Hadron Physics with Strange and Charm Quarks
The PANDA Experiment

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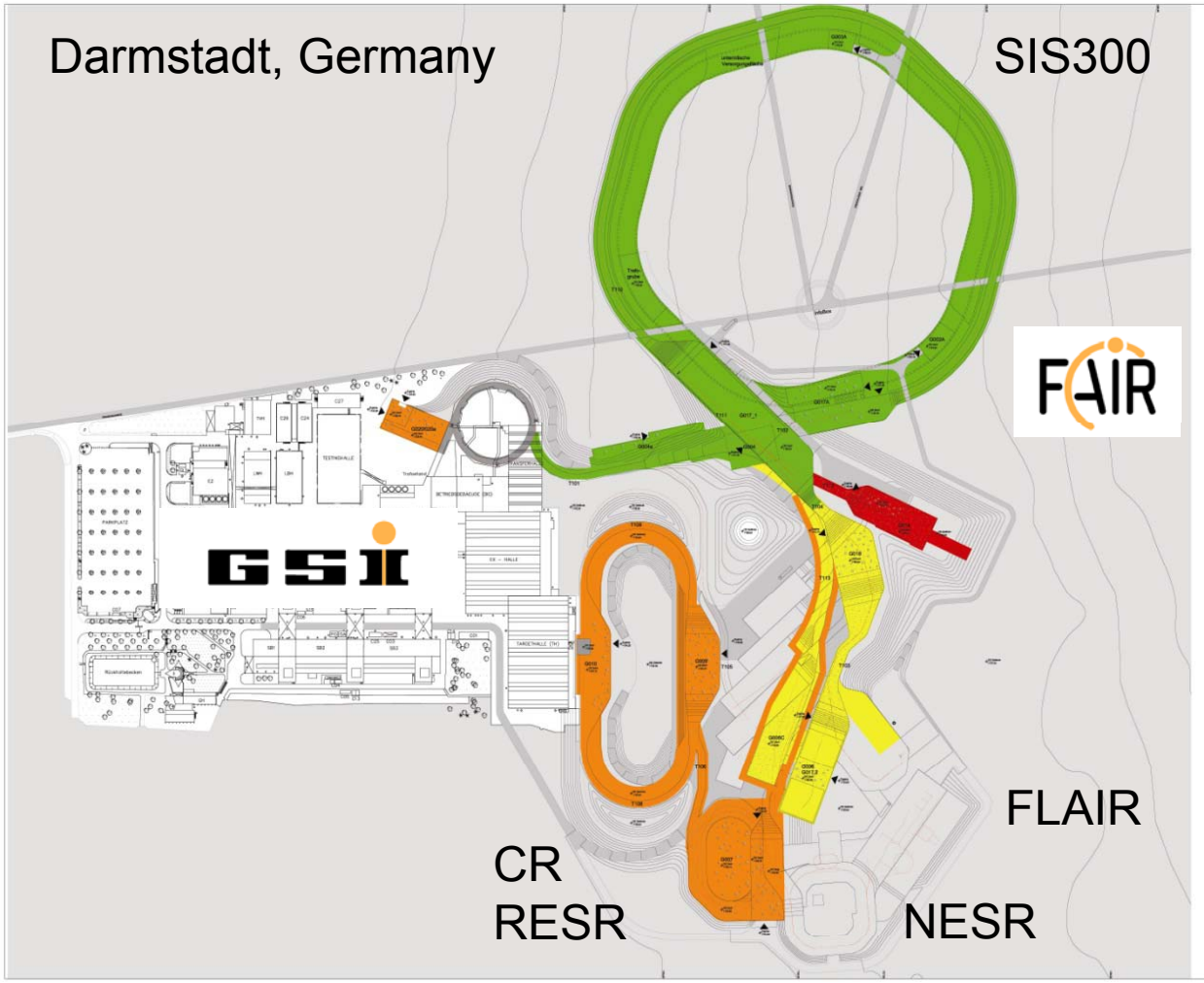
Contents

FAIR – Facility for Antiproton and Ion Research

Convention signed October 4th



Colored:
FAIR Start Version

SIS100

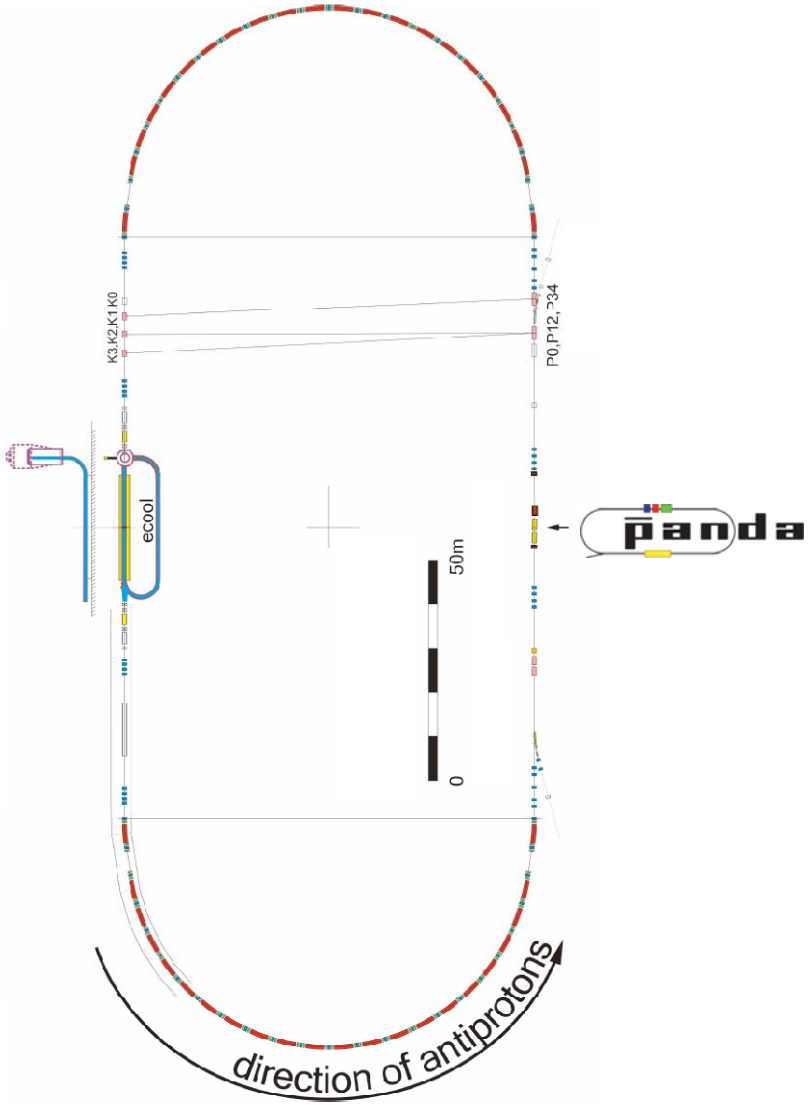
CBM"Light"

Proton Linac
Pbar target
CR
HESR

SuperFRS

"Final Act States"

HESR – High Energy Storage/Synchrotron Ring

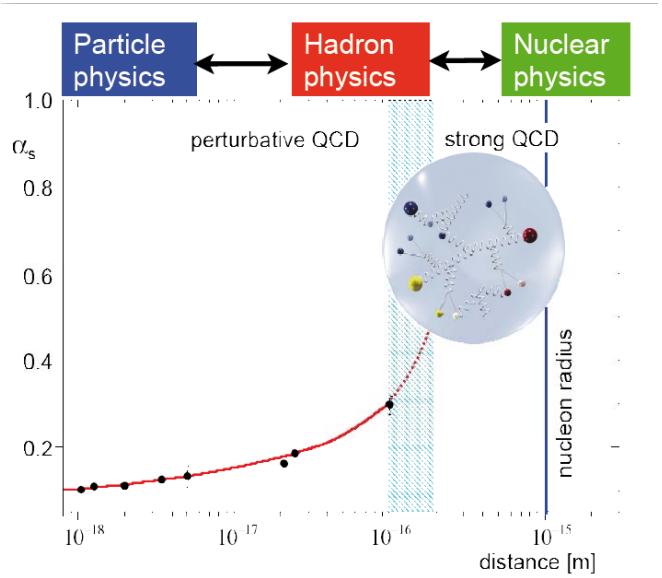


- antiproton ring
- injection 3.5 GeV/c
- 1.5 – 15 GeV/c (0.83 – 14 GeV)
- 10^{10} to 10^{11} stored particles
- bunched beam
- high resolution mode
  - $2 \cdot 10^{31} cm^{-2} s^{-1}$ (10^{10} pbar)
  - $\sigma_p/p \leq 2 \cdot 10^{-5}$
  - $p \leq 9$ GeV/c, e^- cooling
- high luminosity mode
  - $2 \cdot 10^{32} cm^{-2} s^{-1}$ (10^{11} pbar)
  - $\sigma_p/p \sim 10^{-4}$
  - $p \leq 15$ GeV/c, stochastic cooling

RESR not part of the Start version:
Accumulation in the HESR,
limits intensity

Physics with Antiprotons at PANDA

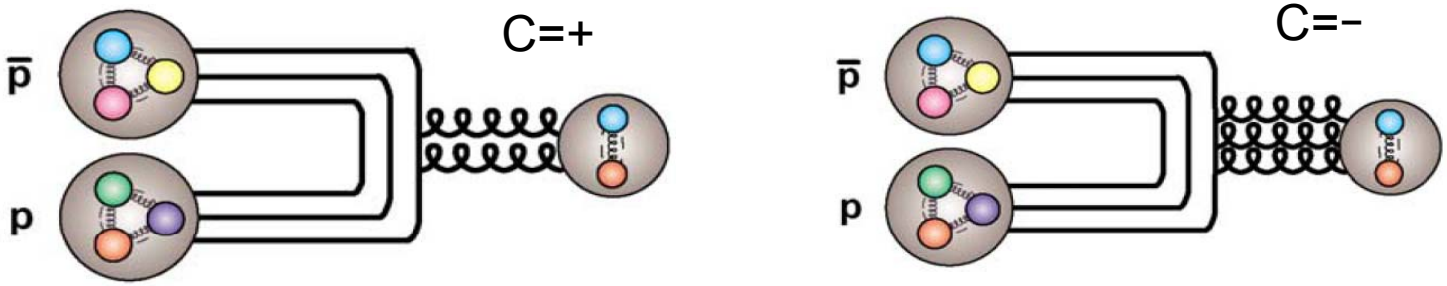
- Hadron Spectroscopy (up to charm)
  - Charmonium and open Charm
  - Search for Exotics: Glueballs, Hybrids
  - Multiquark States, XYZ states
  - Baryons
- Hadron Properties in Nuclear Matter
- Nonperturbative Dynamics
- Single and Double Hypernuclei
- Nucleon Structure (time-like form factors, transverse parton distributions)
- CP violation



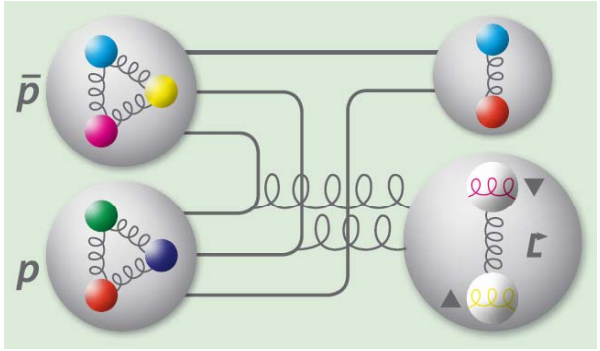
Hadron Physics: perturbation methods not applicable any more

Particle Production in Antiproton Annihilations

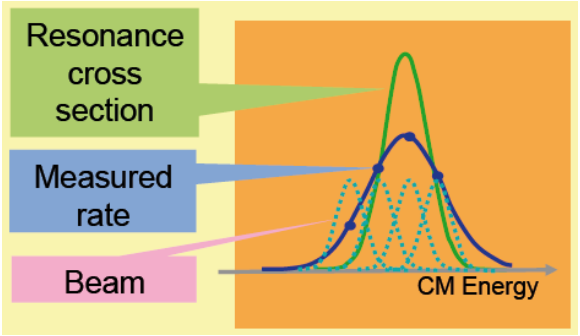
Gluon rich processes



Formation processes: all in $q\bar{q}$ allowed quantum numbers

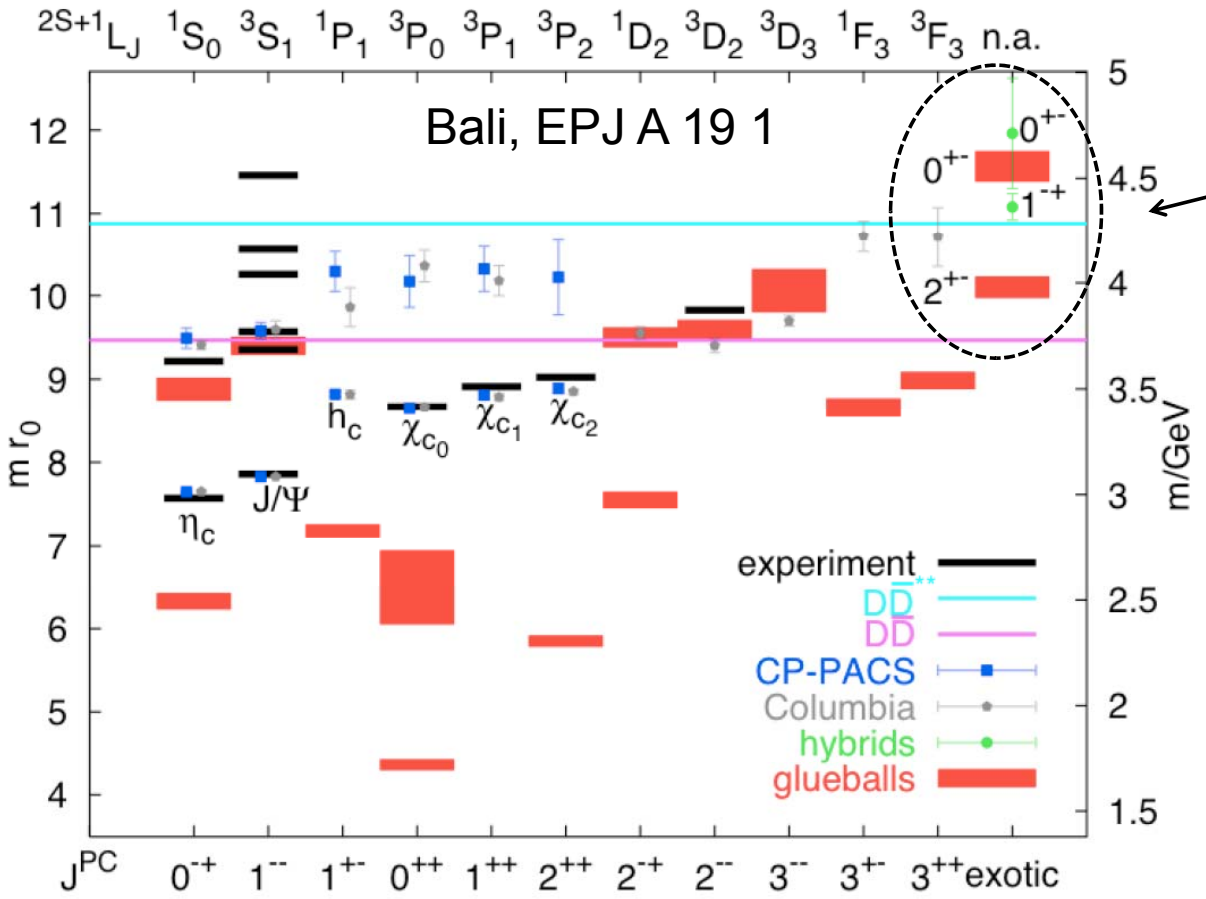


Production processes:
exotic quantum numbers possible



Resonance scan in formation
resolution limited by σ_p/p
FNAL E760: $\sigma \approx 240$ keV
PANDA: ≥ 30 keV

(Charmed) Hadron Spectrum



well arranged region narrow states

Hybrid states
$J^{PC}=1^{-+}$
m = 4.2 – 4.5 GeV
Γ < 50 MeV

Oddballs
$J^{PC}=0^{+-},2^{+-}$
m = 4 – 5 GeV
Γ < 50 MeV

QCD allows for hybrids and glueballs ("pure glue")

PANDA: looking for exotic J^{PC}

Spectroscopy of Charmonium

$\bar{p}p$-Annihilations: high hadronic background

$$\bar{p}p \rightarrow J/\psi + X$$

$$J/\psi \rightarrow e^+e^-$$
$$\rightarrow \mu^+\mu^-$$

$\bar{p}p \rightarrow J/\psi\pi^+\pi^- \rightarrow e^+e^-\pi^+\pi^-;$

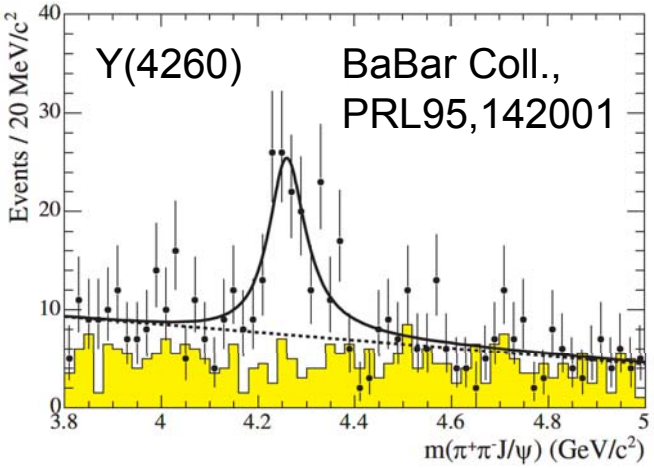
$\bar{p}p \rightarrow J/\psi\pi^0\pi^0 \rightarrow e^+e^-\gamma\gamma\gamma\gamma;$

$\bar{p}p \rightarrow \chi_{c1,c2}\gamma \rightarrow J/\psi\gamma\gamma \rightarrow e^+e^-\gamma\gamma;$

$\bar{p}p \rightarrow J/\psi\gamma \rightarrow e^+e^-\gamma;$

$\bar{p}p \rightarrow J/\psi\eta.$

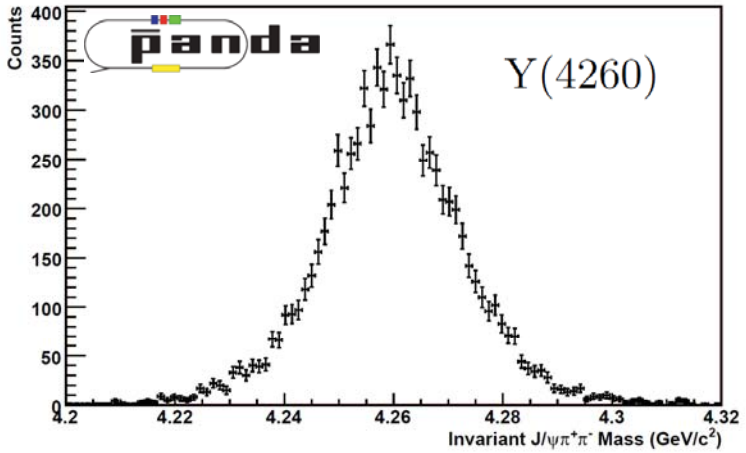
X(3872)	BaBar, Belle, CDF, D0	1^{++}, 2^{-+}, D^0D^*, qqqq ?
X(3930)	Belle	2^{++} $\chi_{c2}(2P)$
X(3940)	Belle	?
X(3945)	BaBar, Belle	??+ $\eta_c(3S)$?
X(4160)	Belle	?
Y(4260)	BaBar, Belle, CLEO	1^{--}
Y(4360)	BaBar, Belle	1^{--}
X(4660)	BaBar, Belle	1^{--}
h_c	CLEO	1^{+-}
η'_c	BaBar, Belle, CLEO	0^{-+}
…		



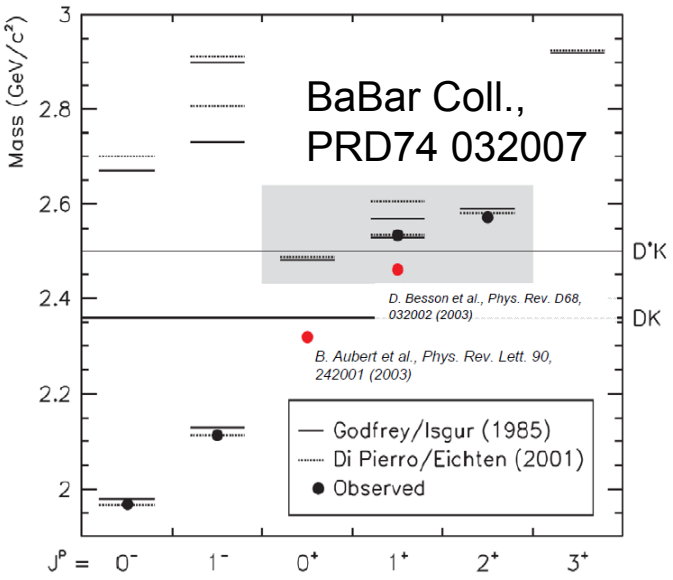
ε=0.32
S/B=2

$J/\psi\pi^+\pi^-$ 100/d

$J/\psi\pi^0\pi^0$ 40/d



Open Charm Mesons



Reported by BaBar, Belle, CLEO:
Narrow states $D_{s0}^*(2317)$, $D_s^*(2460)$

Quark model expects higher masses!

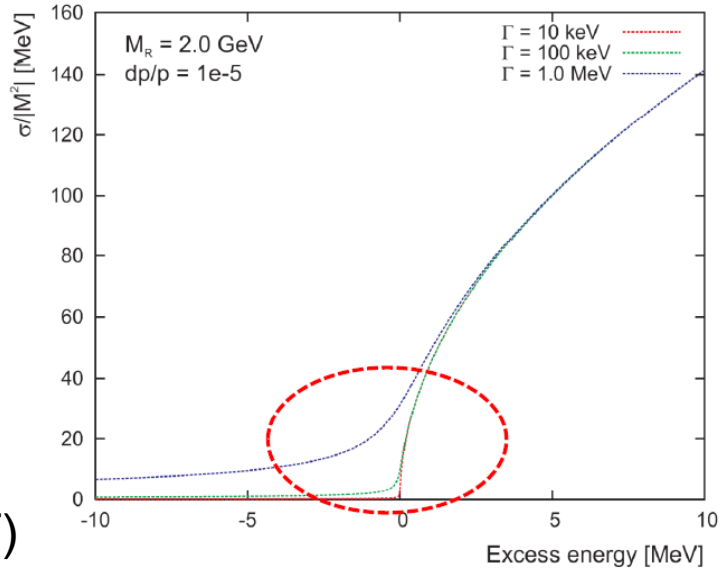
States are close to threshold (DK, D*K)

Interpretation?

Many different theoretical predictions concerning the $D_{s0}^*(2317)$ width (from 6 to 180 keV)

$$\overline{\mathrm{p}}\mathrm{p} \quad \rightarrow \quad D_s^{\pm} D_{s0}^*(2317)^{\mp}$$

Threshold scan: excitation function (m, Γ)



Resolution determined by σ_p/p

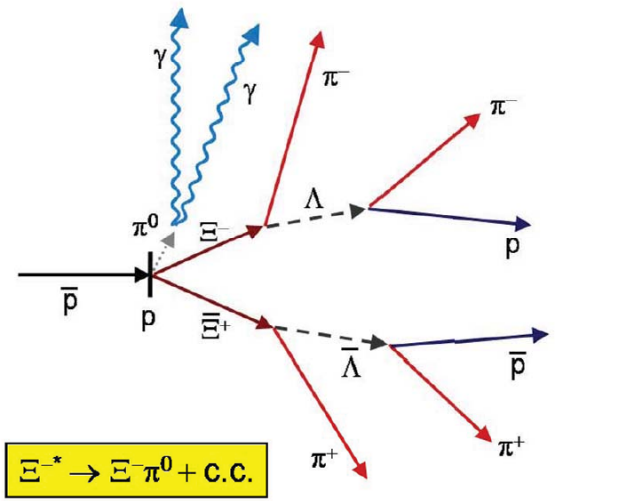
Baryon Spectroscopy

comparable cross sections into mesons and baryon-antibaryon

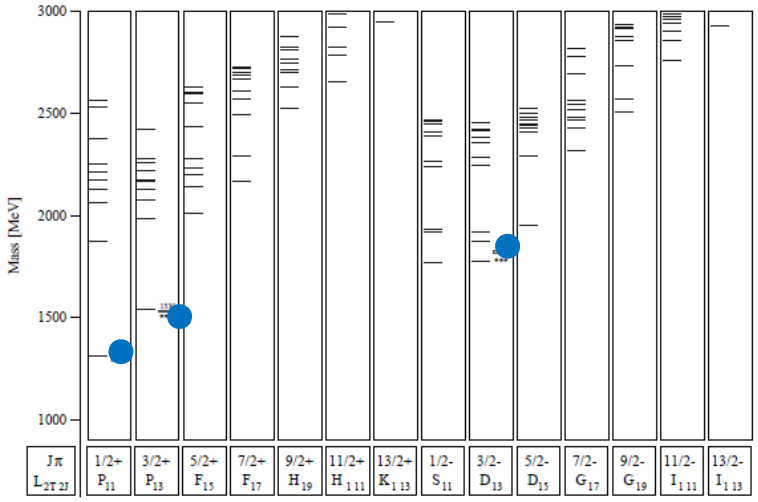
multistrange baryons – very little known so far

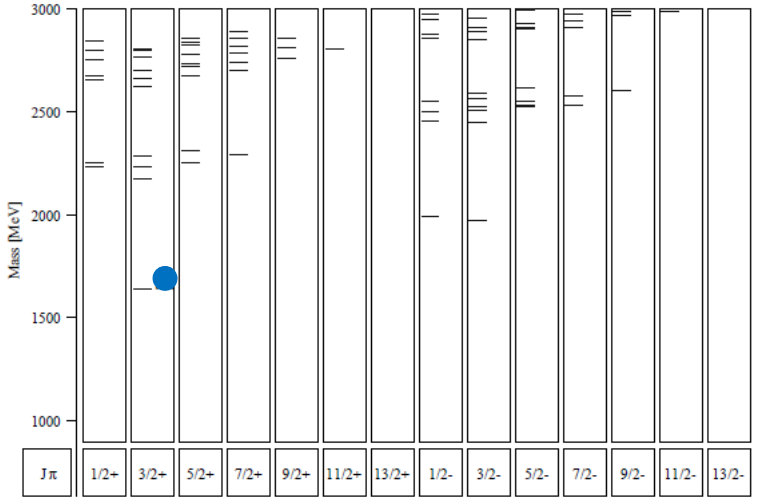
discovery potential

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



Simulation: $\sigma_m(\Xi^-\pi^0) \sim 4$ MeV





Predicted S=−2, S=−3 spectra from Löring, Metsch, Petry EPJA10 447

Hadron Properties in Nuclear Matter

How does the hadron mass come about?

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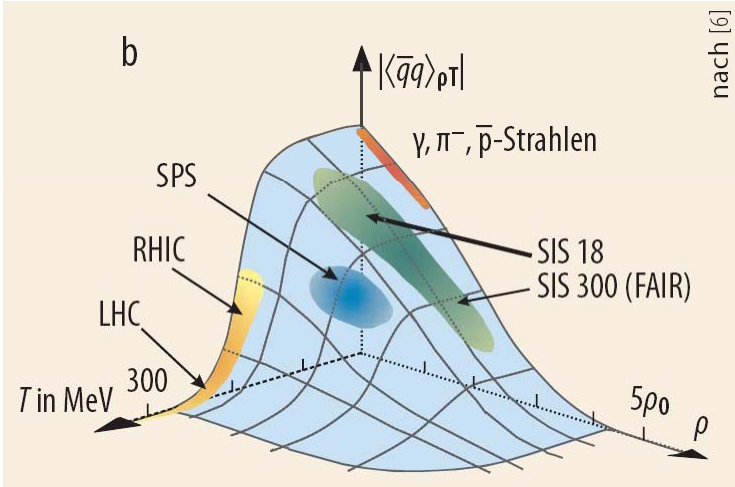
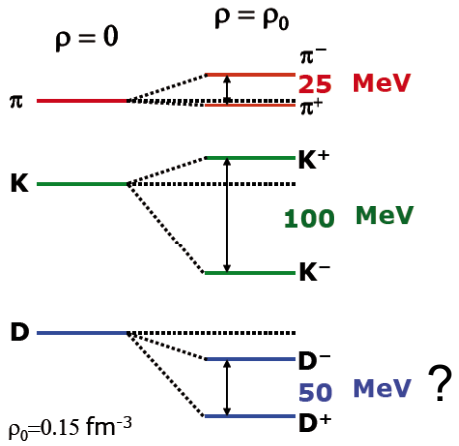


(charmed) hadrons in nuclear matter

mass splitting?
mass shift?



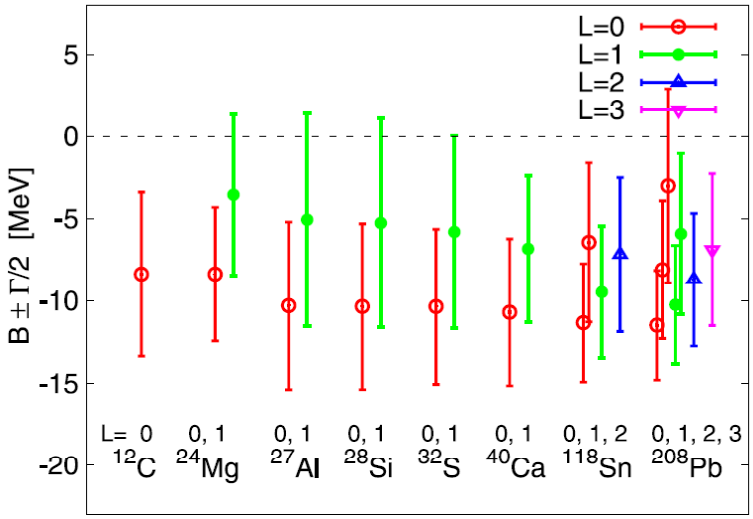
?

(Quasi)bound states ?

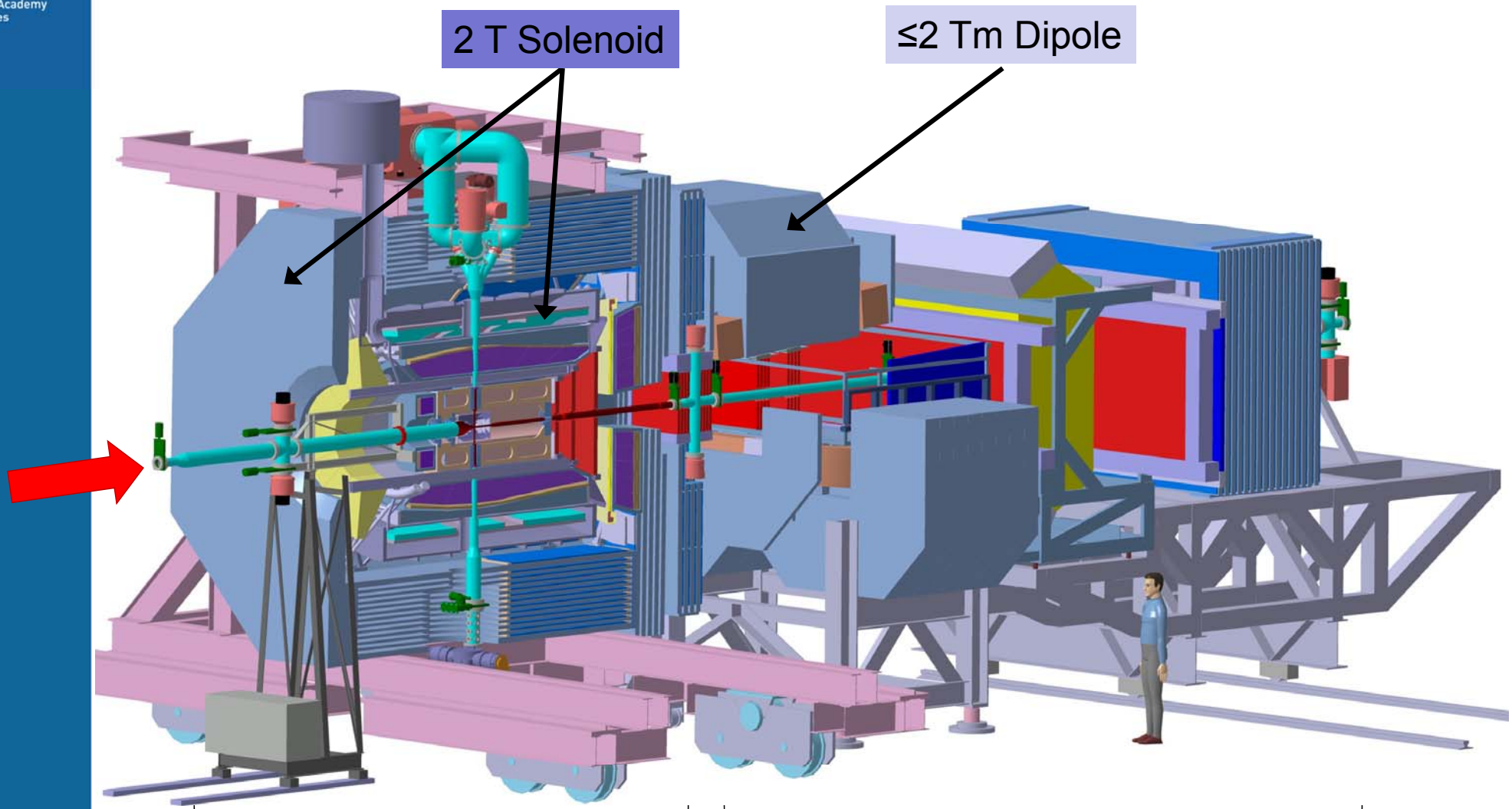
$$\bar{p} + A_Z \rightarrow D^- + \{(A-1)_Z - D^0\}_{\text{bound}}$$
$$\rightarrow \bar{D}^0 + \{(A-1)_{Z-1} - D^0\}_{\text{bound}}$$

$$D^{*+} + A_Z \rightarrow \pi^+ + \{A_Z - D^0\}_{\text{bound}}$$

García-Recio et al., PLB690 368



The PANDA Detector



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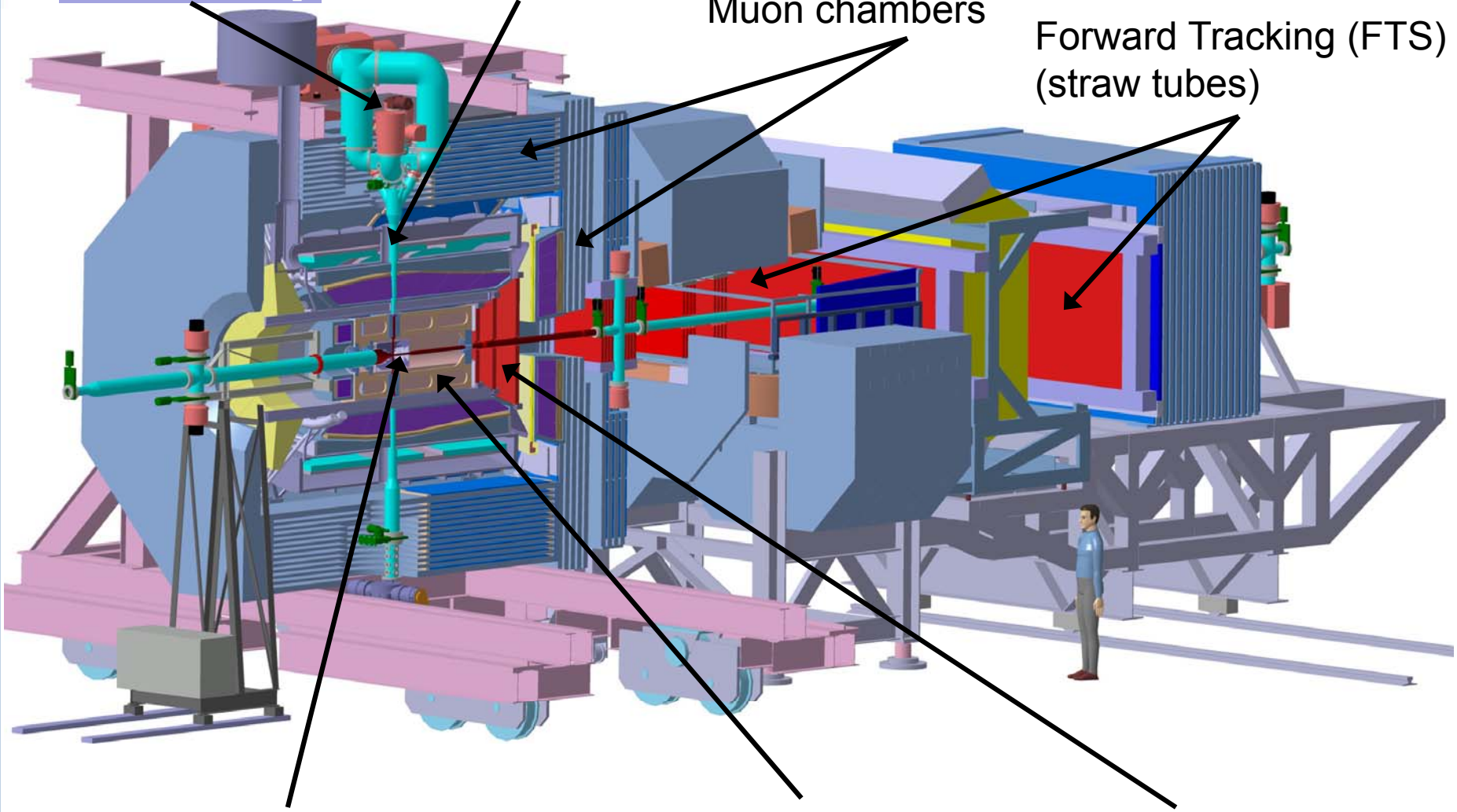

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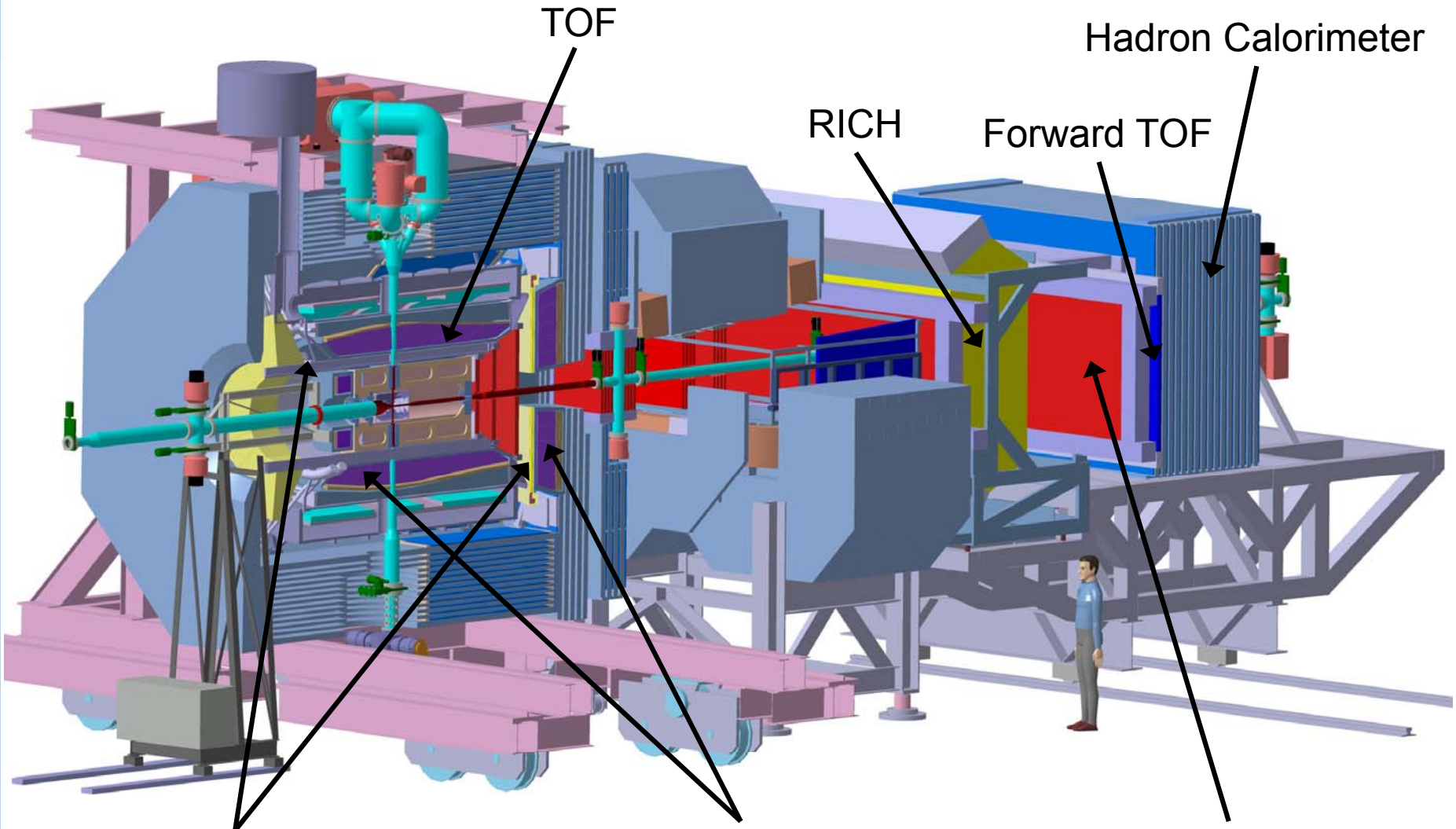
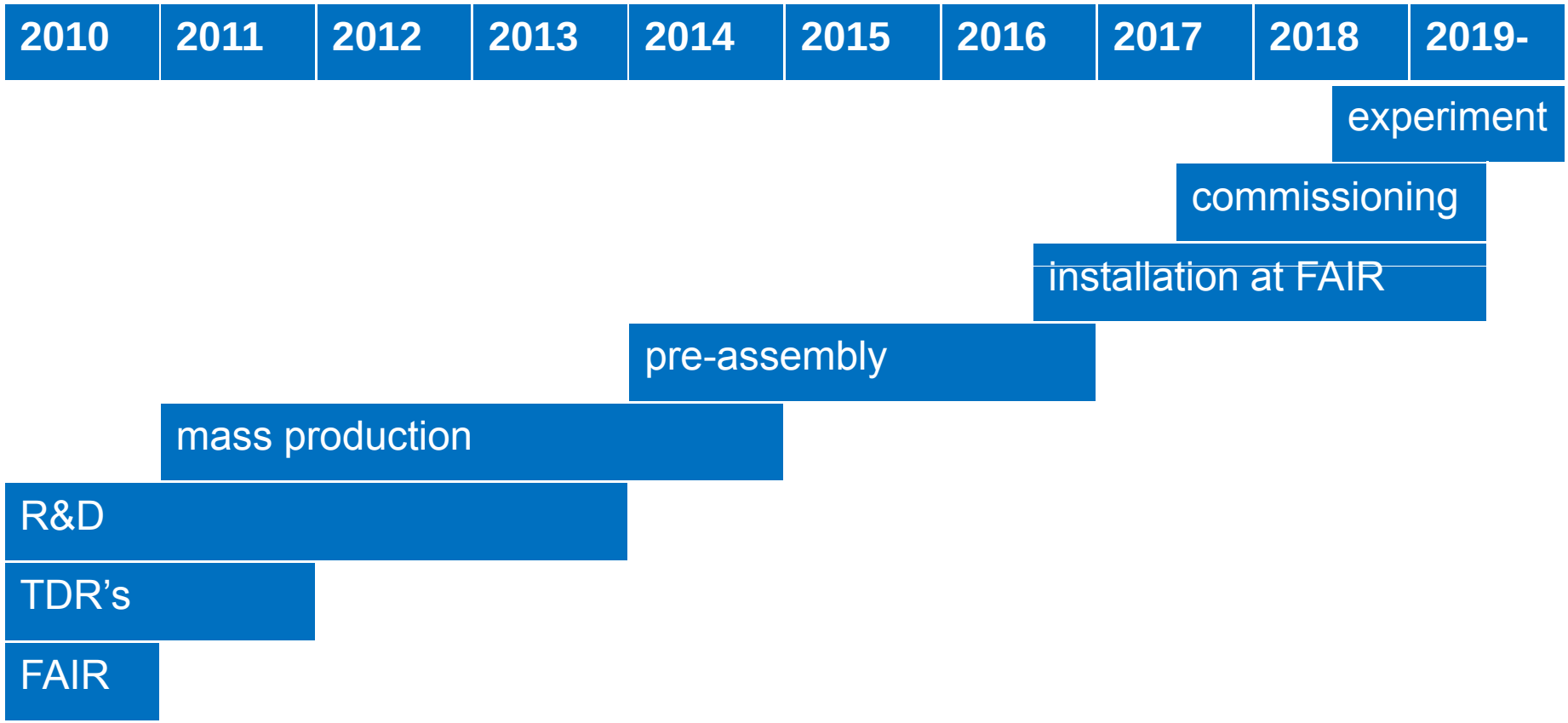


Cherenkov (DIRC)
PID for π,K,p > 1 GeV/c

Electromagnetic Calorimeter (EMC) – PWO crystals
$\sigma_E/\sqrt{E} < 2\%$, 1 MeV<E<10 GeV

Forward EMC
$\sigma_E/\sqrt{E} \approx 4\%$

Timeline



Caveat:
The overall time scale is driven by the civil construction and infrastructure!

Summary

- Legal foundation of FAIR has happened recently
  - Detailed construction planning in 2011
  - Civil construction starts end of 2011
  - Installation of experiments should start from 2017
- PANDA: Antiproton Annihilations
  - HESR: $\bar{p}$ from 1.5 to 15 GeV/c → *charmed hadrons*
  - High resolution/high luminosity
  - Hydrogen target (cluster jet, pellets)
  - Nuclear targets
- Hadron spectroscopy
- Properties of hadrons in nuclear matter
- Broad physics program
- Detector planning and construction
  - Two TDR's (Magnets and EMC) already approved
  - Pre-Assembly of a nearly complete setup

www-panda.gsi.de

> 400 scientists
17 countries
> 50 institutions

New Panda Family Member in Vienna