π^+ and π^- response
- Generally most recent G4 models give higher yield at large E_{reco}/E_{true}
- Some form of real data validation direly needed

(Simulations by E. Atomssa)

R&D activities







- **Prototype 120 crystals**
  - **Mounting tools ready**
  - **1st tests (40 crytals equipped) expected end 2013 /beg 2014 with Cosmics and γ/e beams**
- **Cooling**
  - **Design and realisation of cooling bench prottype**
  - **Validation of simple modelization → good agreement**
- **Next steps**
  - **2014:**
    - **Buy a cooling machine, transfer lines and CC devices**
    - **Define the concept of the full size machine for a budget request (IPN contribution to PANDA)**
  - **2015-2017: build the full cooling system for the barrel**

B. Gajewski, M. Imre
C. Le Galliard, G. Minier
P. Rosier, L. Seminor
A. Maroni, C. Theneau…

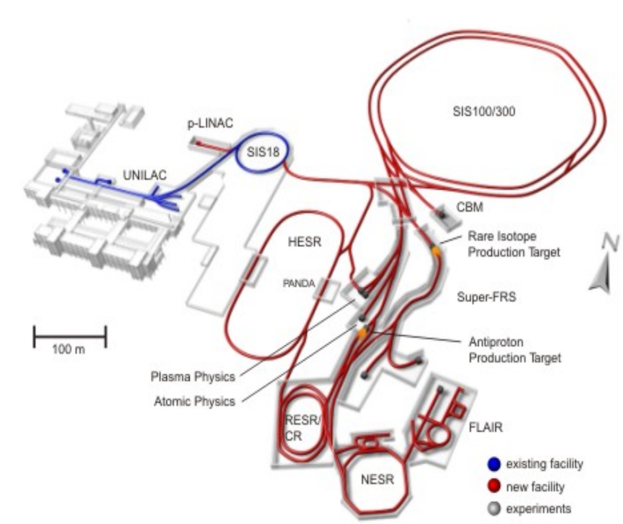
LATEST news from FAIR

France as a shareholder

- National Assembly ratified on 25/7/2013
- Expecting application decree by president soon
- Contribution of France to FAIR complex = 27 M€

No contribution was foreseen to the detector up to now

Civil Construction



Areal view May 2013

from I. Lehmann, PANDA coll meet. In Bochum Sept 2013

Resources Review Boards

- **To negotiate**
  - Funding, in particular, missing funding
  - Construction MoUs
  - Operations Budget during commissioning and running phase of experiments
- **Consisting of**
  - Representatives from all funding agencies involved in the Collaboration (D. Guillemaud-Mueller + TH)
  - Collaboration Management
  - FAIR Management
- **Meetings (jointly)**
  - Once or twice a year
  - Organised by FAIR Research Division
  - Reports / assessments from Spokesperson and ECE Chair
  - 1st meeting 4-5 July 2013 → Successful and very constructive
  - 2nd meeting Feb 2014

Adapted from I. Lehmann

Status of PANDA Experiment

- Technical Design Reports PANDA

Total Approved	Approved ECE 1	Submitted ECE 2	Announced 2013	Total exp.
4+1?	2	2	7	**16**

- PANDA funding (total cost in 2013 ~87 M€, RRB july 2013, including an escalation factor of 1.30 from 2005)
  - 55% already approved
  - 14% expression of interest
  - 28% missing → additional collaborators or common projects
- In preparation
  - **Collaboration Contracts, General Specifications**
  - **Timelines**
  - **New risk assessment/management**
  - **General Conditions for Experiments (running costs)**
  - **Cost Book (to be approved end 2013 by the PANDA collaboration)**
- Construction MoUs
  - To be agreed upon in 2014

Adapted from I. Lehmann

PANDA technical status (oct 2013)

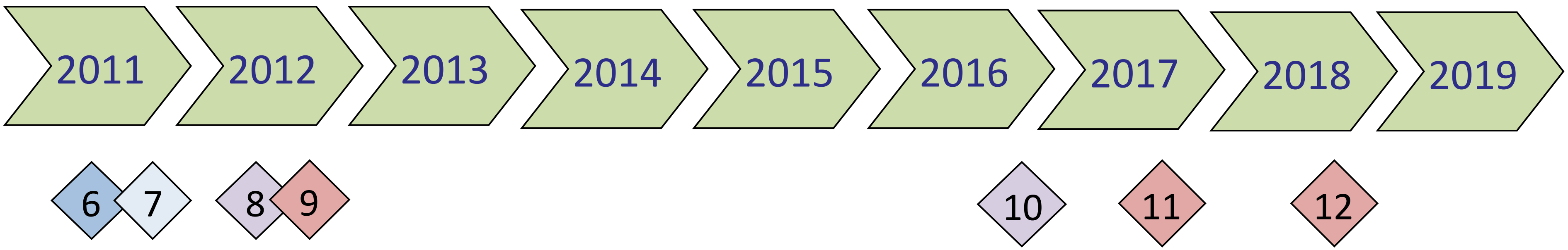
Present status

Most TDRs complete by end of 2014
Start of construction in 2014
Start of assembly at Jülich in 2016/7
Mounting at FAIR in 2017/18

Critical items

Absence of funding for the solenoid magnet and for the barrel crystals (1/3 missing)
→ Look for additional collaborators or common items
Time delivery for magnet critical: first contract with CERN for first study agreed upon
Crystal delivery by SICCAS (China) might take some additional years (up to end of 2016?)

Timelines



- 6 Submission building permits
- 7 Site preparation
- 8 Civil construction contracts
- 9 Building of accelerator & detector components
- 10 Completion of civil construction work
- 11 Installation & commissioning of accelerators and detectors
- 12 Data taking

From Inti Lehmann (Bochum meeting/sept 2013

The $\bar{P}$ANDA Collaboration

More than 520 physicists from 67 institutions in 17 countries

Aligarh Muslim University
U Basel
IHEP Beijing
U Bochum
Magadh U, Bodh Gaya
BARC Mumbai
IIT Bombay
U Bonn
IFIN-HH Bucharest
U & INFN Brescia
U & INFN Catania
NIT, Chandigarh
AGH UST Cracow
JU Cracow
U Cracow
IFJ PAN Cracow
GSI Darmstadt

Karnatak U, Dharwad
TU Dresden
JINR Dubna
U Edinburgh
U Erlangen
NWU Evanston
U & INFN Ferrara
FIAS Frankfurt
LNF-INFN Frascati
U & INFN Genova
U Glasgow
U Gießen
Birla IT&S, Goa
KVI Groningen
Sadar Patel U, Gujart
Gauhati U, Guwahati
IIT Guwahati

IIT Indore
Jülich CHP
Saha INP, Kolkata
U Katowice
IMP Lanzhou
INFN Legnaro
U Lund
U Mainz
U Minsk
ITEP Moscow
MPEI Moscow
TU München
U Münster
BINP Novosibirsk
IPN Orsay
U & INFN Pavia
IHEP Protvino

PNPI Gatchina
U of Silesia
U Stockholm
KTH Stockholm
Suranree University
South Gujarat U, Surat
U & INFN Torino
Politechnico di Torino
U & INFN Trieste
U Tübingen
TSL Uppsala
U Uppsala
U Valencia
SMI Vienna
SINS Warsaw
TU Warsaw

PANDA@IPN in the future

1. **Electron tracking, PID and event filtering**
2. **Feasibility of 'Transition Distribution Amplitudes' (TDA)**
3. **pbar p → $\mu^-\mu^+$ (radiative correction free)**
4. **Phenomenology**
5. **Proto 120 crystals: assembly and tests**
6. **Cooling machine concept (demonstrator for pre-assembly at Julich)**

7.MOU