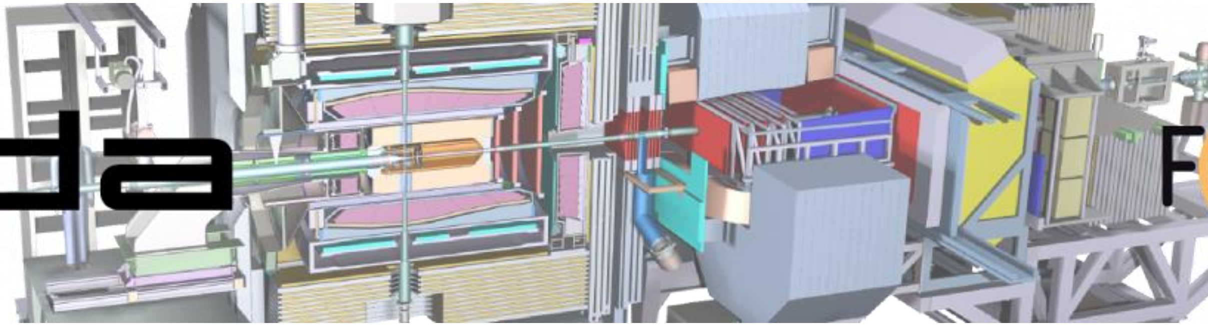
PANDA Physics @ FAIR

Anastasios Belias
for the PANDA Collaboration
GSI, Darmstadt, Germany

EXA2017, Vienna
September 15th, 2017

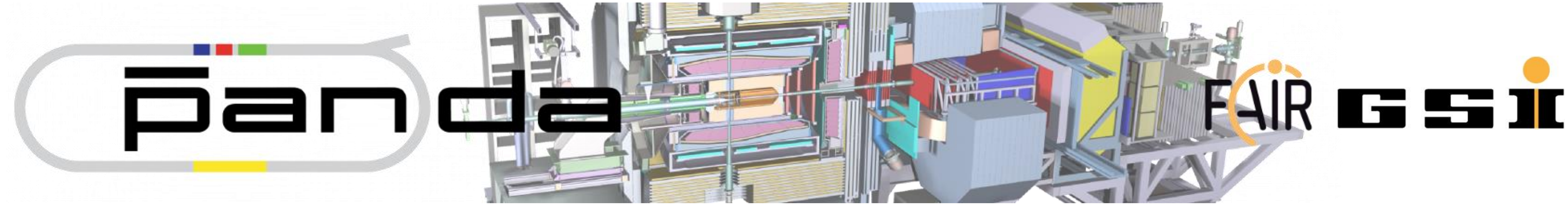


PANDA Physics @ FAIR

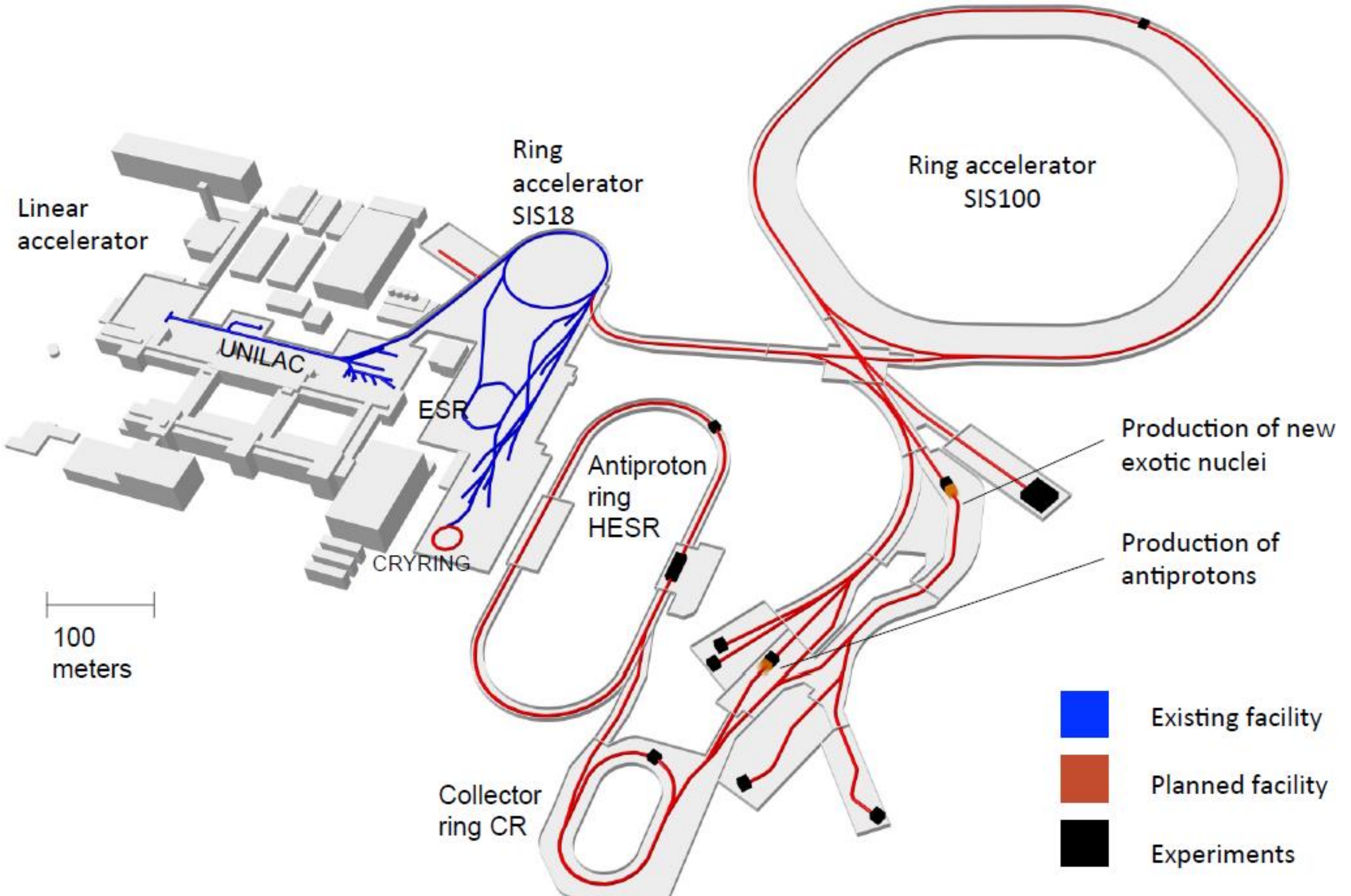
The Facility

PANDA Physics Goals

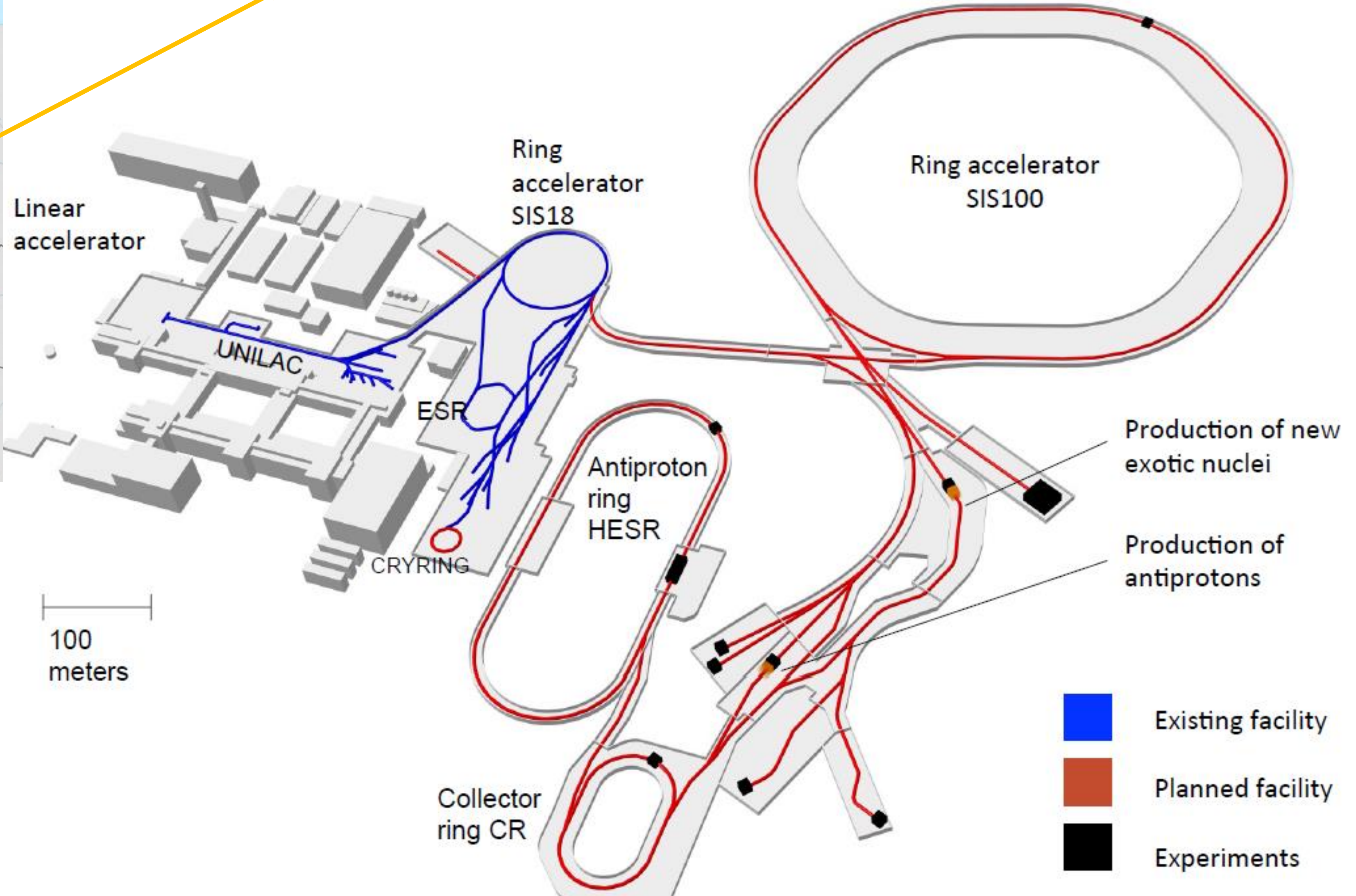
Status & Outlook



Facility for Antiproton and Ion Research
@ GSI, Darmstadt, Germany



Facility for Antiproton and Ion Research
@ GSI, Darmstadt, Germany



Facility for Antiproton and Ion Research

Nuclear Structure & Astrophysics
(rare isotope beams)

Hadron Physics
(stored and cooled
15 GeV/c anti-protons)

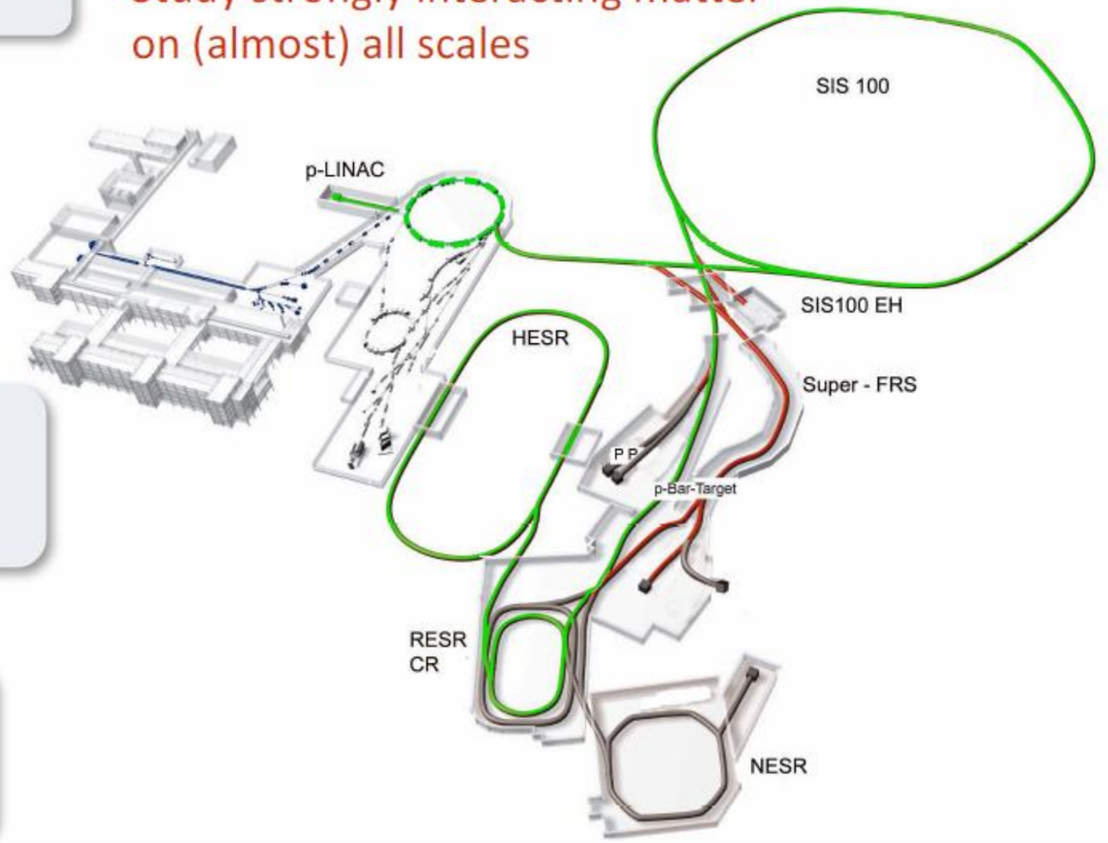
QCD-Phase Diagram
(HI beams 2 to 45 GeV/u)

Fundamental Symmetries & Ultra-High EM Fields
(anti-protons & highly stripped ions)

Dense Bulk Plasmas
(ion beam bunch compression
& petawatt-laser)

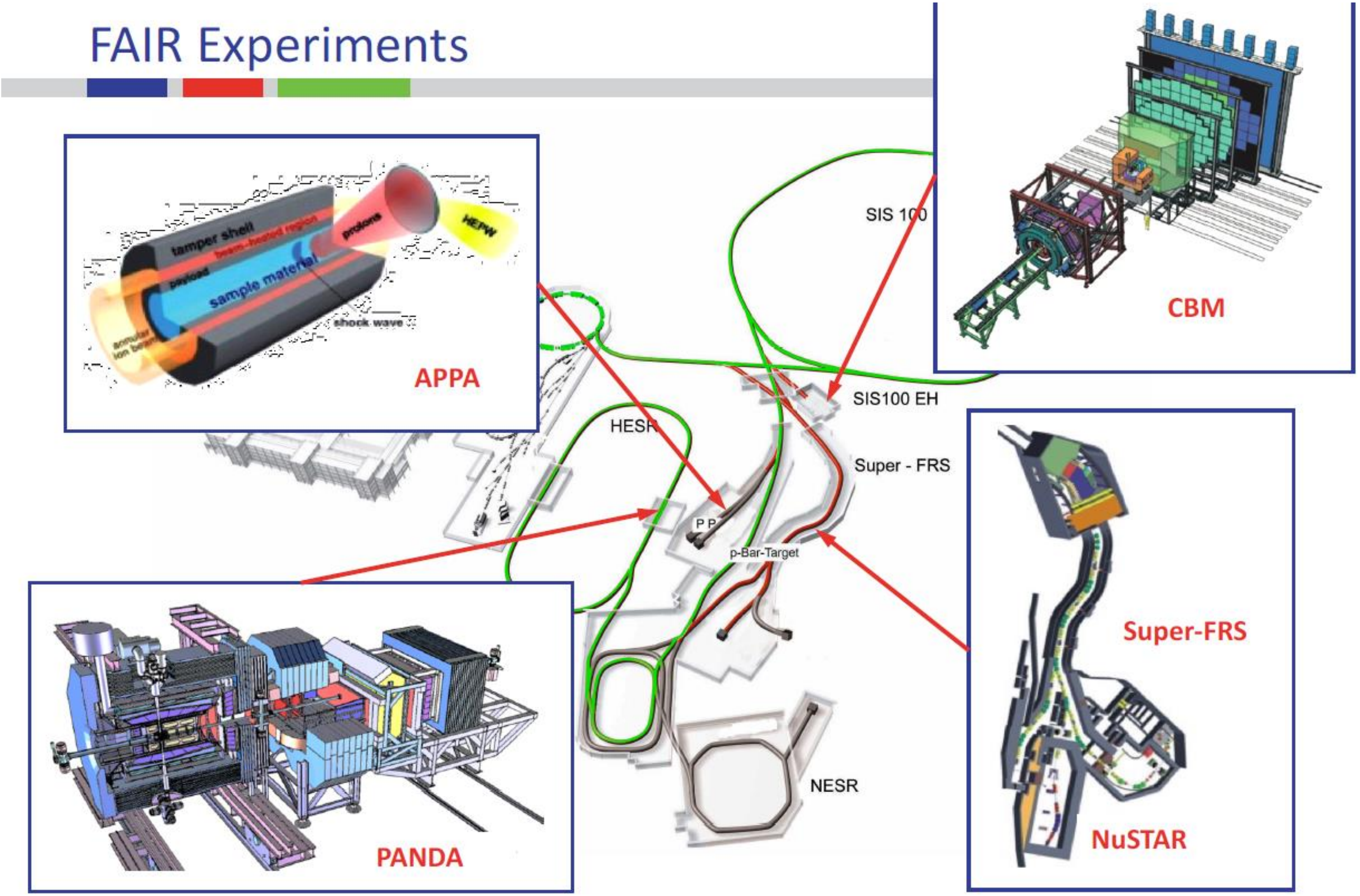
Materials Science & Radiation Biology
(ion & anti-proton beams)

Our Mission
Study strongly interacting matter on (almost) all scales



Accelerator Physics

Facility for Antiproton and Ion Research

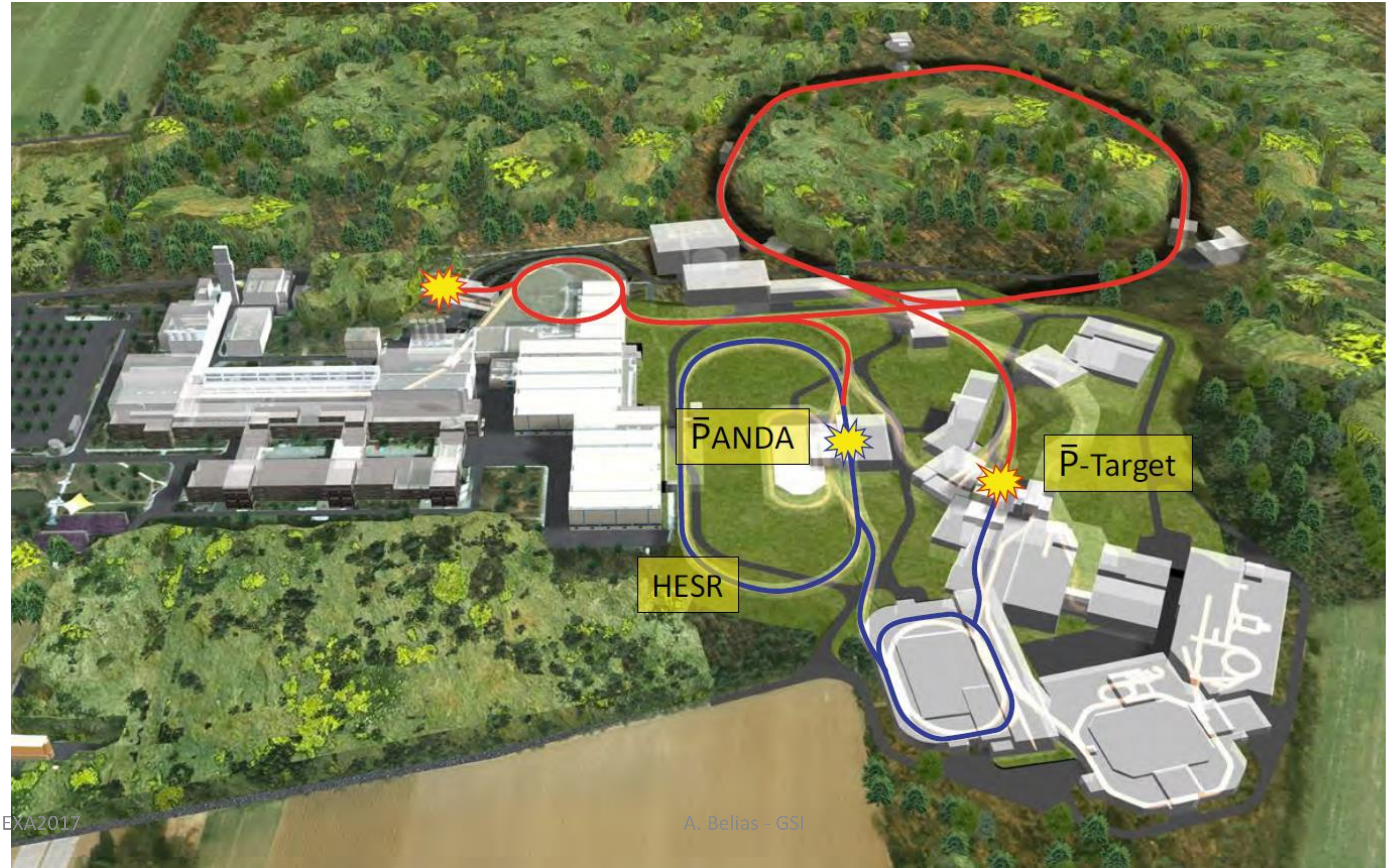


Facility for Antiproton and Ion Research

Facility for Antiproton and Ion Research

AntiProton ANnihilation at DArmstadt

HESR & PANDA @ FAIR

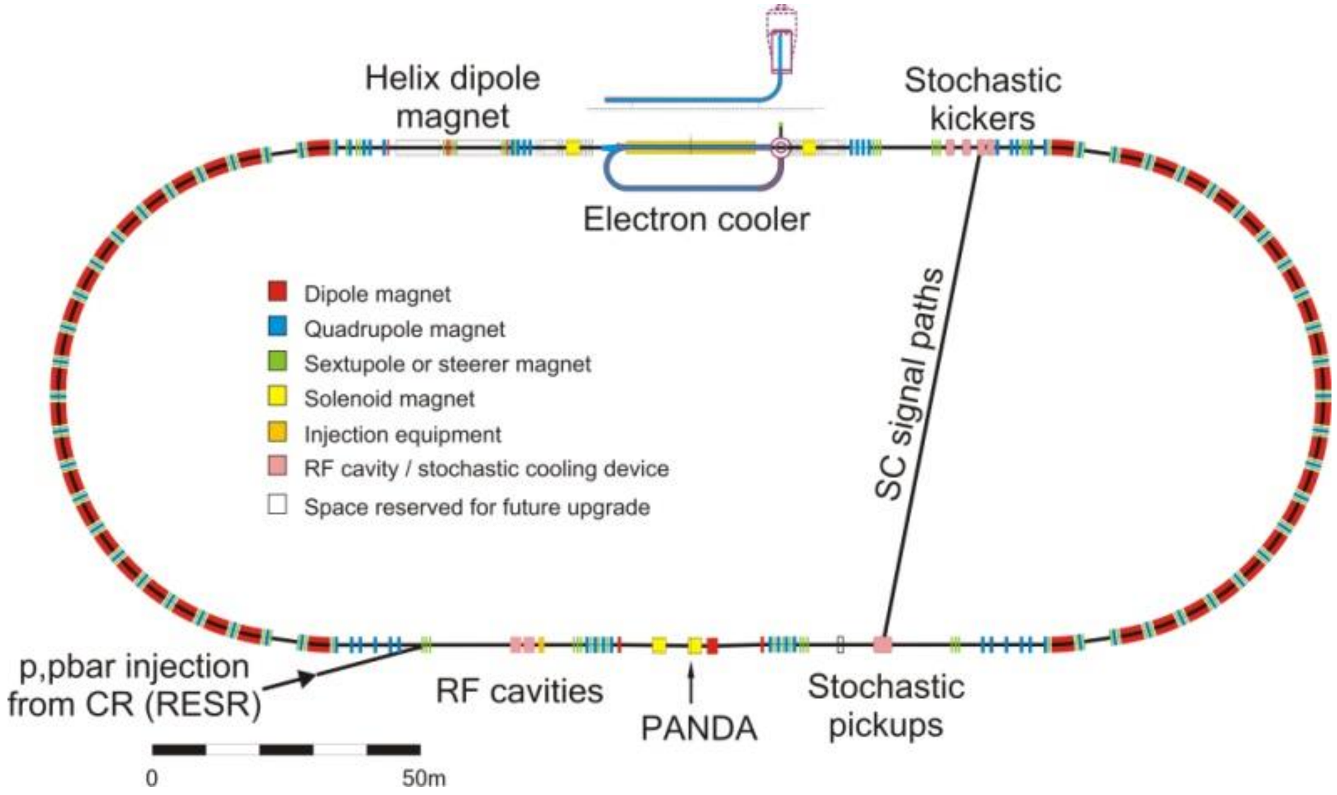


HESR - High Energy Storage Ring

➔ **Forschungszentrum Jülich**

Circumference	575 m
Momentum	1.5 – 15 GeV/c
Electron Cooling	up to 9 GeV/c
Stochastic Cooling	Full range

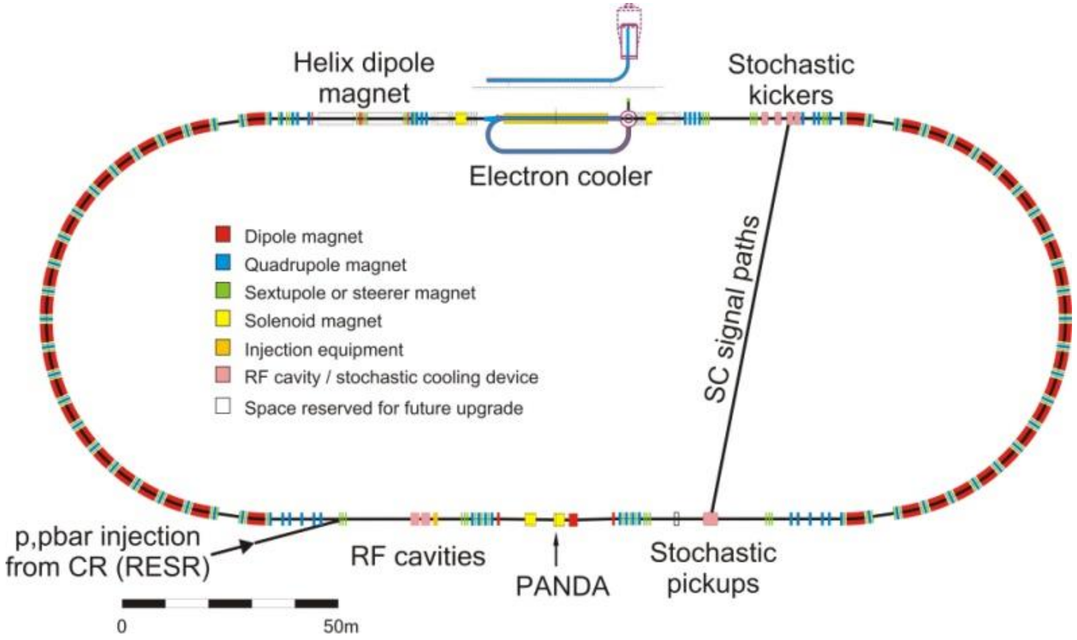
Mode	High luminosity (HL)	High resolution (HR)
$\Delta p/p$	$\sim 10^{-4}$	$\sim 4\text{x}10^{-5}$
$L(cm^{-2}s^{-1})$	$2\text{x}10^{32}$	$2\text{x}10^{31}$
Stored p̄	10^{11}	10^{10}



HESR - High Energy Storage Ring

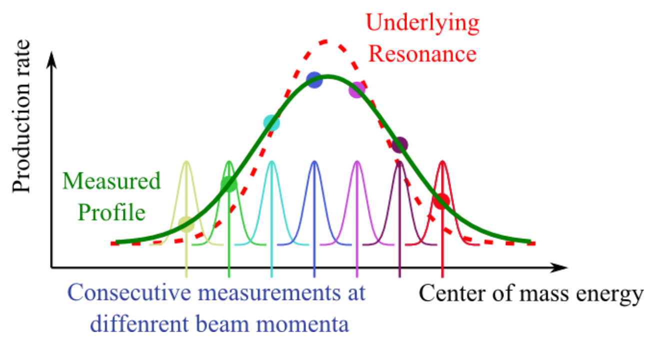
➔ **Forschungszentrum Jülich**

Mode	High luminosity (HL)	High resolution (HR)
$\Delta p/p$	$\sim 10^{-4}$	$\sim 4\times10^{-5}$
$L(cm^{-2}s^{-1})$	2×10^{32}	2×10^{31}
Stored p̄	10^{11}	10^{10}



$e^+ e^-$	p p̄
Low hadronic background	High hadronic background
Direct production restricted to 1^{--} states	Direct production of various states

Production experiments



PANDA Physics Goals

Hadron Spectroscopy

Experimental Goals: *mass, width & quantum numbers J^{PC} of resonances*

Charm Hadrons: *charmonia, D-mesons, charm baryons*

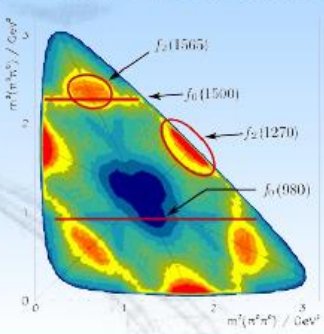
→ Understand new XYZ states, $D_s(2317)$ and others

Exotic QCD States: *glueballs, hybrids, multi-quarks*

Spectroscopy with Antiprotons:

Production of states of all quantum numbers

Resonance scanning with high resolution



PANDA Physics Goals

Hadron Spectroscopy

Experimental Goals: mass, width & quantum numbers J^{PC} of resonances

Charm Hadrons: charmonia, D-mesons, charm baryons

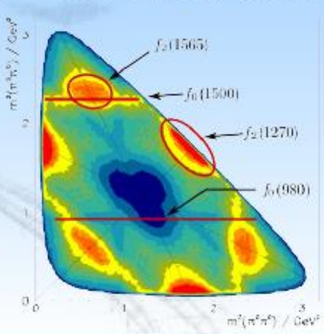
➔ Understand new XYZ states, $D_s(2317)$ and others

Exotic QCD States: glueballs, hybrids, multi-quarks

Spectroscopy with Antiprotons:

Production of states of all quantum numbers

Resonance scanning with high resolution



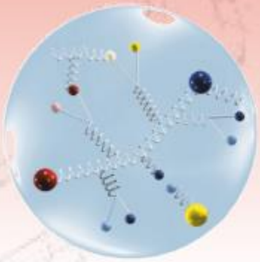
Hadron Structure

Time-like Nucleon Formfactors

➔ Measurable in annihilation, discrepancy with space-like

Generalized Parton Distributions

Drell-Yan Process



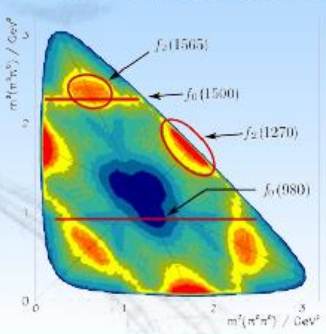
PANDA Physics Goals

Hadron Spectroscopy

Experimental Goals: *mass, width & quantum numbers J^{PC} of resonances*

Charm Hadrons: charmonia, D-mesons, charm baryons

→ Understand new XYZ states, $D_s(2317)$ and others



Exotic QCD States: glueballs, hybrids, multi-quarks

Spectroscopy with Antiprotons:

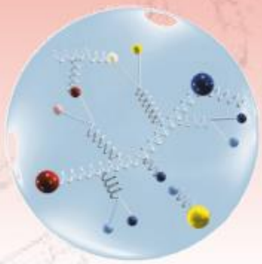
Production of states of all quantum numbers

Resonance scanning with high resolution

Hadron Structure

Time-like Nucleon Formfactors

→ Measurable in annihilation, discrepancy with space-like



Generalized Parton Distributions

Drell-Yan Process

Nuclear Physics

Hypernuclei: Production of double Λ-hypernuclei

→ γ-spectroscopy of hypernuclei, YY interaction

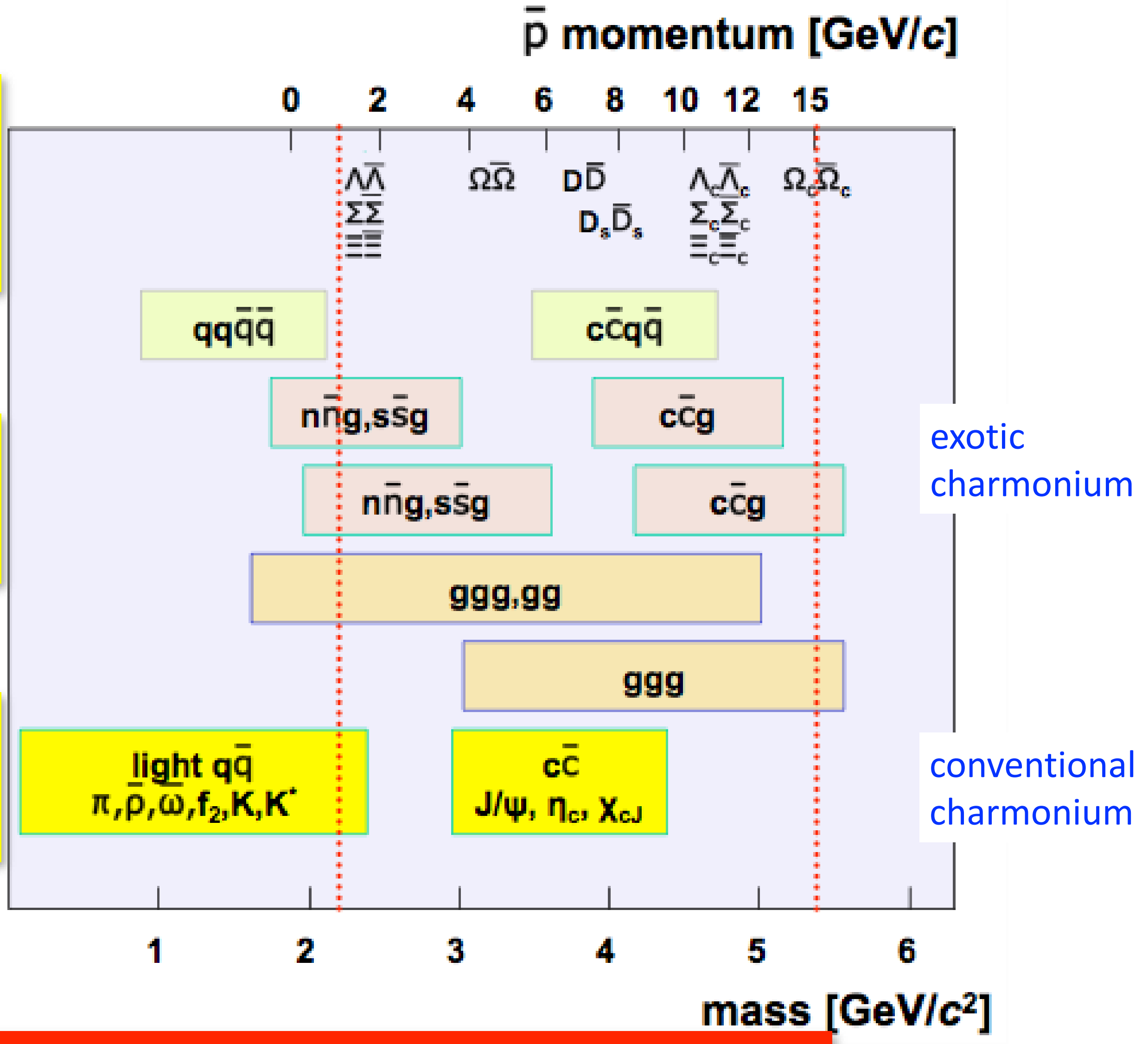
Hadrons in Nuclear Medium

Accessible Hadrons in PANDA

Large mass-scale coverage
- center-of-mass energies from 2 to 5.5 GeV
- from light, strange, to charm-rich hadrons
- from quark/gluons to hadronic degrees of freedom

High hadronic production rates
- charm + strange factory -> discovery by statistics!
- gluon-rich production -> potential for new exotics

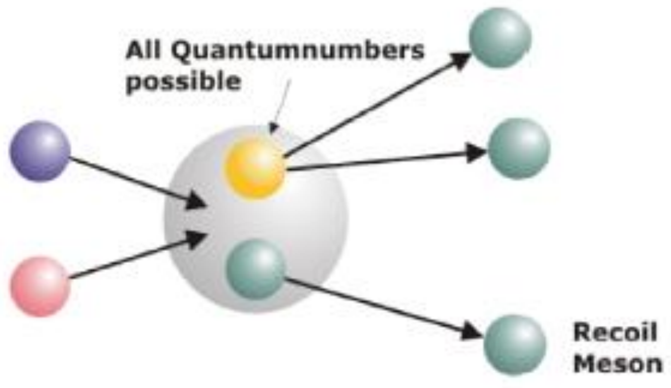
Access to large spectrum of J^{PC} states
- direct formation of *all* conventional J^{PC} states
- large sensitivity to high spin states



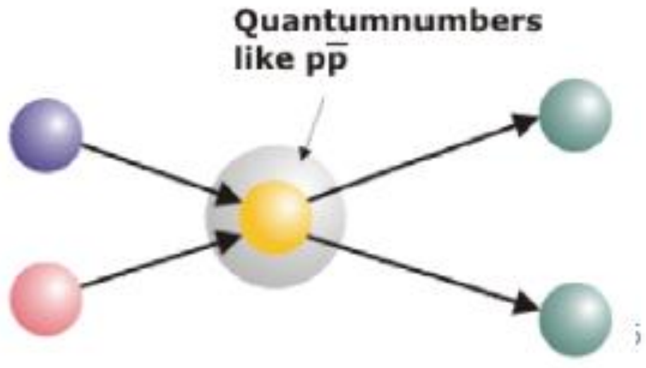
Systematic and precise tool to rigorously study the dynamics of QCD

Antiproton annihilations: gluon rich environment

Production: all states with exotic and non-exotic quantum numbers accessible with a recoil
- high discovery potential

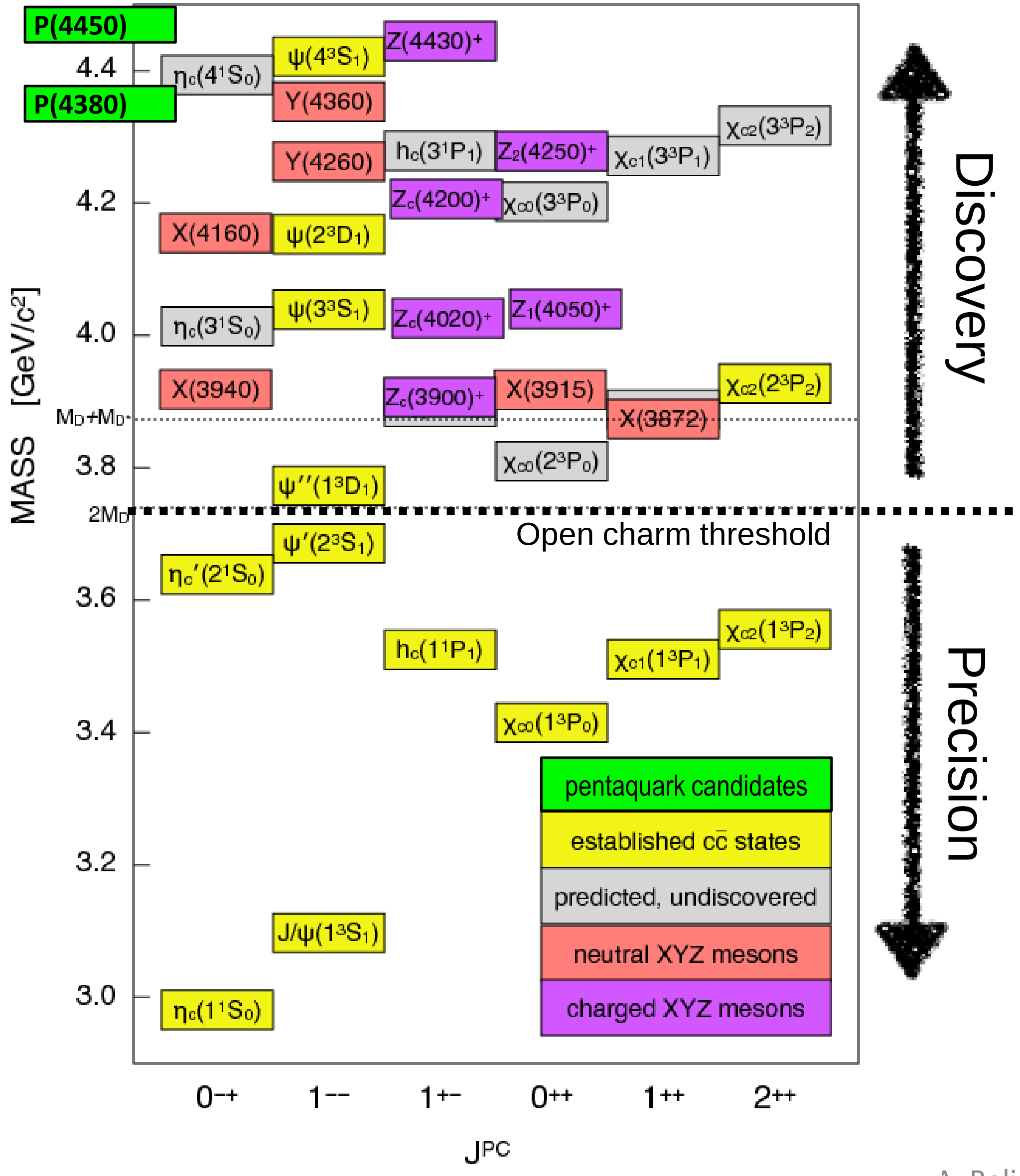


Formation: all states with non-exotic quantum numbers accessible
- not only limited to 1^{--} as e^+e^- colliders
- precision physics of known states



antiproton probe unique

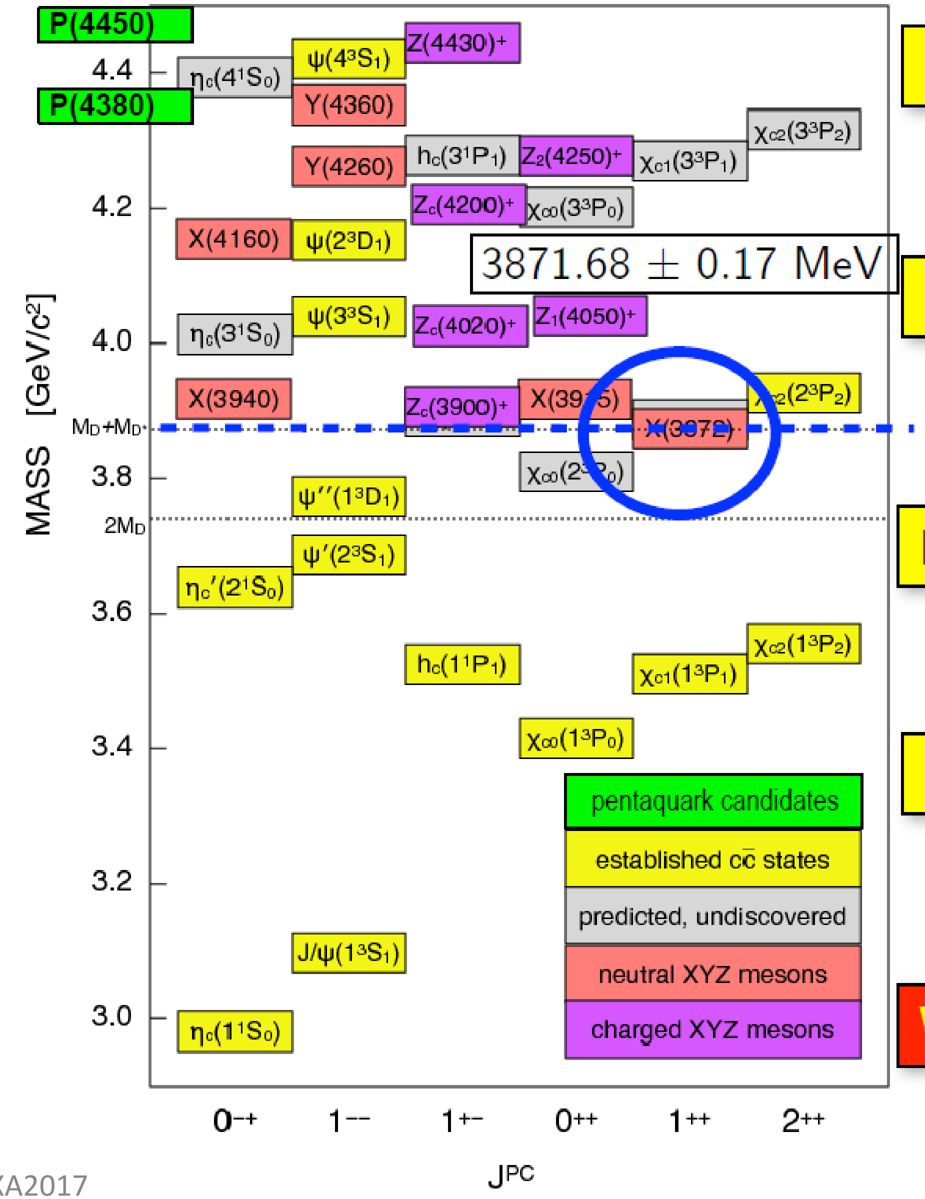
Charmonium-like particles - terra incognita



- line shape of X(3872)
- neutral + charged Z-states
- hidden-charm pentaquark
- X,Y,Z decays
- search for h_c', $^3F_4$, …
- spin-parity/mass & width of $^3D_2$

- line shape/width of the h_c
- radiative decays (multipole)
- light-quark spectroscopy

Case study: the nature of the X(3872)



Strikingly narrow:

$$\Gamma < 1.2\,\text{MeV} \quad (\Gamma(\psi'') = 27\,\text{MeV})$$

Suspiciously close to DD* threshold:

$$\Delta E = -0.13 \pm 0.40\,\text{MeV}$$

Large isospin breaking:

$$B(X \to \rho J/\Psi) \approx B(X \to \omega J/\Psi)$$

Spin-parity:

$$J^{PC} = 1^{++}$$ PRL110, 222001 (2013)

What is its nature?

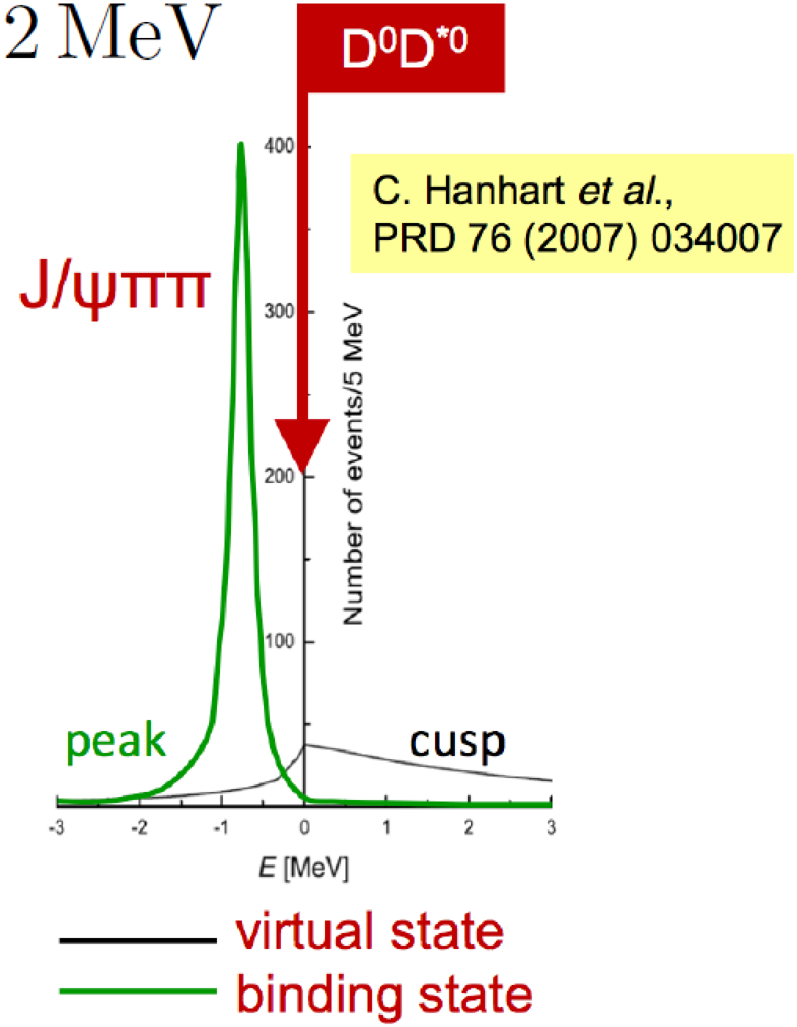
Case study: the nature of the X(3872)

Strikingly narrow:

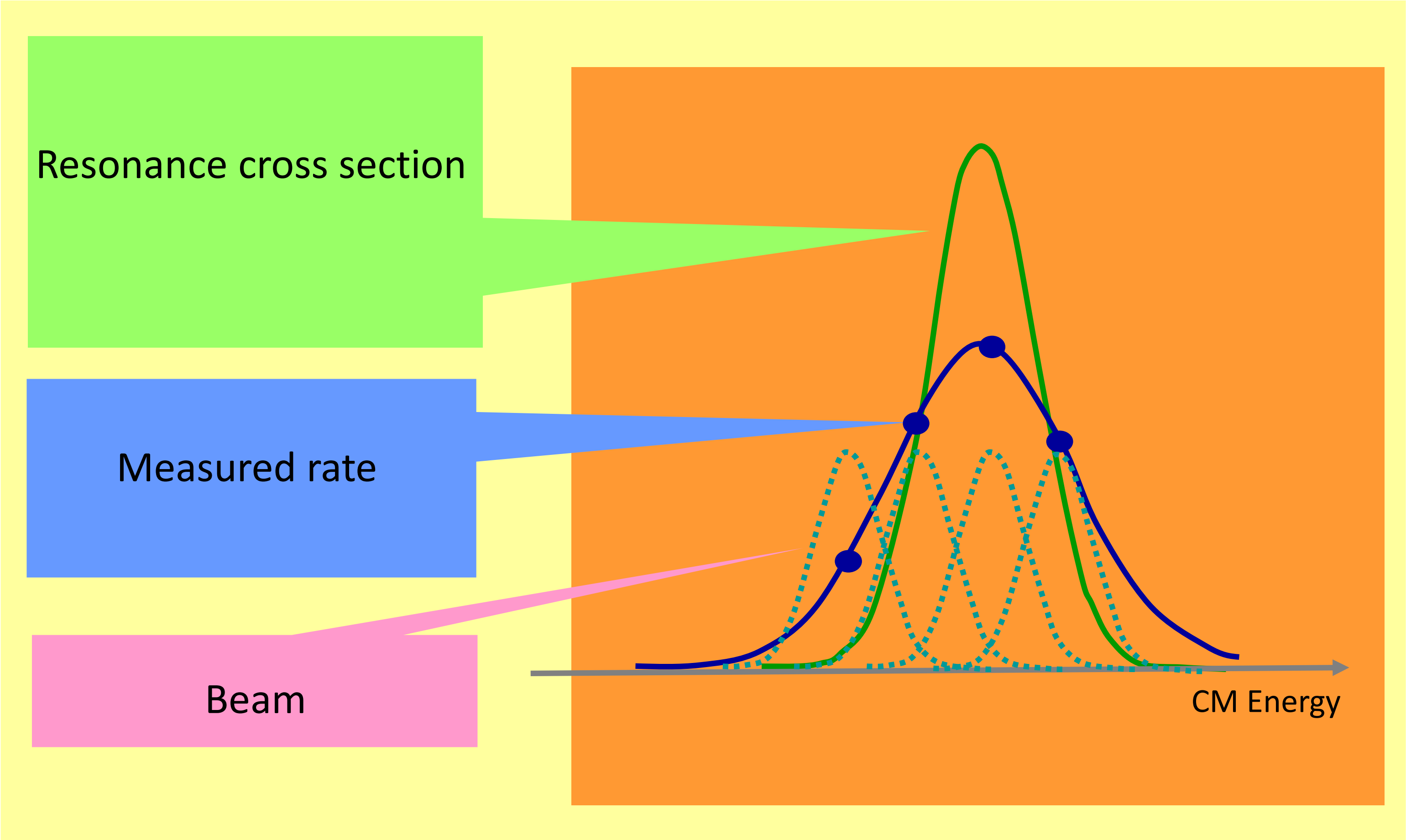
$\Gamma < 1.2\,\mathrm{MeV}$

Theoretical line-shape:
- depends on final state …
- … and nature of particle
-> sensitive observable!

PANDA:
- direct formation of X(3872)
- tagging of various final states (neutral&charged)
- access to line-shape parameters



Resonance scanning



Line shape measurement using HESR's superb mass resolution

Resonance scanning (MC study)

Cross sections:

$$\sigma(\bar{p}p \to X(3872)) = 50\ nb$$
$$\sigma_{non-res}(\bar{p}p \to J/\psi\pi^+\pi^-) = 1.2\,nb$$
$$\sigma(\bar{p}p \to \text{inelastic}) = 46\,mb$$
$$B(X(3872) \to J/\psi\pi^+\pi^-) = 5\%$$

Luminosity:

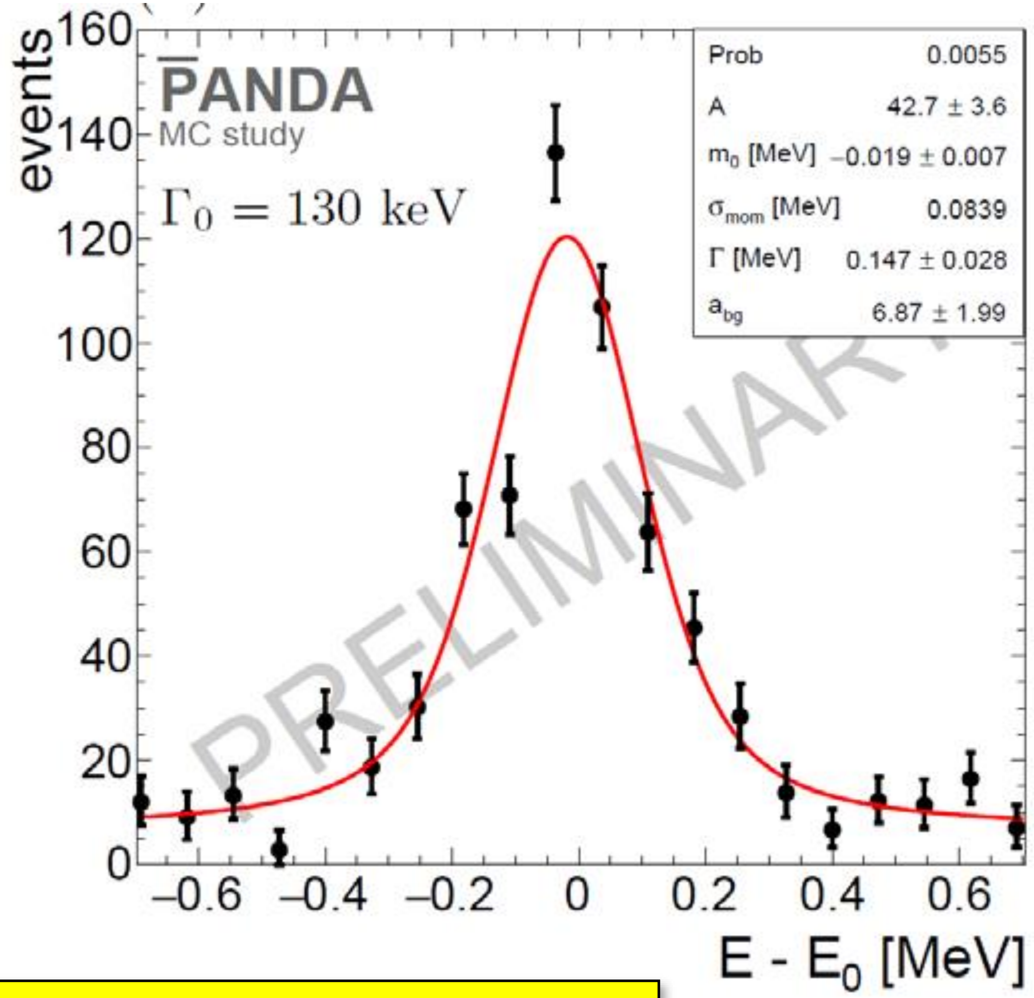
$$1170\ (\text{nb} \cdot \text{day})^{-1}$$

Energy resolution (HESRr):

$$\Delta E = 84\ \text{keV}$$

20 points each 2 days data taking!

$$\bar{p}p \to X(3872) \to J/\psi\pi^+\pi^-$$



Width sensitivity down to 100 keV achievable on day-one

Klaus Goetzen et al.

Resonance scanning (MC study)

Cross sections:

$$\sigma(\bar{p}p \to X(3872)) = 50\ nb$$
$$\sigma_{non-res}(\bar{p}p \to J/\psi\pi^+\pi^-) = 1.2\,nb$$
$$\sigma(\bar{p}p \to \text{inelastic}) = 46\,mb$$
$$B(X(3872) \to J/\psi\pi^+\pi^-) = 5\%$$

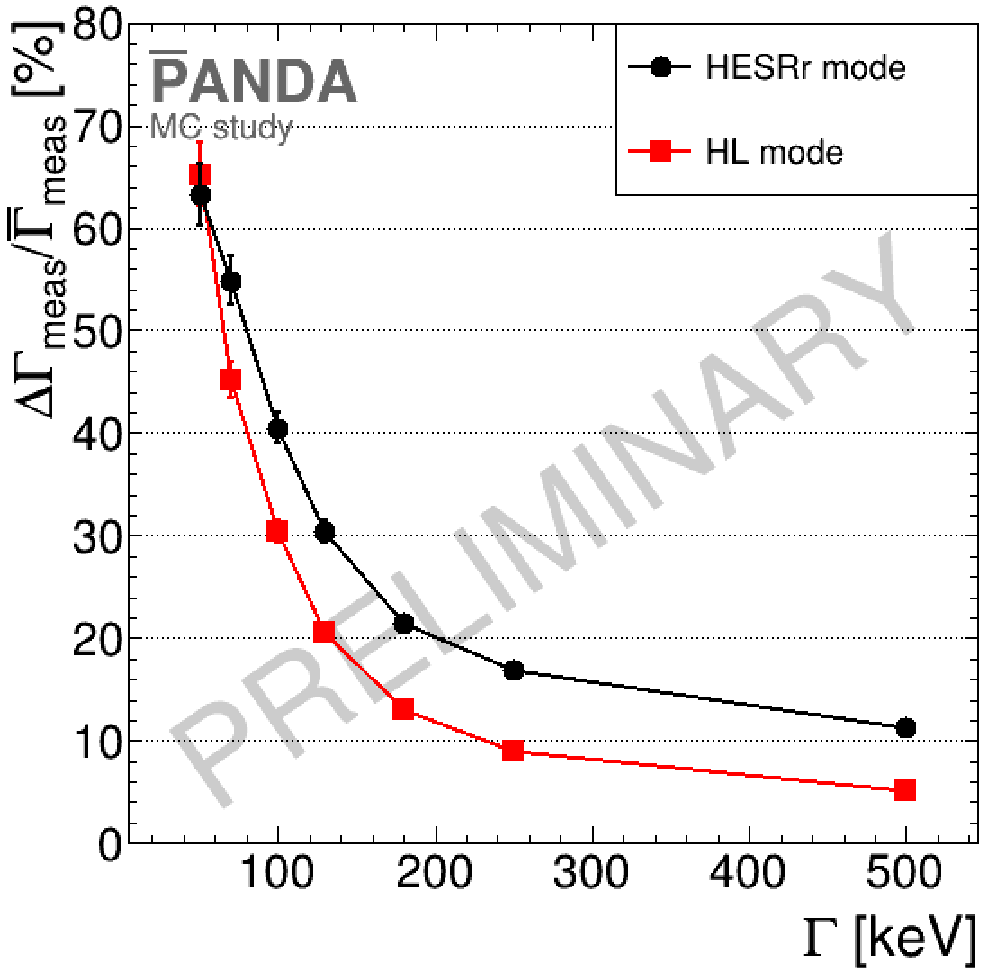
Luminosity:

Energy resolution (HESRr):

$$\Delta E = 84\ \text{keV}$$

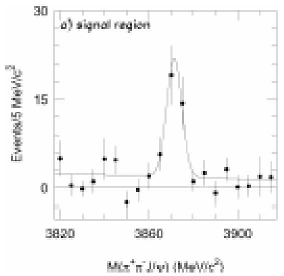
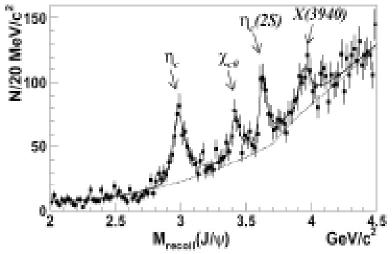
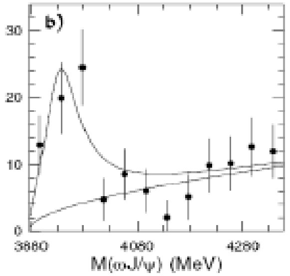
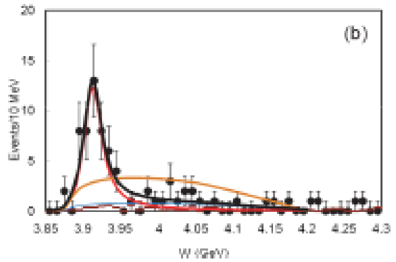
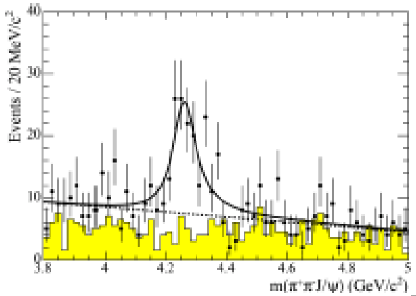
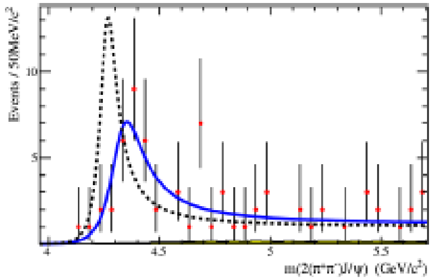
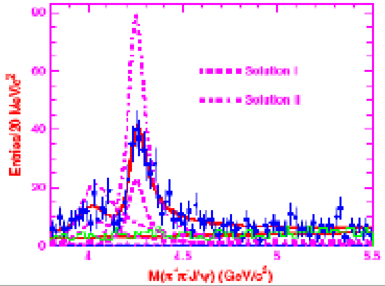
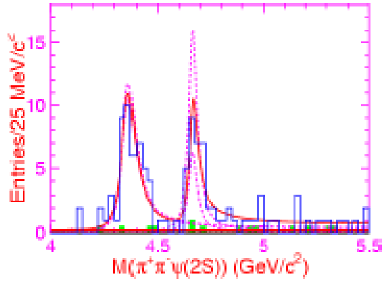
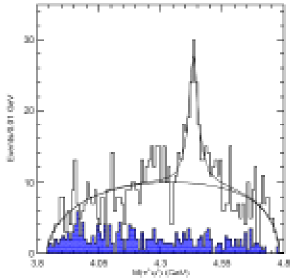
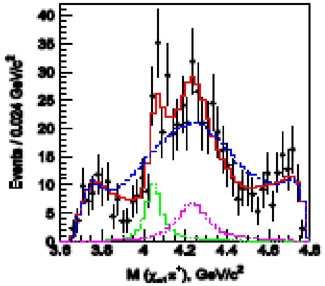
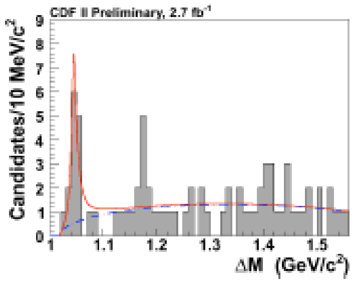
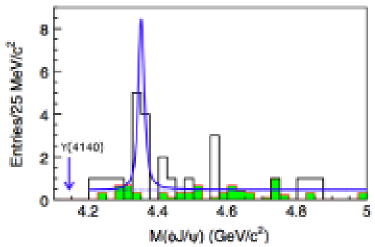
20 points each 2 days data taking!

$$\bar{p}p \to X(3872) \to J/\psi\pi^+\pi^-$$



Klaus Goetzen et al.

X, Y, Z - Discoveries

X(3872) PRL 91,262001 (2003) 	X(3940) PRL 98,082001 (2007) 	Y(3940) PRL 94,182002 (2005) 	X(3915) PRL 104,092001 (2010) 
Y(4260) PRL 95,142001 (2005) 	Y(4350) PRL 98,212001 (2007) 	Y(4008) PRL 99,182004 (2007) 	Y(4660) PRL 99,142002 (2007) 
Z(4430)$^-$ PRL 100,142001 (2008) 	Z_1^- & Z_2^- PRD 78,072004 (2008) 	Y(4140) PRL 102,242002 (2009) 	X(4350) PRL 104,112004 (2010) 

X, Y, Z rates at PANDA

How many X(3872), Y(4260), Z(3900)+ can *PANDA* produce?

HESR: average luminosity 1170 nb^{-1}/d (MSV0-3, no RESR)

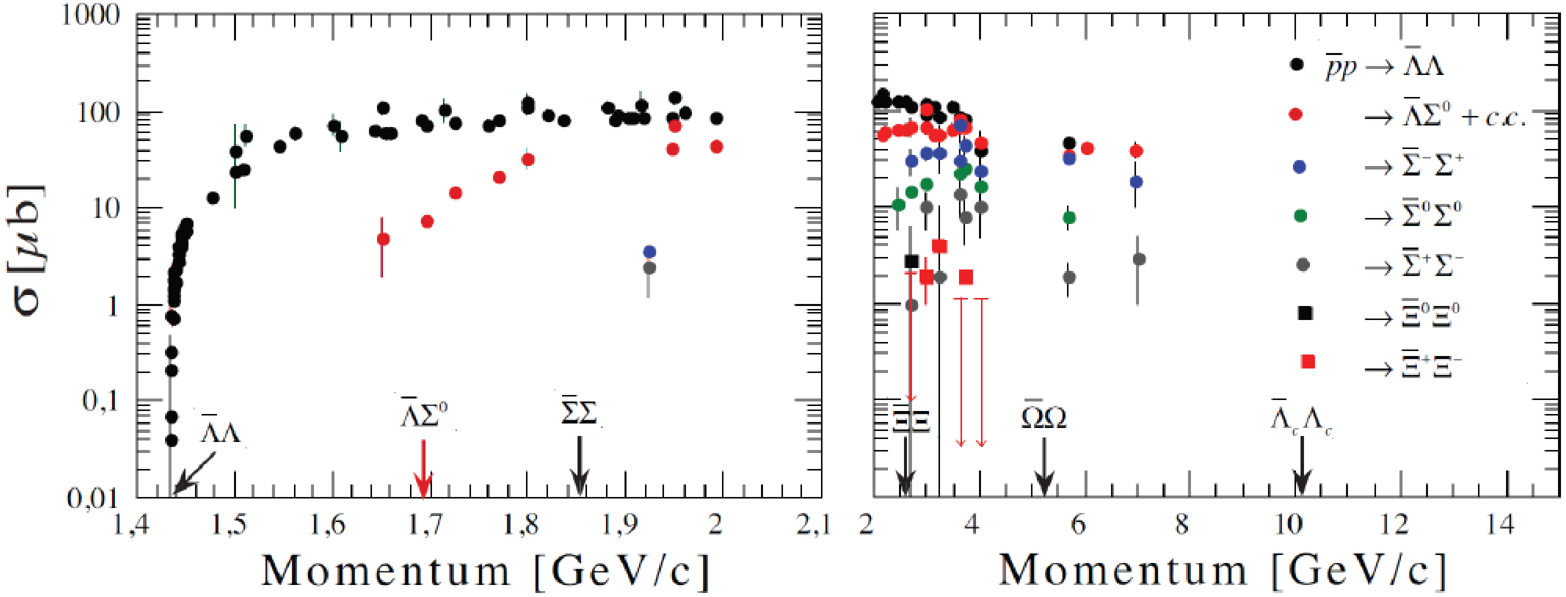
- PANDA: estimate of cross section:
  σ(pbar p -> X(3872)) = 100nb i.e. 1.17×10^5 X(3872) produced per day
  X(3872) -> $J/\psi\rho^0 \rightarrow e^+e^-/\mu^+\mu^- \pi^+\pi^-$ only:
  statistics: ~120 reconstructed events per day (full simulation)
  with RESR: factor 10 more
  precise measurement of width/line shape by energy scan ~100keV,
  decisive for 4 quark states

PANDA: ~120 X(3872)/day, 820 Y(4260)/day, 180 Z(3900)/day

PANDA is a X,Y,Z factory
high statistics X,Y,Z data sample

PANDA Release Note
RN-QCD-2016-002, QWG 2016

Exploring the hyperon sector



- A lot of data on $\bar{p}p \to \bar{\Lambda}\Lambda$ near threshold, mainly from PS185 at LEAR*
- Very scarce data bank above 4 GeV
- Only a few bubble chamber events on $\bar{p}p \to \bar{\Xi}\Xi$
- No data on $\bar{p}p \to \bar{\Omega}\Omega$ nor $\bar{p}p \to \bar{\Lambda}_c\Lambda_c$

Karin Schoenning

* See e.g. T. Johansson, AIP Conf. Proc. of LEAP 2003, p. 95

PANDA is a hyperon factory

$$\bar{p}p \to \bar{\Lambda}\Lambda,\ \bar{\Sigma}^-\Sigma^+,\ \bar{\Sigma}^0\Sigma^0,\ \bar{\Sigma}^-\Sigma^+,\ \bar{\Xi}^0\Xi^0,\ \bar{\Xi}^+\Xi^-,\ \bar{\Omega}^+\Omega^-,\ \bar{\Lambda}_c^-\Lambda_c^+$$

Λ	Σ^+	Σ^0	Σ^-	Ξ^0	Ξ^-	Ω^-	Λ_c^+
$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$
$p\pi^-$	$p\pi^0$	$\Lambda\gamma$	$n\pi$	$\Lambda\pi^0$	$\Lambda\pi$	ΛK	$\Lambda\pi$
64%	52%	$\approx 100\%$	$\approx 100\%$	$\approx 100\%$	$\approx 100\%$	68%	$\approx 1\%$

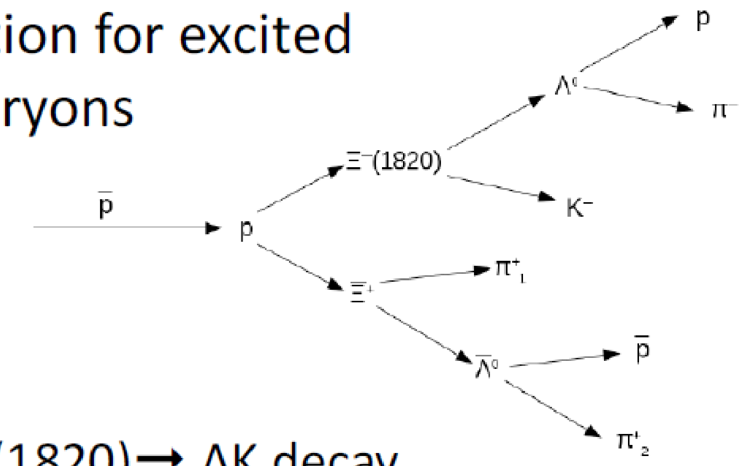
Momentum (GeV/c)	Reaction	σ (μb)	Efficiency (%)	Rate (with 10^{31} cm^{-2}s^{-1})
1.64	$\bar{p}p \to \bar{\Lambda}\Lambda$	64	11	29 s^{-1}
4	$\bar{p}p \to \bar{\Lambda}\Sigma^o$	~40	~30	50 s^{-1}
4	$\bar{p}p \to \bar{\Xi}^+\Xi^-$	~2	~20	1.5 s^{-1}
12	$\bar{p}p \to \bar{\Omega}^+\Omega^-$	~0.002	~30	~4 h^{-1}
12	$\bar{p}p \to \bar{\Lambda}_c^-\Lambda_c^+$	~0.1	~35	~2 day^{-1}

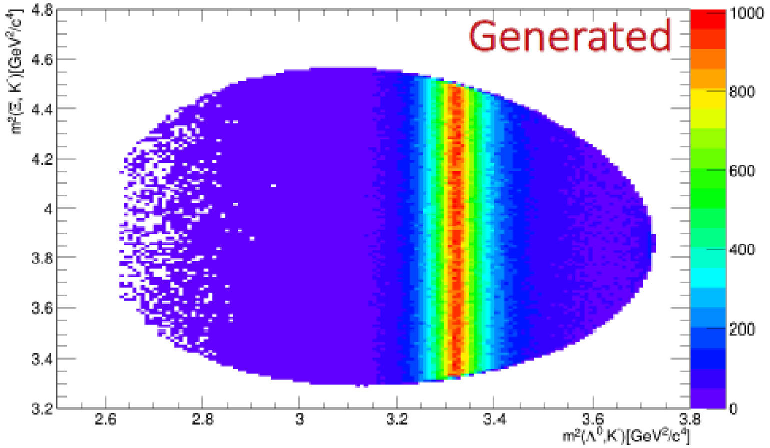
Day 1

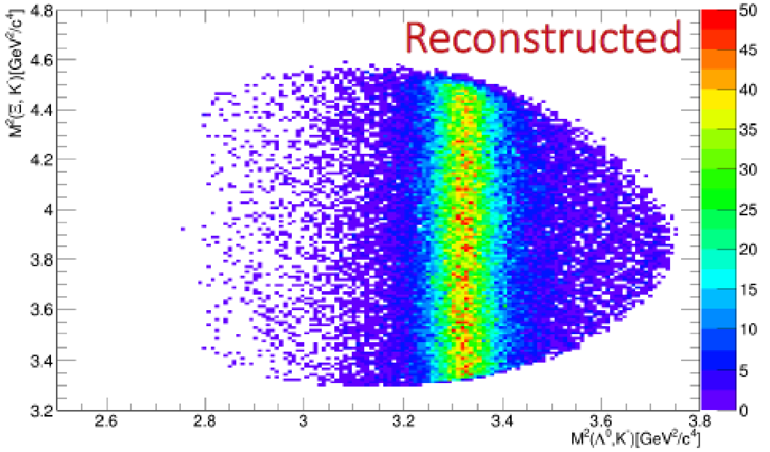
Karin Schoenning

Ξ(1820)

High signal rates and high background rejection for excited double strange baryons







$\bar{p}_{beam}$ = 4.6 GeV/c

Consider the $\Xi^{*-}(1820) \rightarrow \Lambda K$ decay,

assume BR = 100% and σ = 1 μb

Simplified MC framework

Day-1 luminosity: $10^{31} cm^{-2} s^{-1}$

Results

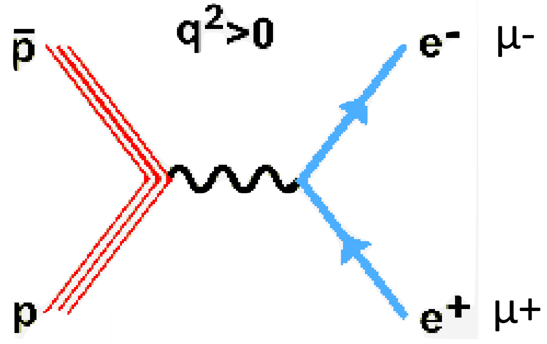
~30 % inclusive efficiency for $\Xi^{*-}(1820)$

~5 % exclusive efficiency for $\bar{\Xi}^{+}\Xi^{*-}(1820)$

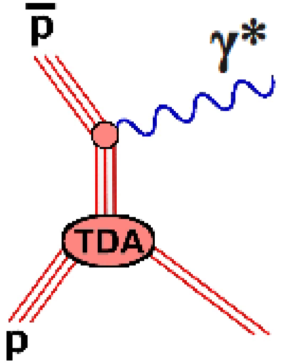
Low background level ➞ ~15000 exclusive events / day

Hadron Sructure Studies at PANDA

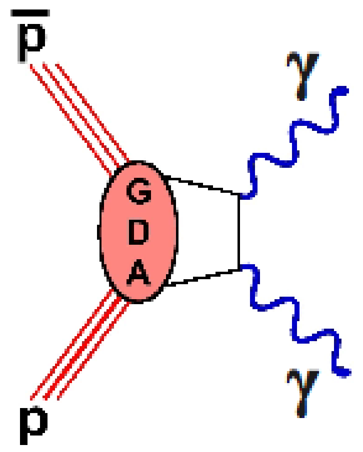
Time-like Electromagnetic Form Factors
(lepton pair production) arXiv:1606.01118



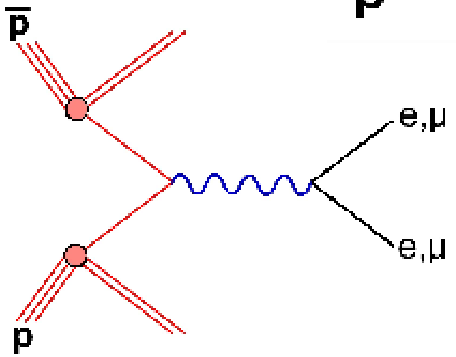
Transition Distribution Amplitudes
(meson production) arXiv:1409.0865



Generalised Distribution Amplitudes
(time-like Compton, hard exclusive processes)

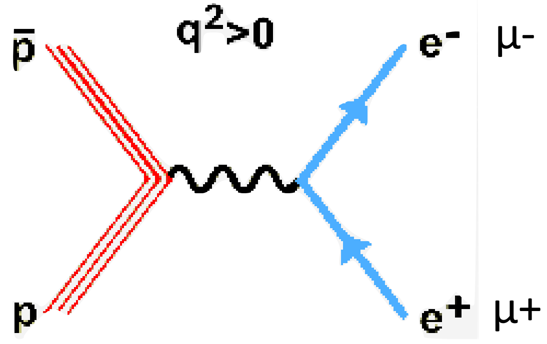


Transverse Parton Distribution Functions
(Drell-Yan production)



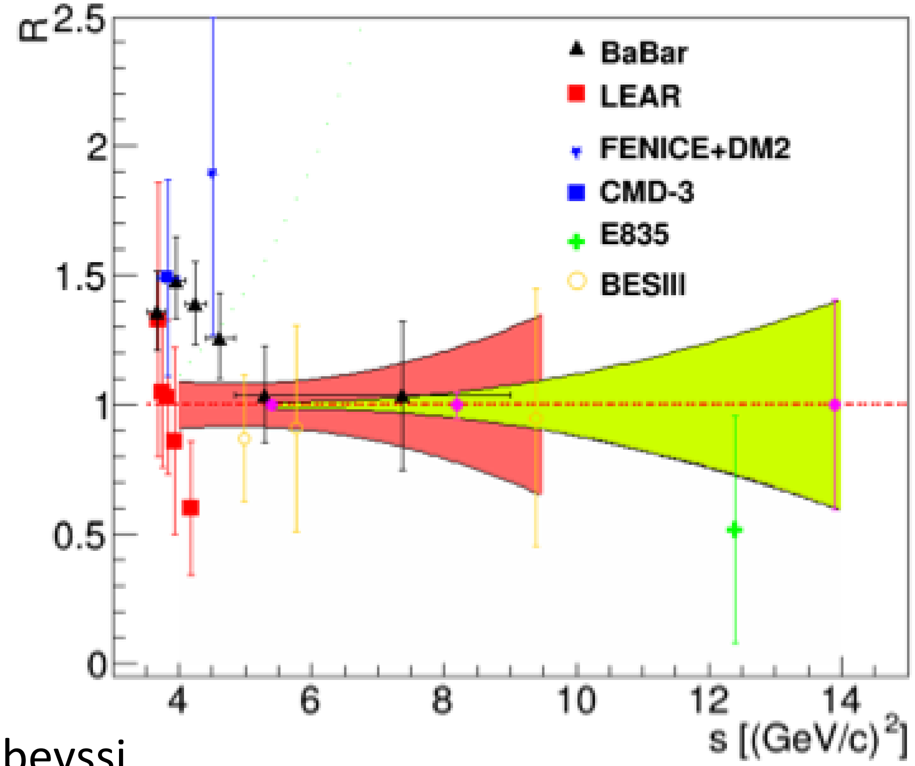
Time-like proton electromagnetic form factors

Time-like Electromagnetic Form Factors
(lepton pair production) arXiv:1606.01118



Eur.Phys.J. A52 (2016) no.10, 325

$$R = |G_E|/|G_M|$$



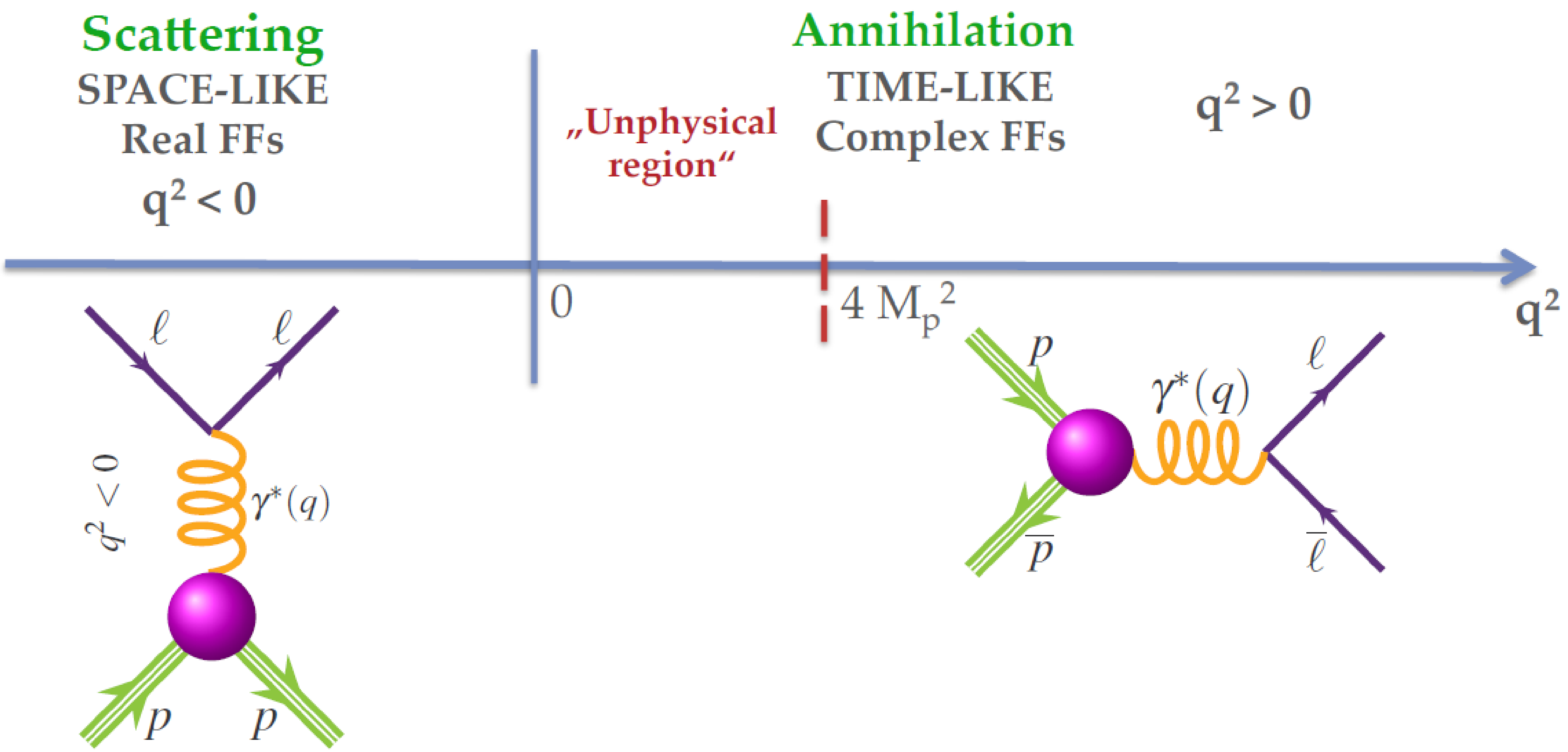
21 scan points 2015 (552 pb^{-1})

Monte Carlo Sim., R=1 (C. Morales)

$L=2\ fb^{-1}$
$2.10^{32}\ cm^{-1} s^{-1}$

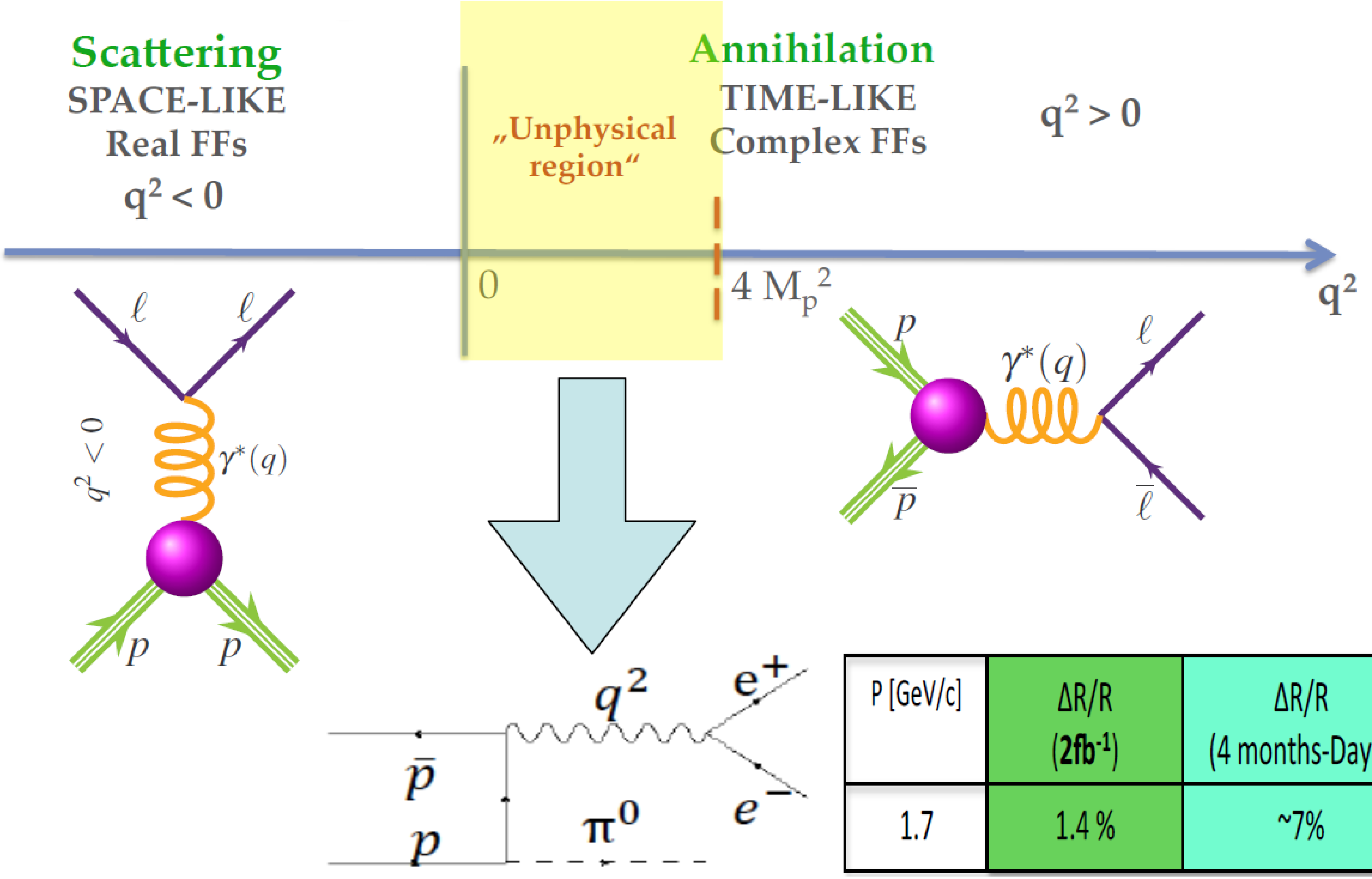
~5 months data taking /point

Proton form factors in the *unphysical* region



I. Zimmermann, J. Boucher

Proton FFs in the *unphysical* region



P [GeV/c]	ΔR/R ($2 fb^{-1}$)	ΔR/R (4 months-Day1)
1.7	1.4 %	~7%

I. Zimmermann, J. Boucher

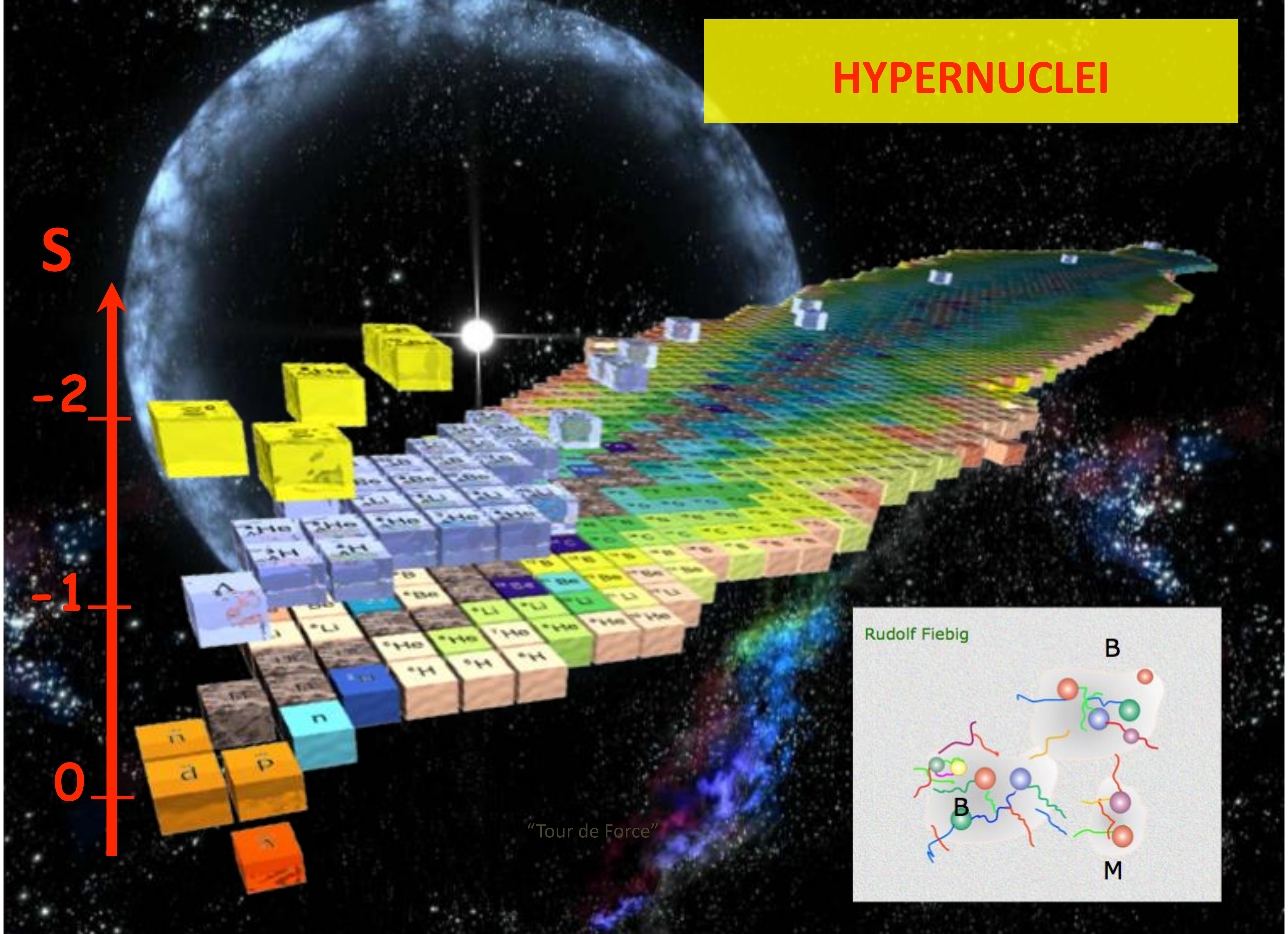
Electromagnetic processes in PANDA

Feasibilty study for the measurement of many electromagnetic processes at PANDA are done

Work in progress

Signal	Physics	s [Gev²]	S/B	Status
$\bar{p}p \rightarrow e^+e^-$	FFs	5.4, 8.2, 13.9	>100	Feasibile
$\bar{p}p \rightarrow \mu^+\mu^-$	FFs	5.4	¼	Feasibile
$\bar{p}p \rightarrow \gamma^*\pi^0$	TDAs	5.0 10.0	$5 . 10^7$ ($1 . 10^7$) $1 . 10^8$ ($6 . 10^6$)	Feasibile
$\bar{p}p \rightarrow J/\psi\pi^0$	TDAs	P=5.513 P=8.0 P=12.0	>8 >70 >600	Feasibile
$\bar{p}p \rightarrow \gamma\gamma$ $\bar{p}p \rightarrow \pi^0\gamma$	GDAs	2.5, 3.5, 4.0, 5.5	1 2	Feasibile
$\bar{p}p \rightarrow \mu^+\mu^- X$	TMD PDFs	30	in progress	Feasibile

HYPERNUCLEI

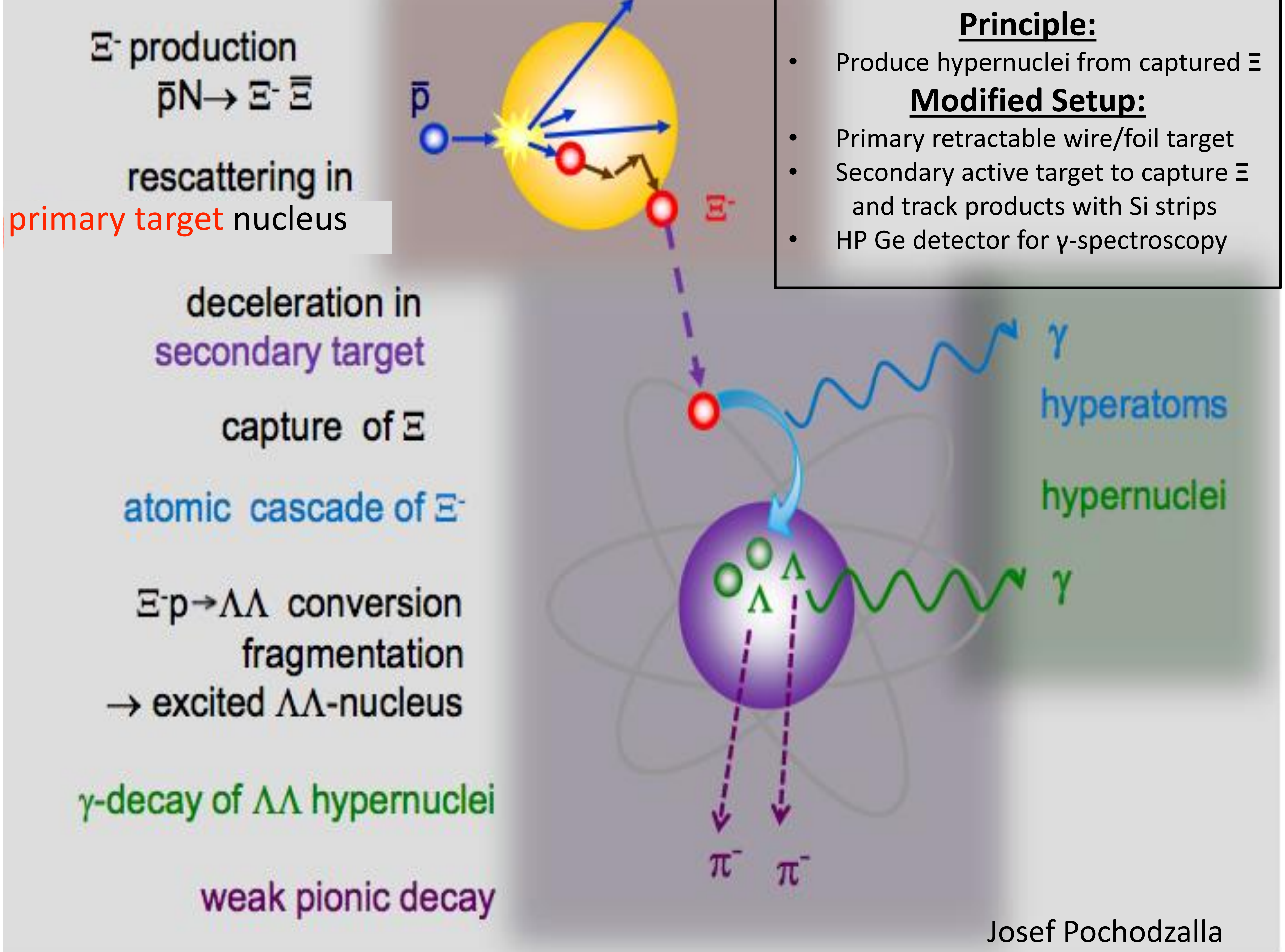


Principle:

- Produce hypernuclei from captured Ξ

Modified Setup:

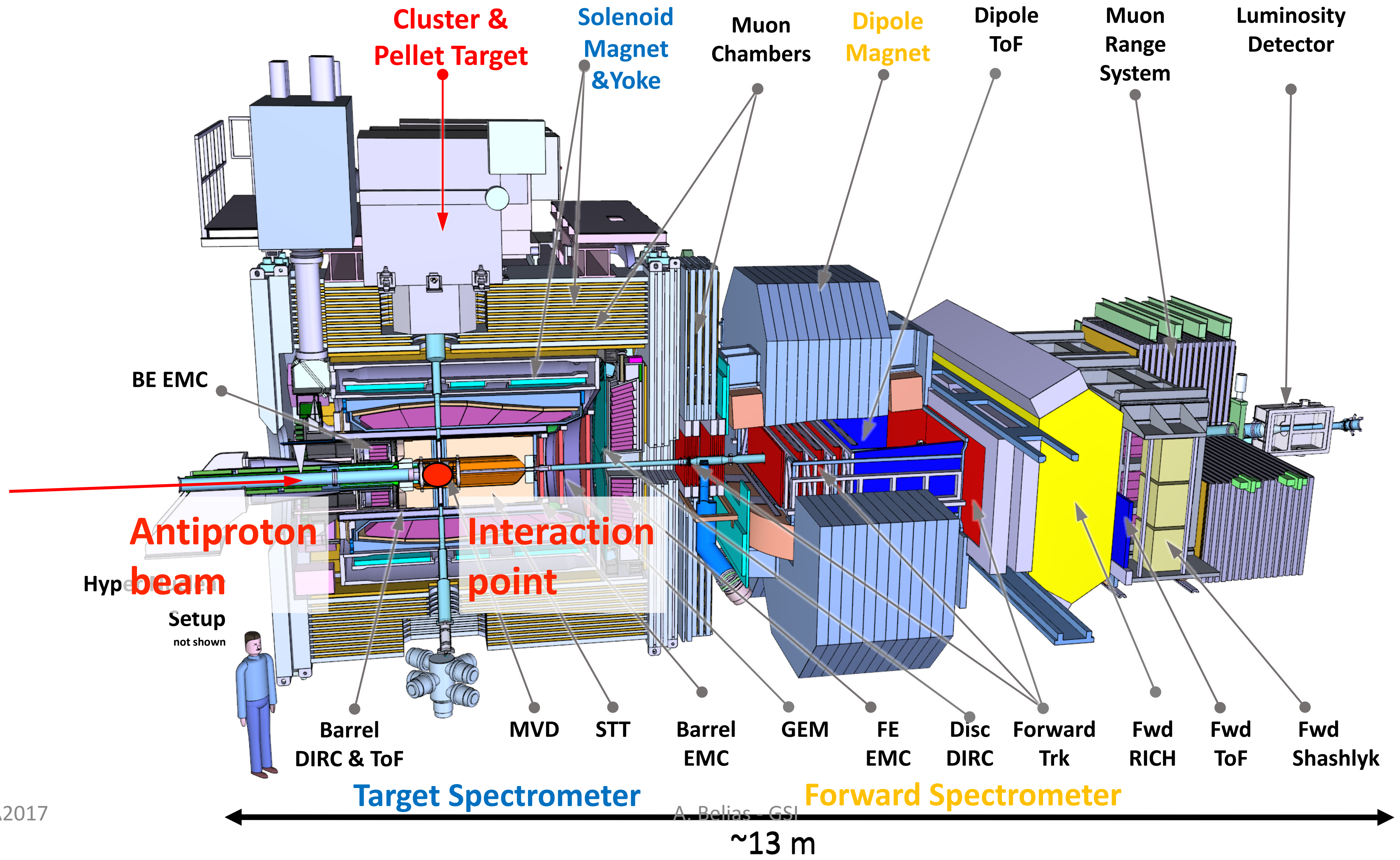
- Primary retractable wire/foil target
- Secondary active target to capture Ξ and track products with Si strips
- HP Ge detector for γ-spectroscopy



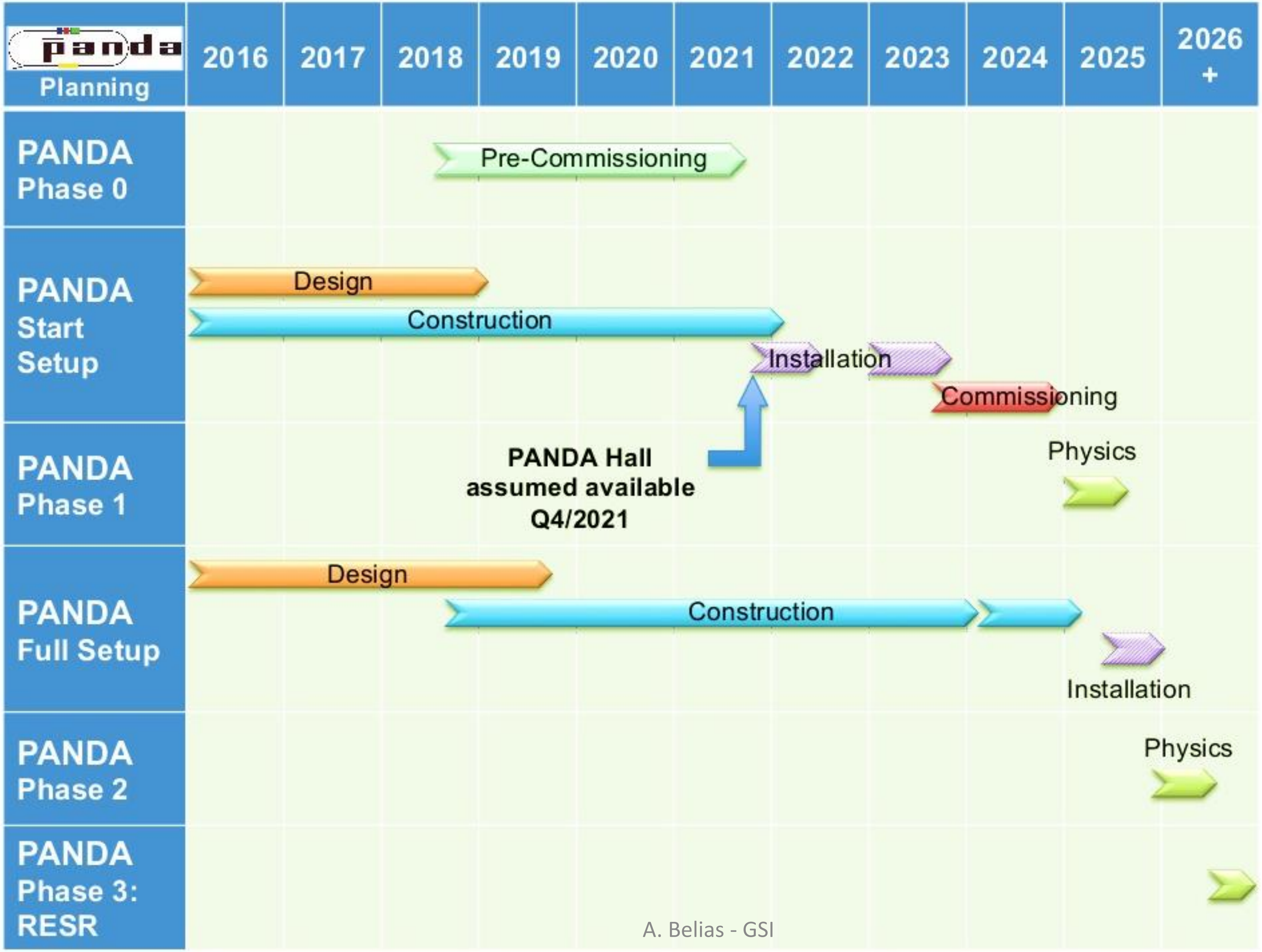
Josef Pochodzalla

What we need

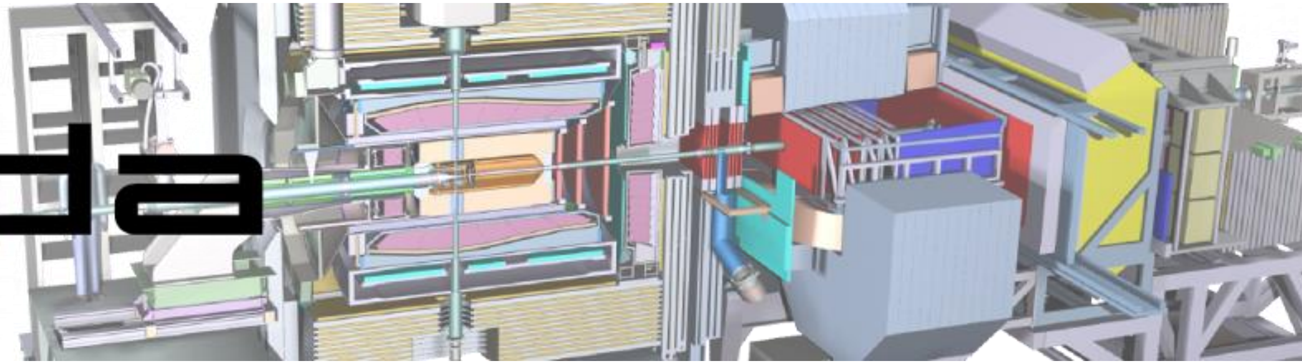
The PANDA Detector



Schedule



Planning
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026 +
PANDA Phase 0
Pre-Commissioning
PANDA Start Setup
Design
Construction
Installation
Commissioning
PANDA Phase 1
PANDA Hall assumed available Q4/2021
Physics
PANDA Full Setup
Design
Construction
Installation
PANDA Phase 2
Physics
PANDA Phase 3: RESR



Present Status of PANDA

- Most Phase 1 detector Technical Design Reports complete in 2017
- Preparation for Construction MoU ongoing
- Sharpened physics focus and detector start sequence ongoing

Timeline of PANDA

- All TDRs of Phase 1 to be completed by 2018
- Ready for mounting at FAIR from 2021
- Installation takes ~2 years

PANDA & FAIR start in hadron physics with antiproton from 2025

- Versatile physics machine with full detection capabilities
- PANDA will shed light on many of today's QCD puzzles

Significant opportunities for visible contributions in PANDA

Key-Experiments of the Start Phase

Concentration on unique and forefront physics topics

- Production of multi-strangeness baryons
  (unexplored, new territory, „Strangeness-Factory“)
- Precise measurement of the line shape of narrow XYZ-states,
  e.g. X(3872)
  (only possible in proton–antiproton, counting experiment,
  clarification of the nature of the states)
- Resonant formation of the
  negative and uncharged partners of the Z-States
  (only possible in proton–antiproton, goal is the nature of the states)
- Measurement of the electromagnetic form factors of the proton in the time-like domain with electrons and muons in the final state
- Production of high spin charmonia
  (only possible in proton–antiproton)
  light mesons, baryons and production of hybrids und glueballs

Summary and Outlook

- **PANDA** – Hadron physics with antiproton beam provides excelent physics opportunities over a broad range

- Antiproton beams for spectroscopy: X,Y,Z-factory, open charm, light mesons, baryons, glue-balls, hybrids, … precision studies with large data samples, measurement of width and cross section

- Nucleon structure via antiproton annihilation: many channels and reactions studied in simulations are accessible and measurable with high precision

- Strangeness studies: hyperon spectrum & hypernuclei with strangeness S=2

PANDA Collaboration

More than 450 physicists from 70 institutions in 19 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
Jülich CHP

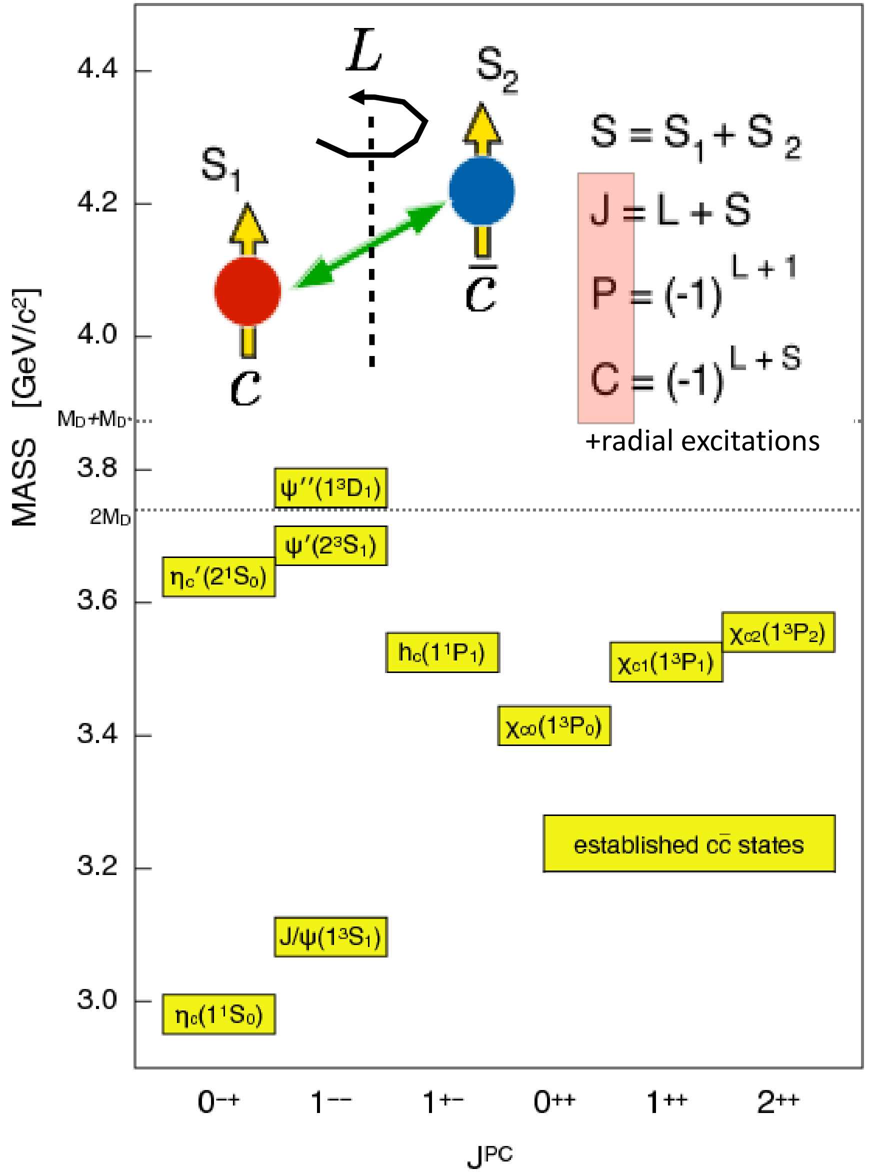
Saha INP, Kolkata
U Katowice
IMP Lanzhou
INFN Legnaro
U Lund
HI Mainz
U Mainz
U Minsk
ITEP Moscow
MPEI Moscow
U Münster
BINP Novosibirsk
Novosibirsk State U
IPN Orsay
U & INFN Pavia
Charles U, Prague
Czech TU, Prague
IHEP Protvino

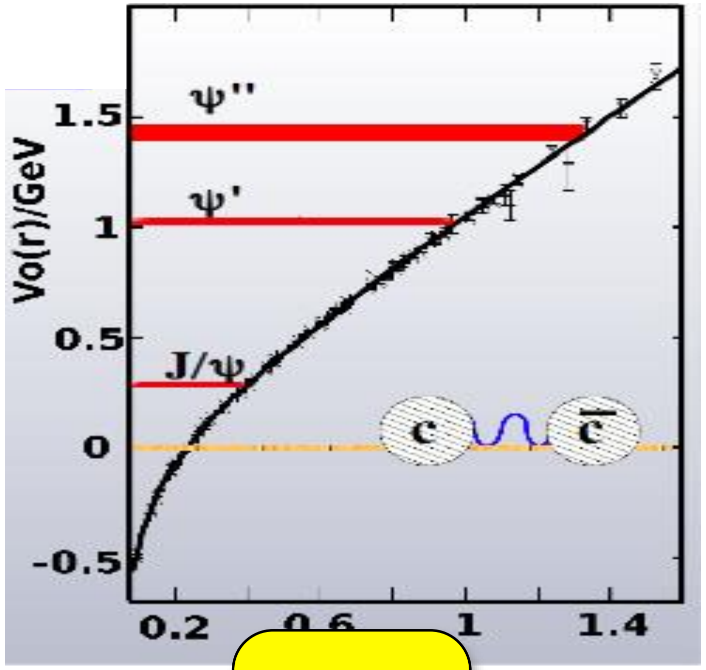
PNPI St. Petersburg
U of Sidney
U of Silesia
U Stockholm
KTH Stockholm
Suranree University
South Gujarat U, Surat
U & INFN Torino
Politecnico di Torino
U & INFN Trieste
U Tübingen
TSL Uppsala
U Uppsala
U Valencia
SMI Vienna
SINS Warsaw
TU Warsaw

Ready 2025

Extra slides

Charmonium - the "hydrogen" of QCD





1974: "November *revolution*"

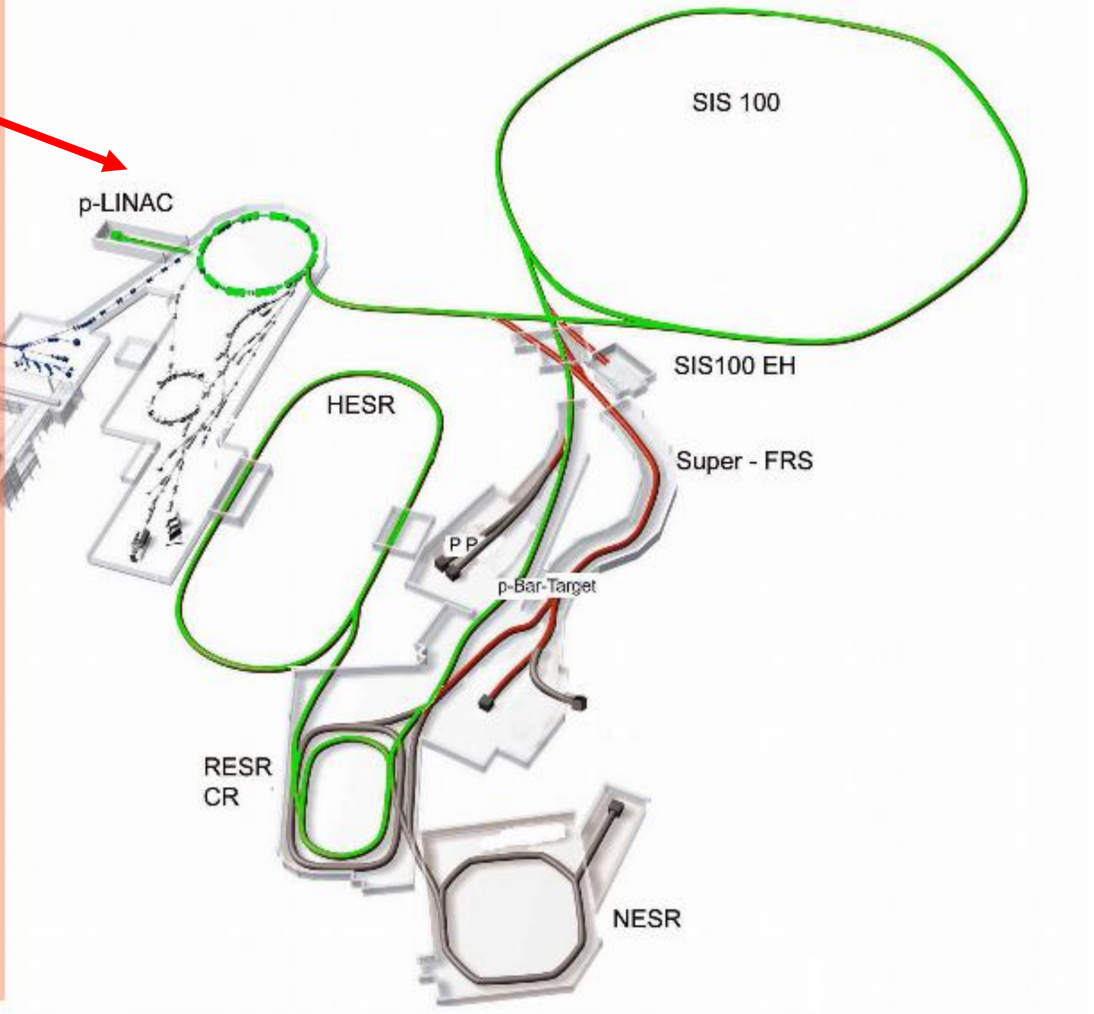
Antiprotons

Antiproton production

- Proton Linac 70 MeV
- Accelerate **p** in SIS18 / 100
- Produce $\bar{p}$ on Cu target
- Collection in CR, fast cooling
- Accumulation in RESR, slow cooling
- Storage in HESR and usage in PANDA

Modularised Start Version

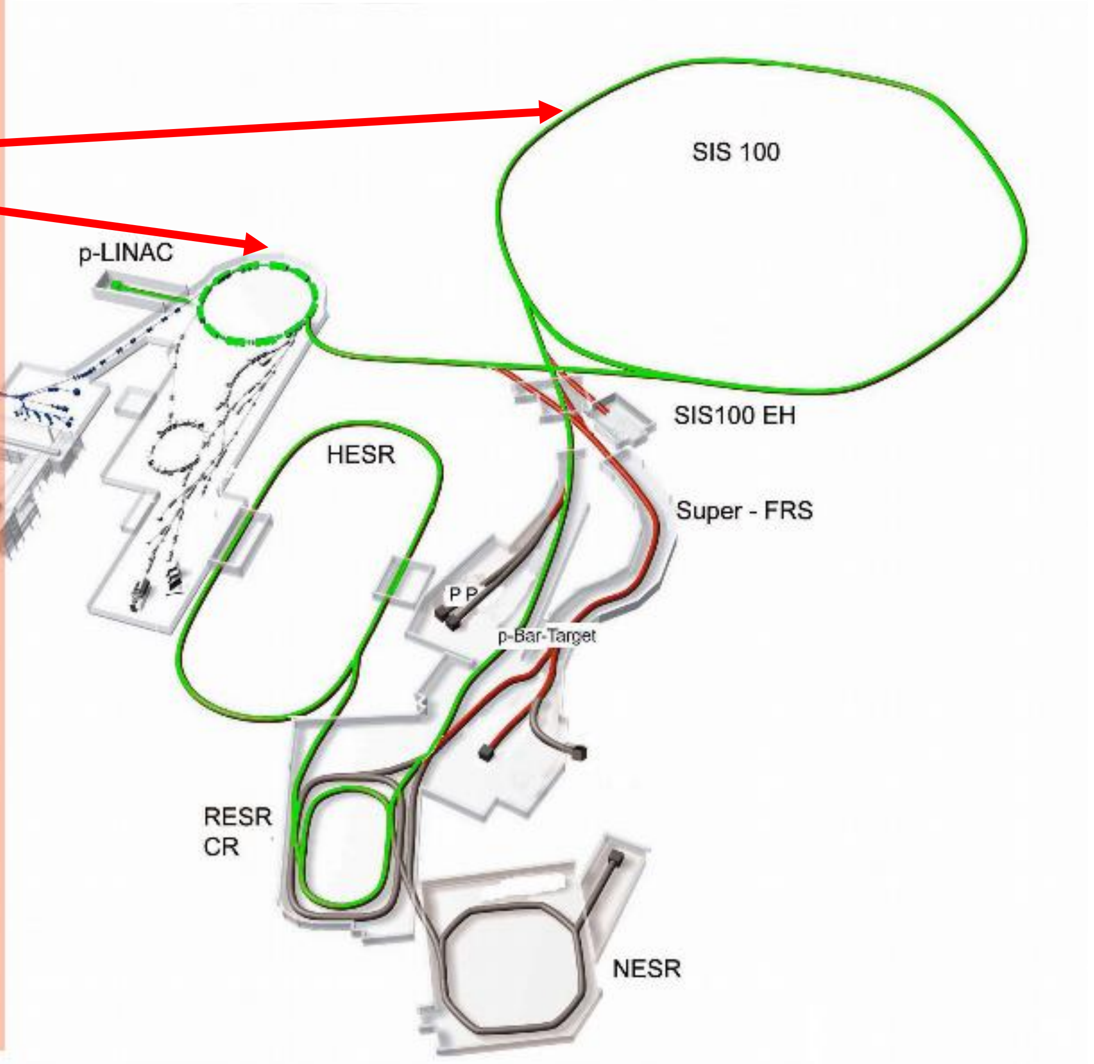
- RESR is postponed (Mod. 4)
- Accumulation in HESR
- 10x lower luminosity



Antiprotons

Antiproton production
- Proton Linac 70 MeV
- Accelerate **p** in SIS18 / 100
- Produce $\bar{p}$ on Cu target
- Collection in CR, fast cooling
- Accumulation in RESR, slow cooling
- Storage in HESR and usage in PANDA

Modularised Start Version
- RESR is postponed (Mod. 4)
- Accumulation in HESR
- 10x lower luminosity



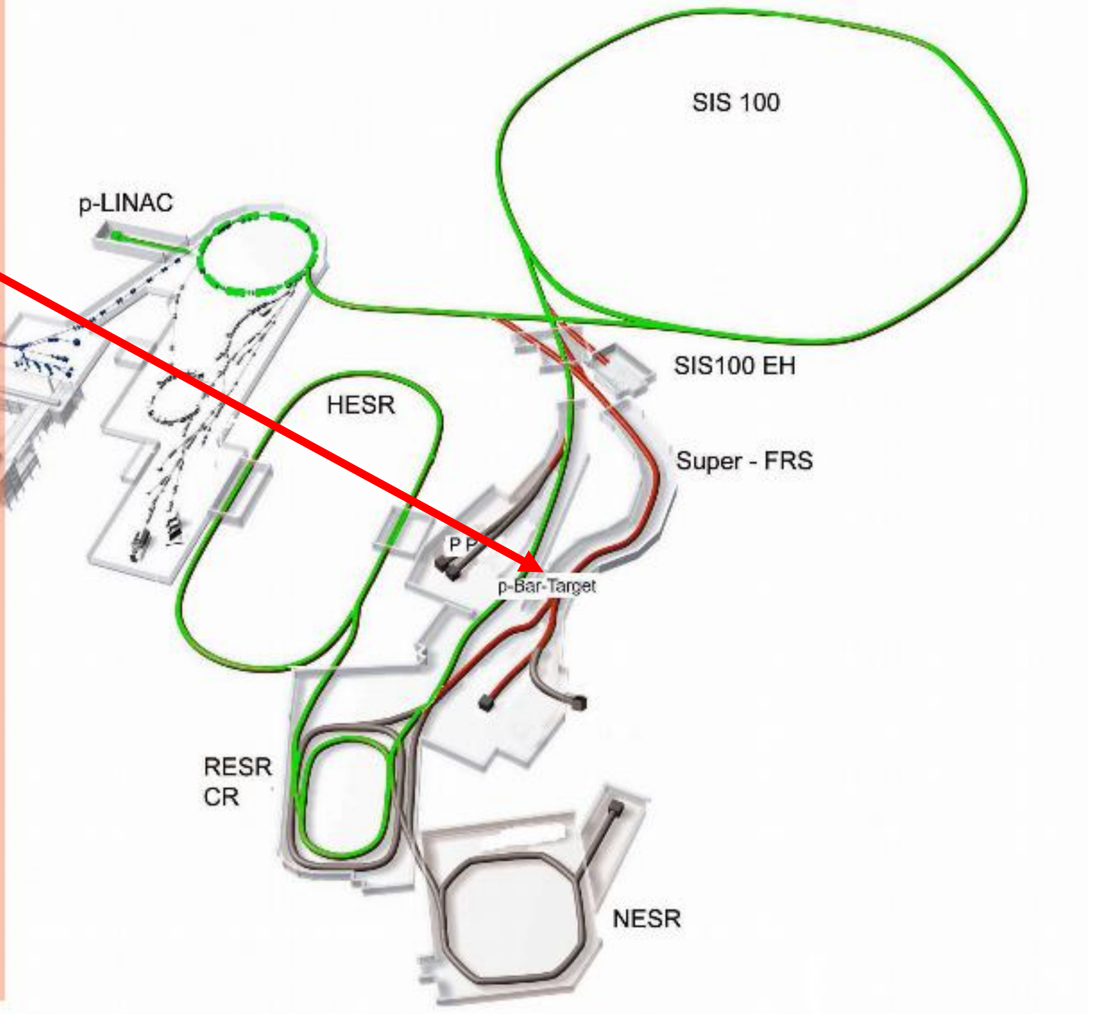
Antiprotons

Antiproton production

- Proton Linac 70 MeV
- Accelerate **p** in SIS18 / 100
- Produce $\bar{p}$ on Cu target
- Collection in CR, fast cooling
- Accumulation in RESR, slow cooling
- Storage in HESR and usage in PANDA

Modularised Start Version

- RESR is postponed (Mod. 4)
- Accumulation in HESR
- 10x lower luminosity



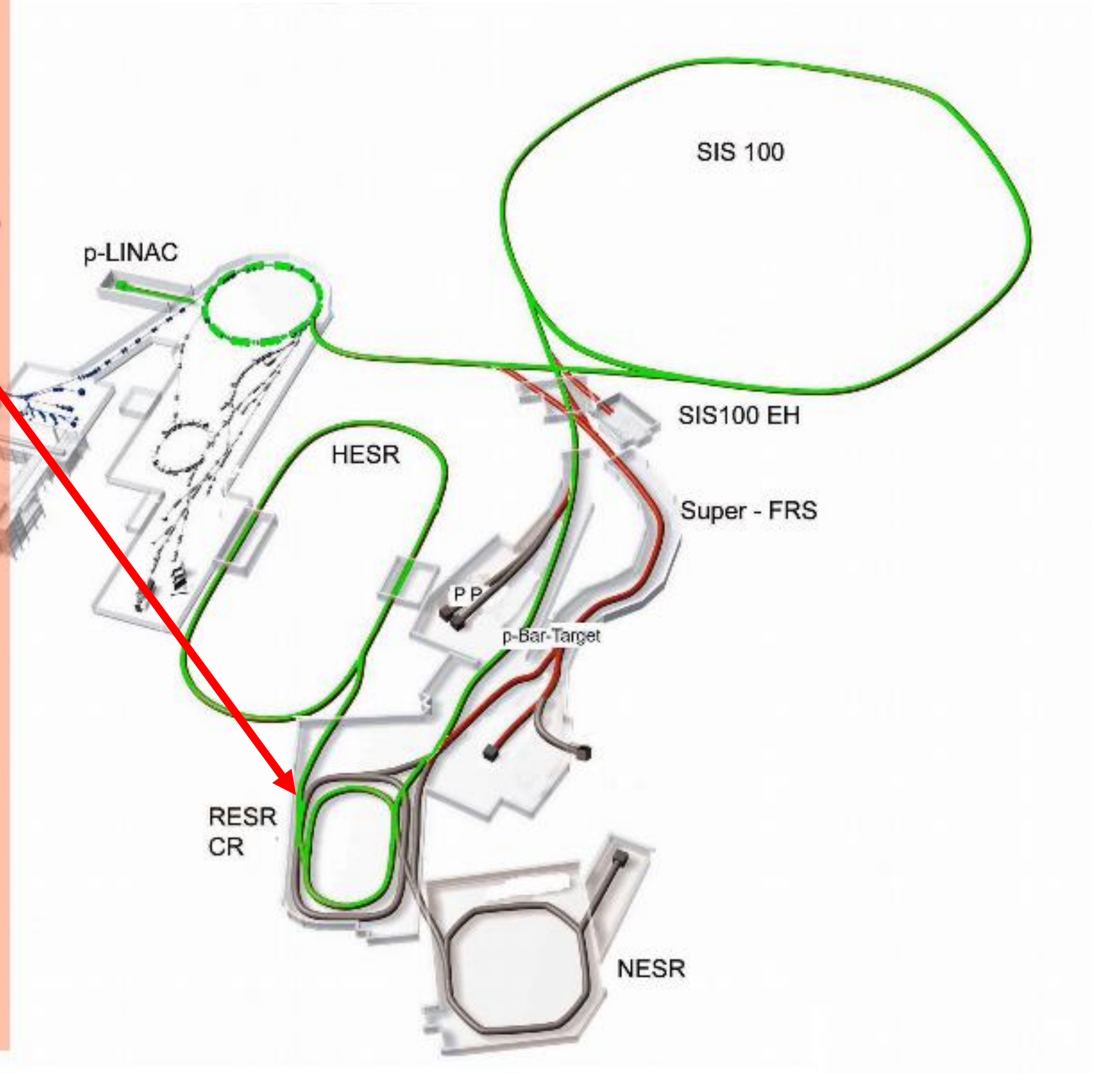
Antiprotons

Antiproton production

- Proton Linac 70 MeV
- Accelerate **p** in SIS18 / 100
- Produce $\bar{p}$ on Cu target
- Collection in CR, fast cooling
- Accumulation in RESR, slow cooling
- Storage in HESR and usage in PANDA

Modularised Start Version

- RESR is postponed (Mod. 4)
- Accumulation in HESR
- 10x lower luminosity



Antiprotons

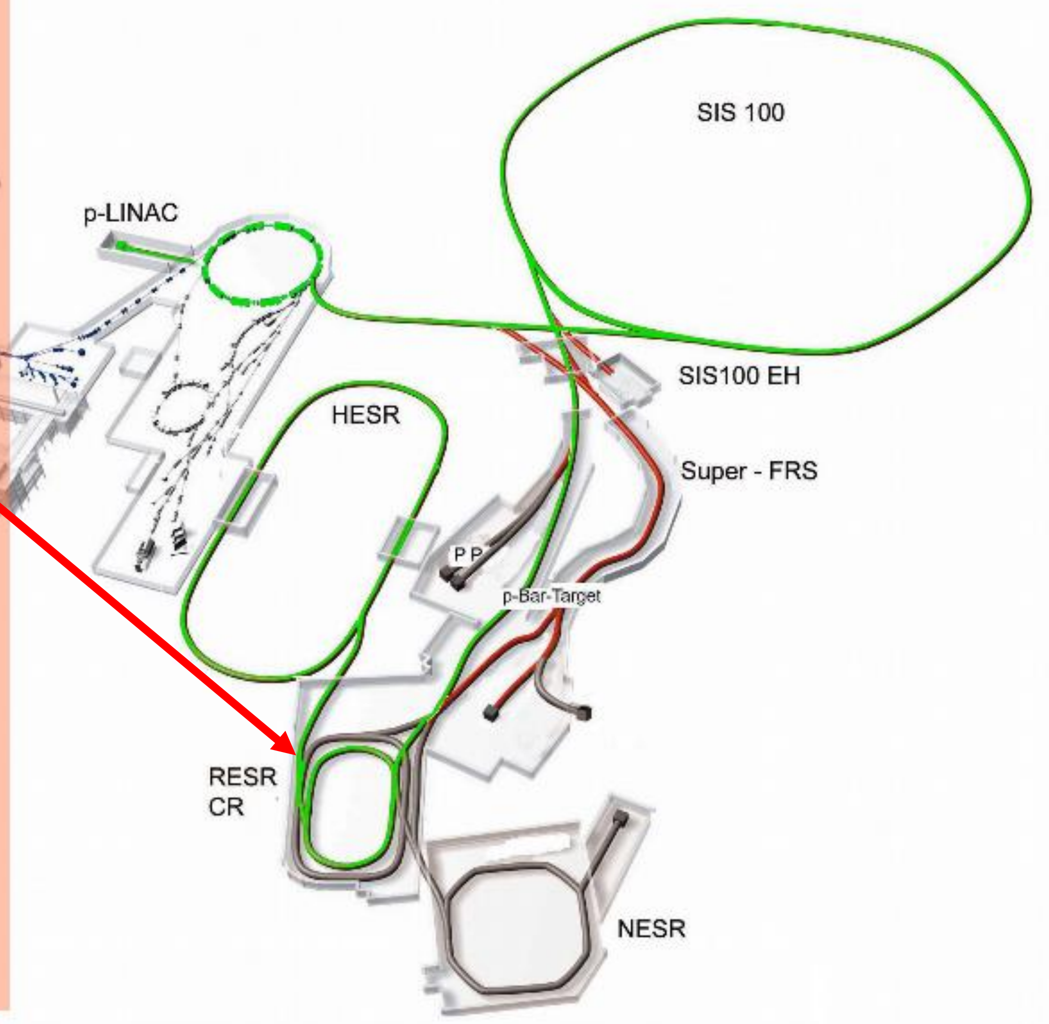
Antiproton production

- Proton Linac 70 MeV
- Accelerate p in SIS18 / 100
- Produce $\bar{p}$ on Cu target

- Collection in CR, fast cooling
- Accumulation in RESR, slow cooling
- Storage in HESR and usage in PANDA

Modularised Start Version

- RESR is postponed (Mod. 4)
- Accumulation in HESR
- 10x lower luminosity



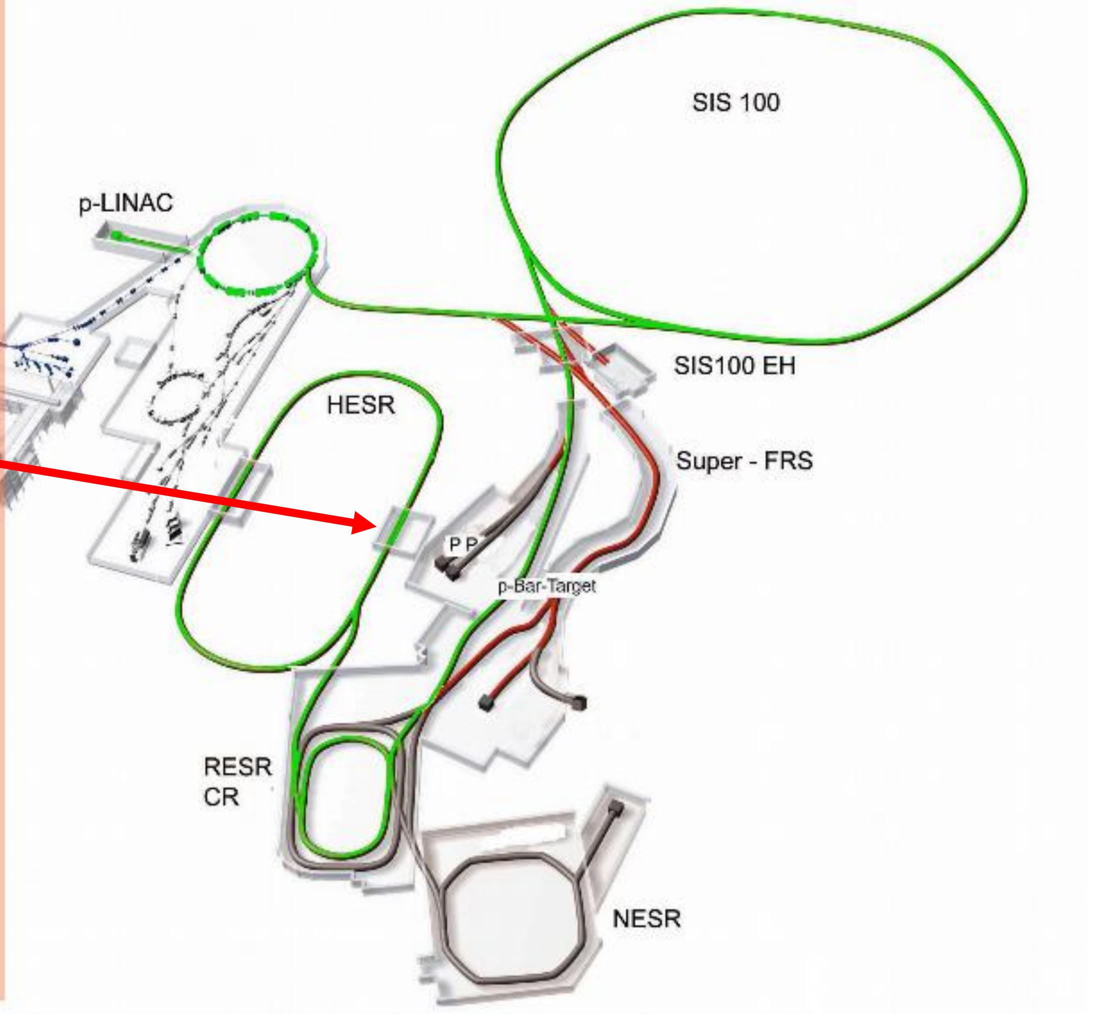
Antiprotons

Antiproton production

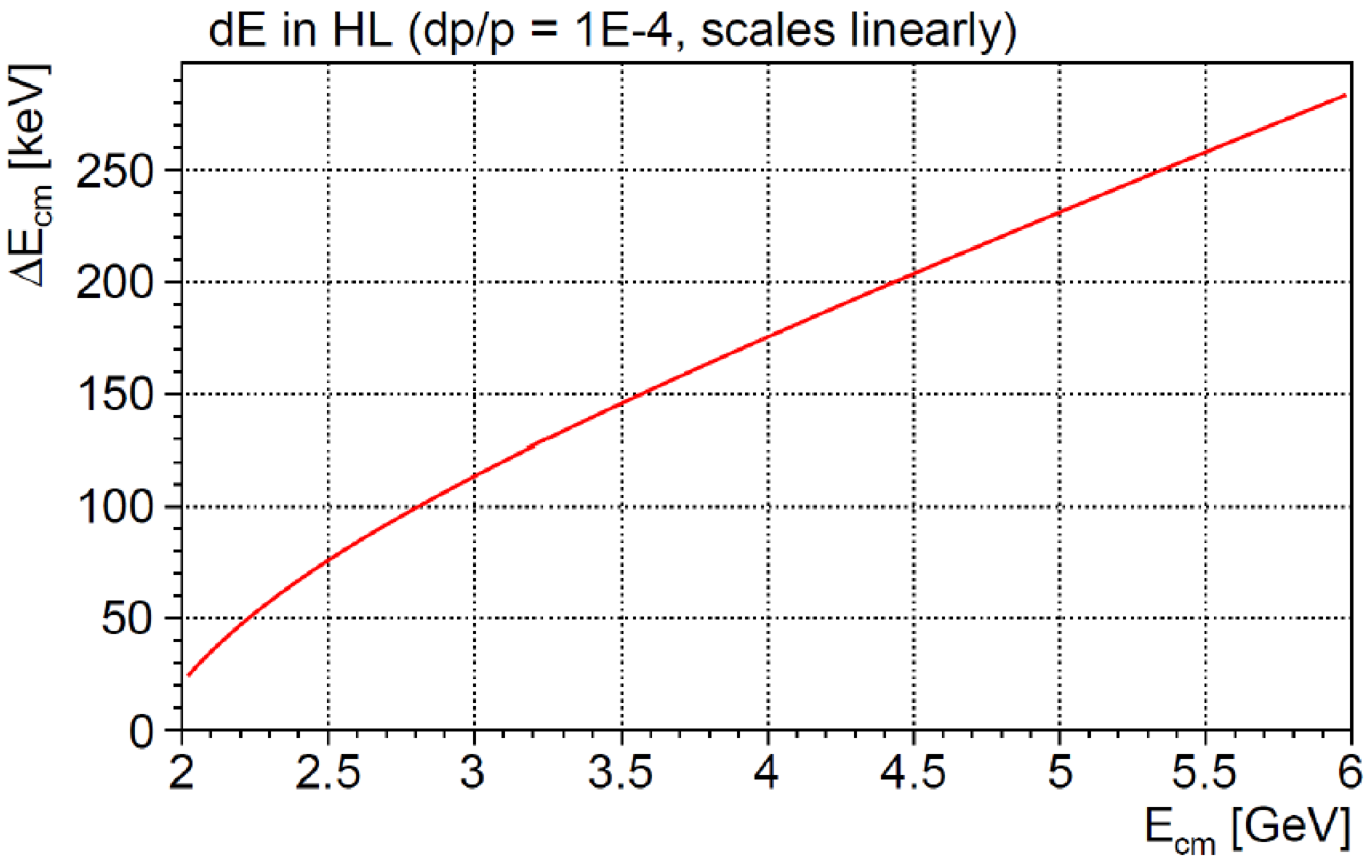
- Proton Linac 70 MeV
- Accelerate **p** in SIS18 / 100
- Produce **$\bar{p}$** on Cu target
- Collection in CR, fast cooling
- Accumulation in RESR, slow cooling
- Storage in HESR and usage in PANDA

Modularised Start Version

- RESR is postponed (Mod. 4)
- Accumulation in HESR
- 10x lower luminosity



Expected Energy Resolution



K. Götzen

Energy resolution 50 – 250 keV (HL)

20 – 80 keV (HR)

PANDA Physics Goals

Hadron Spectroscopy

Experimental Goals: *mass, width & quantum numbers J^{PC} of resonances*

Charm Hadrons*: charmonia, D-mesons, charm baryons*

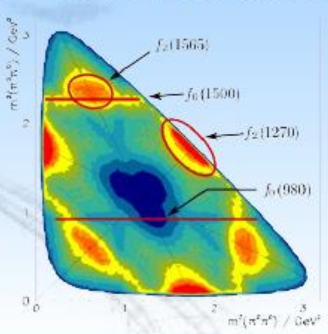
→ Understand new XYZ states, $D_s(2317)$ and others

Exotic QCD States*: glueballs, hybrids, multi-quarks*

Spectroscopy with Antiprotons:

Production of states of all quantum numbers

Resonance scanning with high resolution



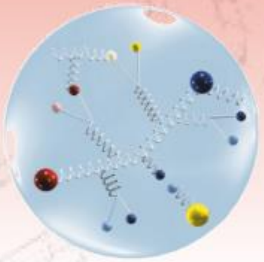
Hadron Structure

Time-like Nucleon Formfactors

→ Measurable in annihilation, discrepancy with space-like

Generalized Parton Distributions

Drell-Yan Process



Nuclear Physics

Hypernuclei*: Production of double Λ-hypernuclei*

→ γ-spectroscopy of hypernuclei, YY interaction

Hadrons in Nuclear Medium

Physics Performance Report for:

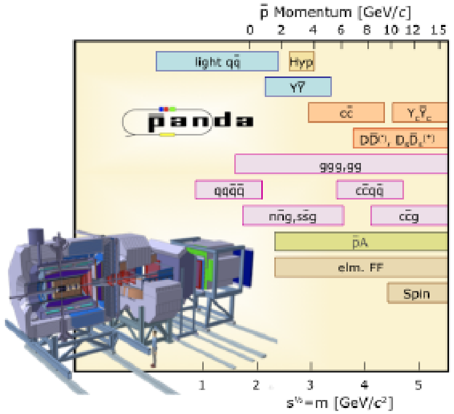
$\overline{\text{P}}$ANDA

(AntiProton Annihilations at Darmstadt)

Strong Interaction Studies with Antiprotons

$\overline{\text{P}}$ANDA Collaboration

To study fundamental questions of hadron and nuclear physics in interactions of antiprotons with nucleons and nuclei, the universal $\overline{\text{P}}$ANDA detector will be build. Gluonic excitations, the physics of strange and charm quarks and nucleon structure studies will be performed with unprecedented accuracy thereby allowing high-precision tests of the strong interaction. The proposed $\overline{\text{P}}$ANDA detector is a state-of-the-art internal target detector at the HESR at FAIR allowing the detection and identification of neutral and charged particles generated within the relevant angular and energy range.
This report presents a summary of the physics accessible at $\overline{\text{P}}$ANDA and what performance can be expected.



arXiv:0903.305

PANDA Physics Program

HEP underlying elementary processes

Spectroscopy

New narrow XYZ:
Search for partner states

Production of exotic QCD states:
Glueballs & hybrids

HEP interference of coupled channels

Nucleon Structure

Generalized parton distributions:
Orbital angular momentum

Drell Yan process:
Transverse structure, valence anti-quarks

Time-like form factors:
Low and high E, e and μ pairs

Bound States of Strong Interaction

astrophysics strange n-stars

Strangeness

Strange baryons:
Spectroscopy
Polarization

nuclear physics hyper-nuclear spectroscopy

Nuclear Physics

Hypernuclear physics:
Double Λ hypernuclei
Hyperon interaction

Hadrons in nuclei:
Charm and strangeness in the medium

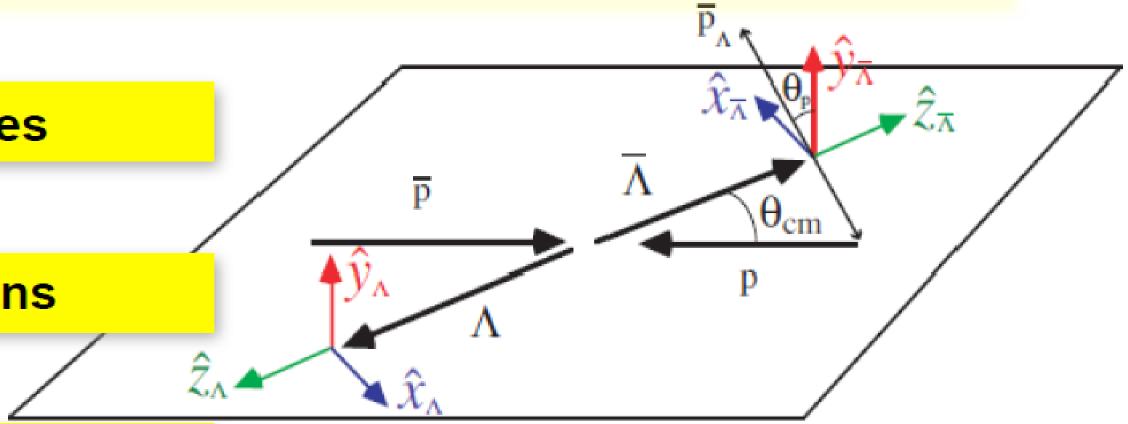
HI collisions comparing QGP to elementary reactions

PANDA is a hyperon factory

Rich set of polarisation observables

(double) strange and charm baryons

Explore hyperon dynamics above 4 GeV



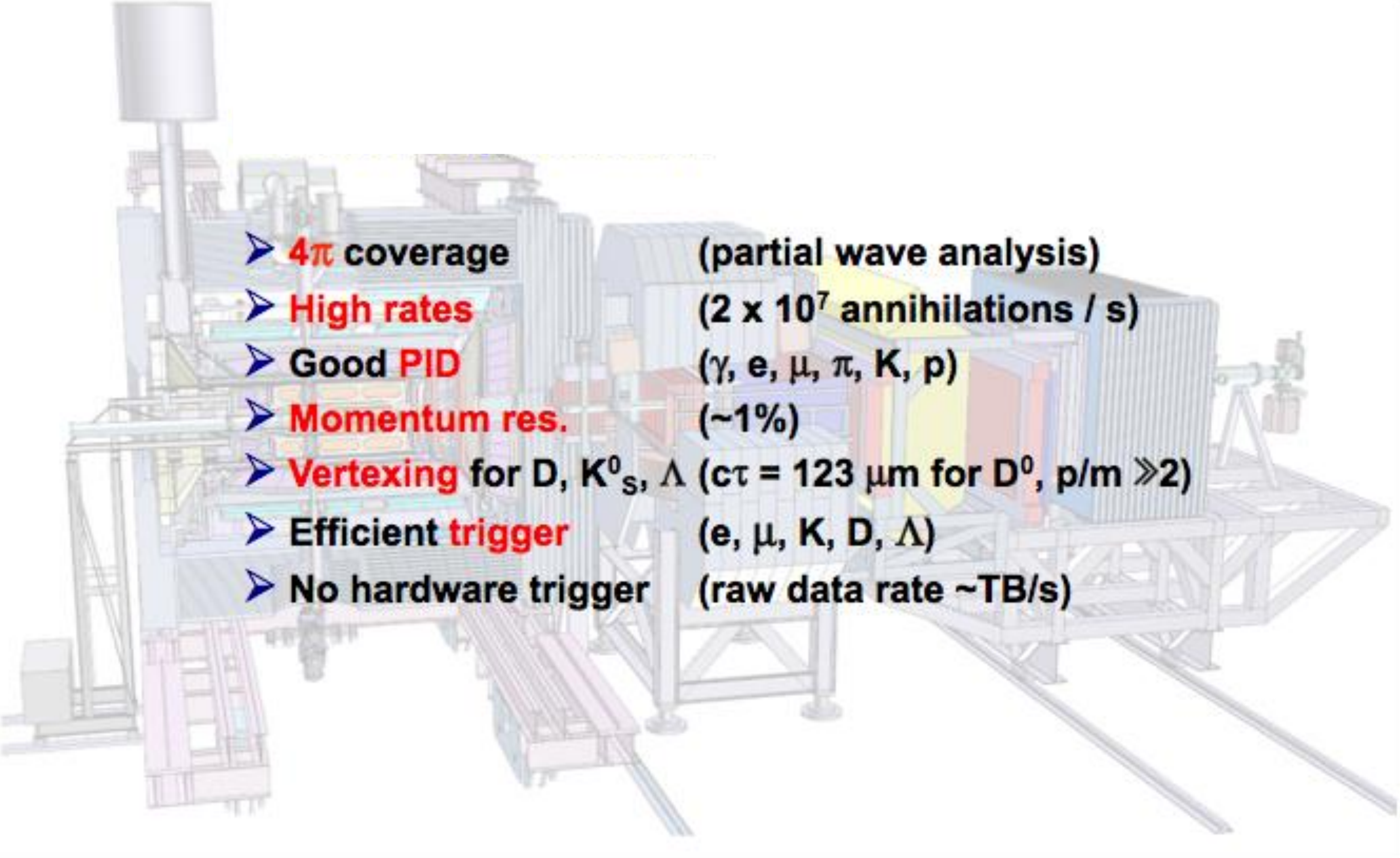
Momentum (GeV/c)	Reaction	σ (μb)	Efficiency (%)	Rate (with 10^{31} cm^{-2}s^{-1})
1.64	$\bar{p}p \rightarrow \bar{\Lambda}\Lambda$	64	11	29 s^{-1}
4	$\bar{p}p \rightarrow \bar{\Lambda}\Sigma^{o}$	~40	~30	50 s^{-1}
4	$\bar{p}p \rightarrow \bar{\Xi}^{+}\Xi^{-}$	~2	~20	1.5 s^{-1}
12	$\bar{p}p \rightarrow \bar{\Omega}^{+}\Omega^{-}$	~0.002	~30	~4 h^{-1}
12	$\bar{p}p \rightarrow \bar{\Lambda}_{c}^{-}\Lambda_{c}^{+}$	~0.1	~35	~2 day^{-1}

Day 1

Glueball Studies at PANDA

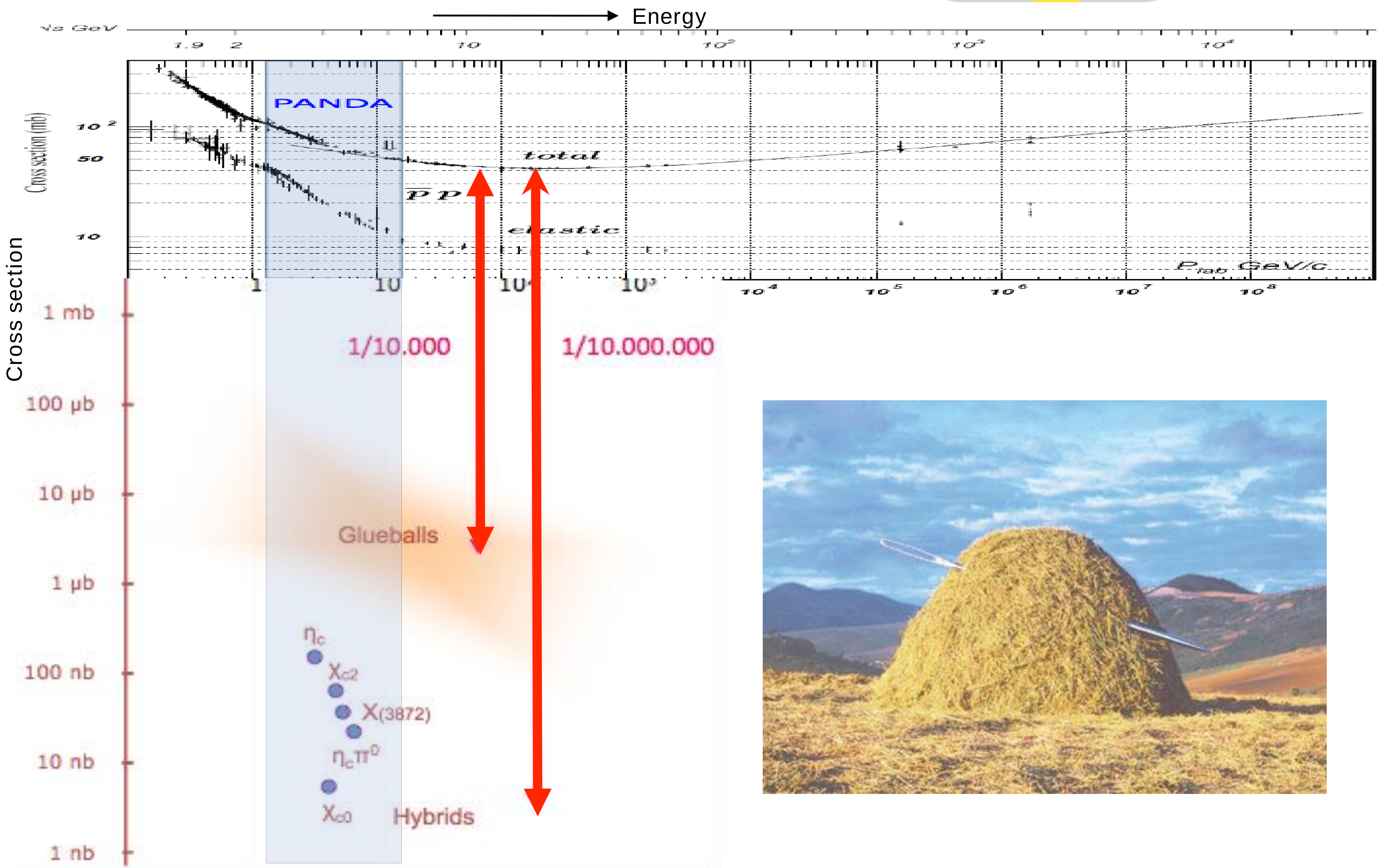
- Study of glueball production in $K^+K^-\pi^0$, $K^+K^-\pi^0\pi^0$, and $\Phi\Phi\pi^0$
  - assuming cross section of 10 nb (including decay to final state)
  - background cross sections 50 to 80 mb
- "Light" glueball m = 2400 MeV/c^2 (could be 2^{++} or 0^{-+})
  - E_{CMS} = 2.57 GeV and 5.47 GeV
  - could be broad, study final states w/o intermediate resonances
- "Heavy" glueball m = 3900 MeV/c^2
  - E_{CMS} = 5.47 GeV
  - could be narrow, assume Γ=10 MeV
  - search for narrow signal in production followed by detailed studies in formation [unique at PANDA]

Detector requirements

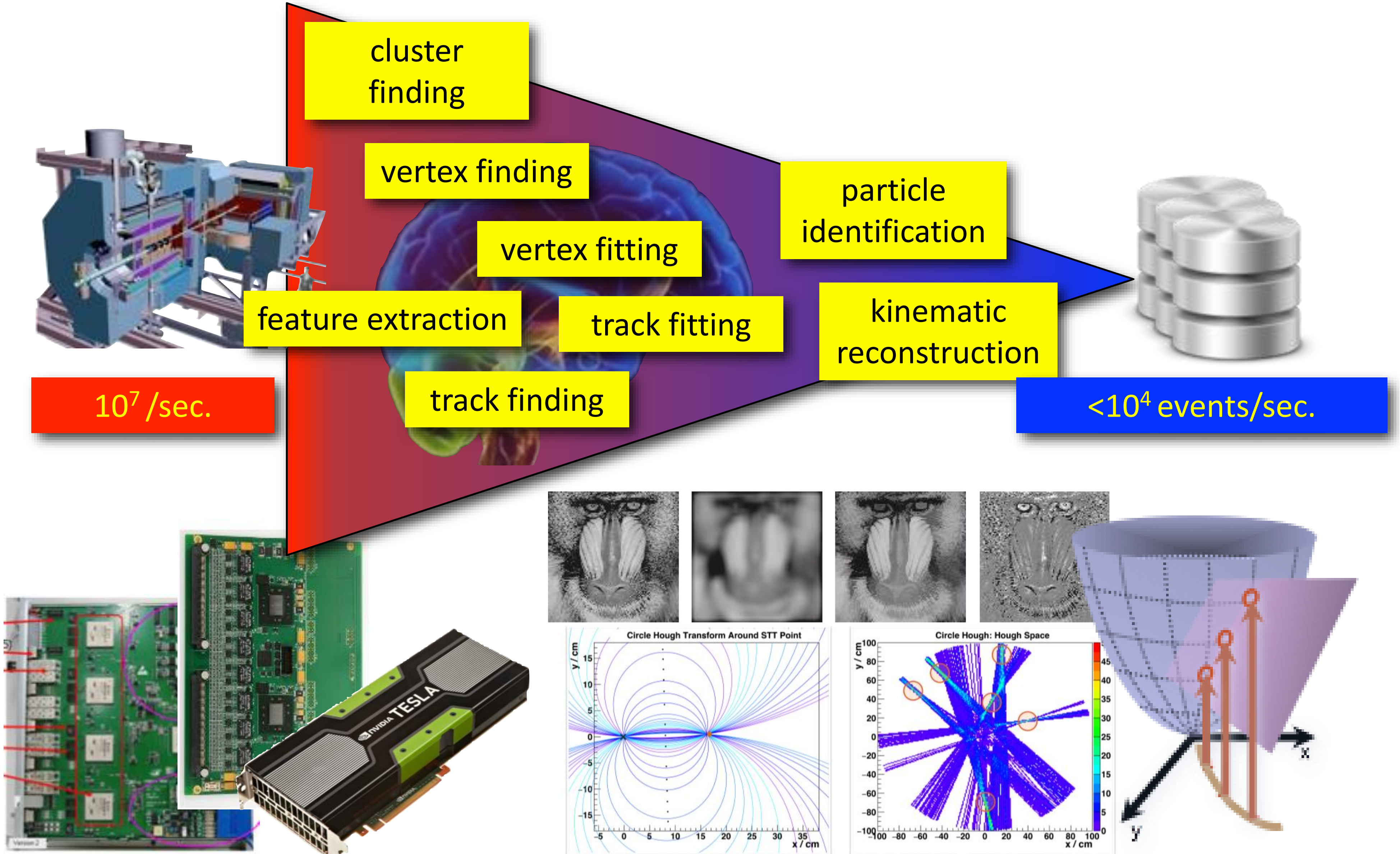


- **4π coverage** (partial wave analysis)
- **High rates** (2 x 10^7 annihilations / s)
- **Good PID** (γ, e, μ, π, K, p)
- **Momentum res.** (~1%)
- **Vertexing for D, K^0_S, Λ** (cτ = 123 μm for D^0, p/m ≫2)
- **Efficient trigger** (e, μ, K, D, Λ)
- **No hardware trigger** (raw data rate ~TB/s)

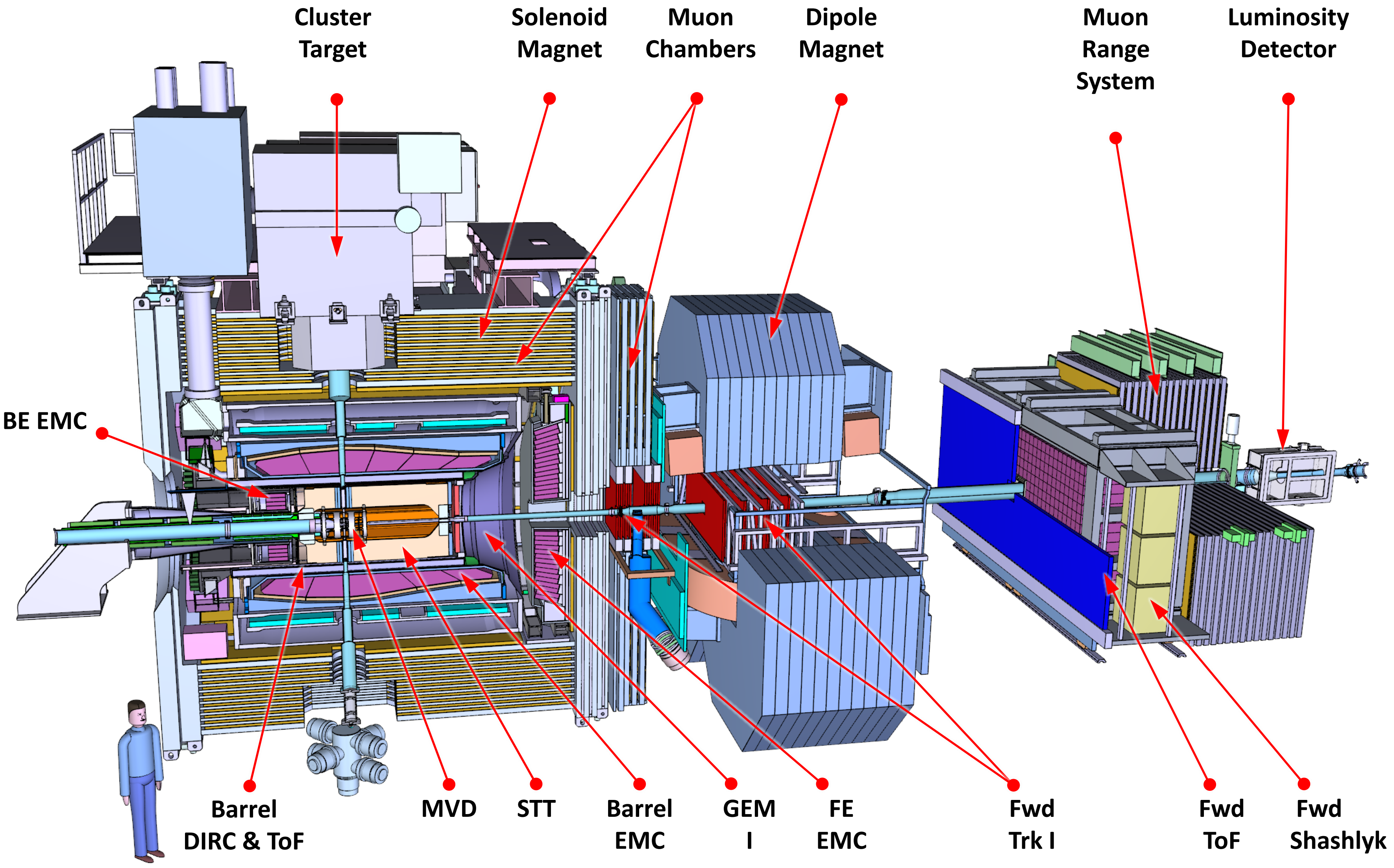
Needle-in-a-haystack



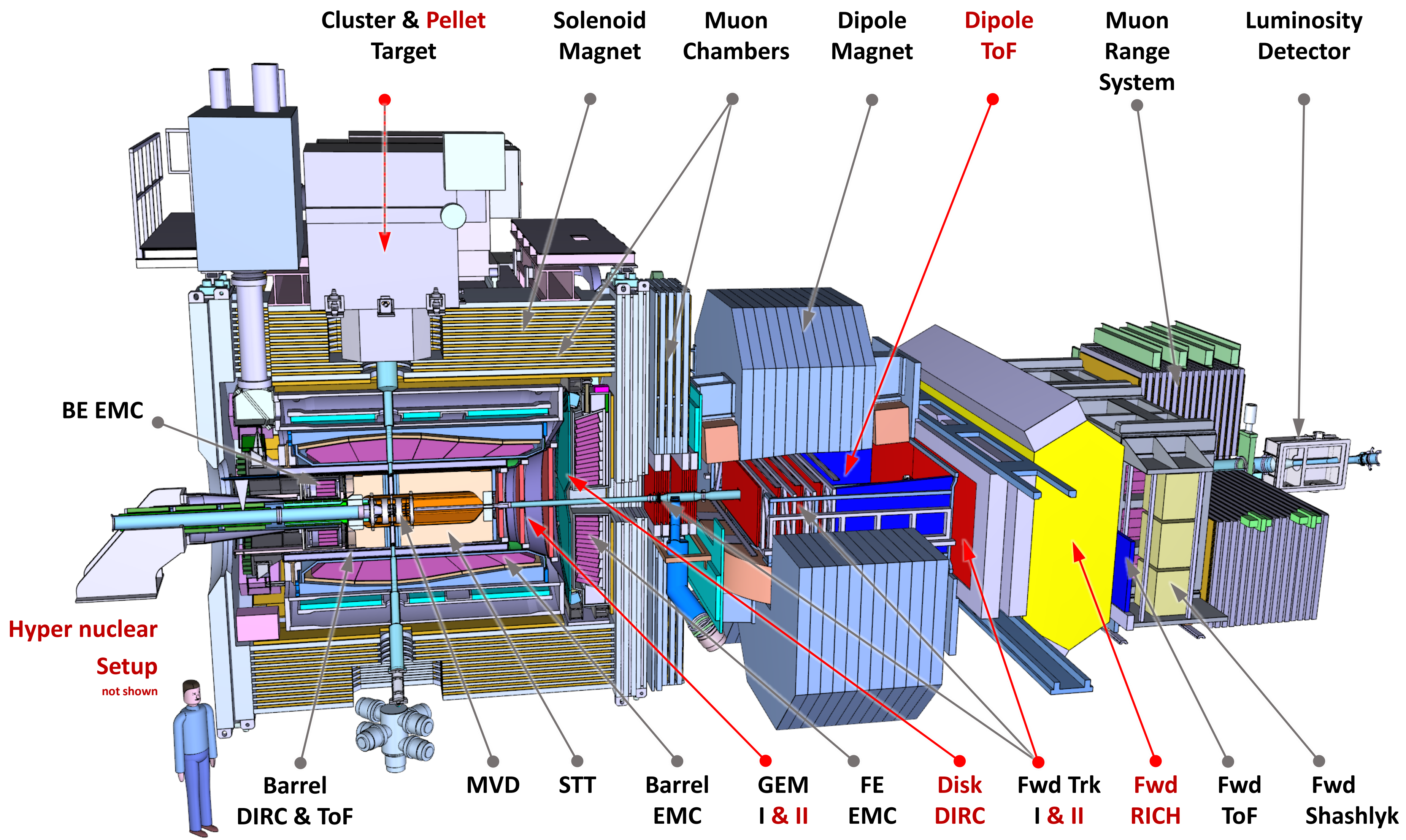
Intelligent *in-situ* data processing



Start-Setup (Phase 1)



Full Setup (Phase 2)



FAIR Groundbreacking Event – 4-July-2017

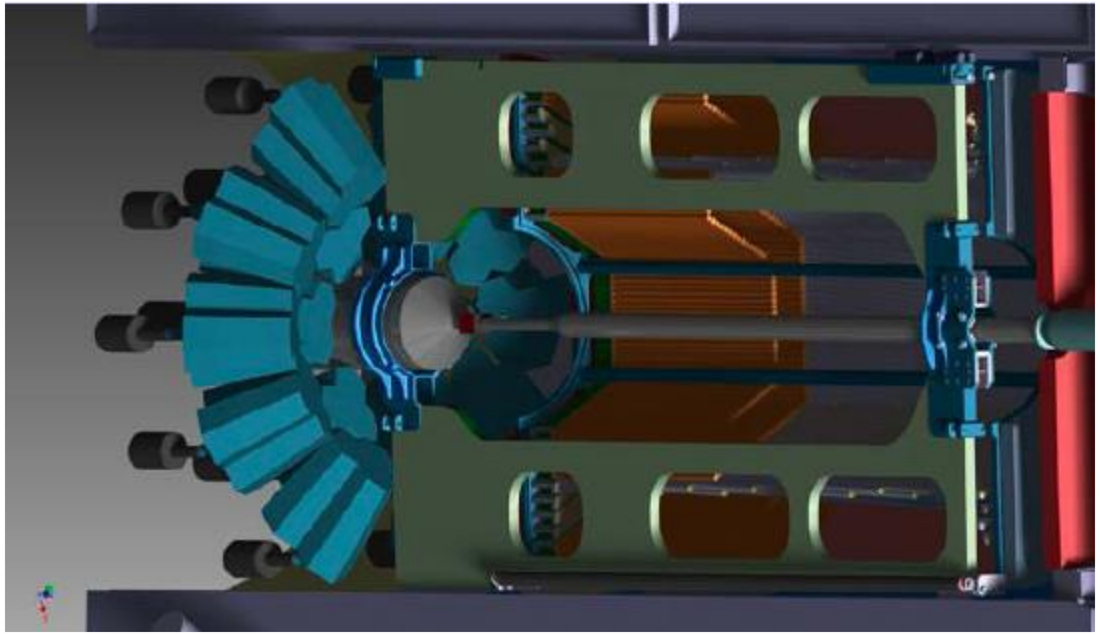
FAIR Council members.

Klaus Peters – PANDA Spokesperson.

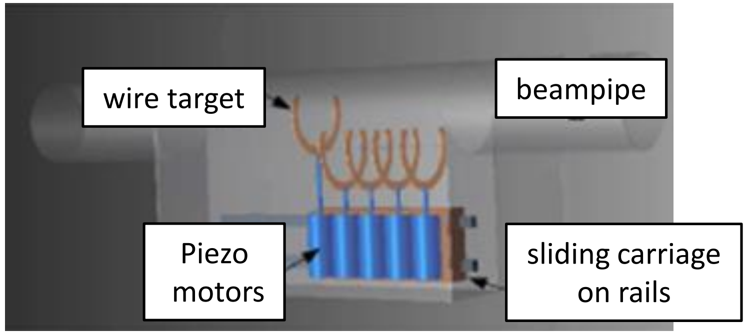
Hypernuclear Setup

Principle:
- Produce hypernuclei from captured Ξ

Modified Setup:
- Primary retractable wire/foil target
- Secondary active target to capture Ξ and track products with Si strips
- HP Ge detector for γ-spectroscopy



Priamary target:
- Diamond wire
- Piezo motored wire holder



Active secondary target:
- Silicon microstrips
- Absorbers