Experimental overview of $\bar{P}$ANDA

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For the $\bar{P}$ANDA collaboration

Workshop for young scientists with research interests focused on physics at FAIR

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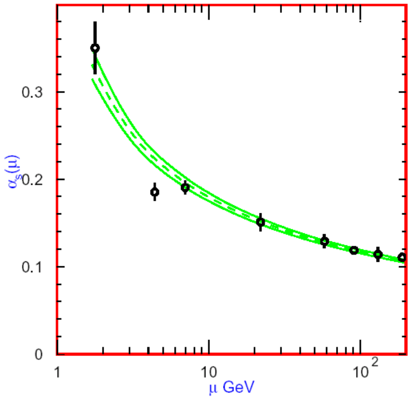
Outline

- Strong Interaction and QCD
- $\bar{P}$ANDA at FAIR
  - Experimental Setup
  - $\bar{P}$ANDA Physics Program
- Summary and Outlook

Quantum Chromodynamics (QCD)

The modern theory of the strong interactions is Quantum Chromodynamics (QCD), the quantum field theory of quarks and gluons based on the non abelian gauge group SU(3). It is part of the Standard Model.



QCD enjoys two peculiar properties:

- At high energy (μ): Asymptotic freedom, where the strong coupling constant α_s becomes small and perturbation theory applies and QCD is well tested. This properties is responsible for the quasi-free behavior exhibited by quarks in hadrons probed at very short distances by deep inelastic scattering.

- At low energy (μ): Confinement, which means that the force between quarks does not diminish as they are separated. Because of this, it would take an infinite amount of energy to separate two quarks. QCD becomes a strongly coupled theory, many aspects of which are not understood. No perturbation theory should be applied.

Theoretical approaches to non-perturbative QCD

- Potential models. Bound system of heavy quarks can be treated in the framework of non-relativistic potential models, with forms which reproduce the asymptotic behavior of QCD. Masses and widths are obtained by solving Schrödinger's equation.
- Lattice QCD (LQCD).
  - The QCD equations of motions are discretized on a 4-dimensional space-time lattice and solved by large-scale computer simulations.
  - Enormous progress in recent years (e.g. gradual transition from quenched to unquenched calculations).
  - Ever increasing precision, thanks also to synergies with EFT.
- Effective Field Theories (EFT). They exploit the symmetries of QCD and the existence of hierarchies of scales to provide effective lagrangians that are equivalent to QCD for the problem at hand.
  - With quark and gluon degrees of freedom (e.g. Non relativistic QCD, NRQCD).
  - With hadronic degrees of freedom (e.g. Chiral Perturbation Theory).

Experimental measurements - What we can learn?

- Confinement. Why do we not observe free quarks?
- Spectroscopy of QCD bound states. Precision measurements of particle spectra to be compared with theory calculations.
  Identification of the relevant degrees of freedom.
  - light quarks, $c\bar{c}$, $b\bar{b}$
  - D meson
  - baryons
- Search for new forms of hadronic matter: hybrids, glueballs, multi quark states...
- Hadrons in nuclear matter. Origin of mass
- Study of nucleon structure
- Spin physics

Experimental techniques

e^+e^- collisions

- direct formation
- two-photon production
- initial state radiation (ISR)
- B meson decays
- double charmonium production

(*BABAR* , Belle, BES, CLEO(-c), LEP...)

Advantages:
- Low hadronic background
- High discovery potential

Disadvantages:
- Direct formation limited to vector states ($J^{PC} = 1^{--}$: photon quantum numbers)

All the other states can be produced in the radiative decays of the vector states.
- The precision in the measurement of masses and widths is limited by the detector resolution.

$p\bar{p}$ annihilation

(LEAR, Fermilab E760/E835, $\bar{P}$ANDA)

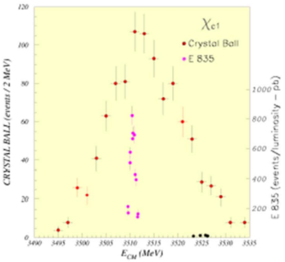
Disadvantages:
- High hadronic background

Advantages:
- High discovery potential
- Direct formation for all (non-exotic) states
- The measurement of masses and widths is very accurate because it depends only on the beam parameters.

$p\bar{p}$ annihilation

In $p\bar{p}$ collisions the coherent annihilation of the three quarks in the $\bar{p}$ with the three quarks in the p makes it possible to form directly states with all non-exotic quantum numbers.

The measurement of masses and widths is very accurate because it depends only on the beam parameters, not on the experimental detector resolution, which determines only the sensitivity to a given final state.



Experimental method

The cross section for the process:

$p\bar{p} \to R \to$ final state

is given by the Breit-Wigner formula:

$\sigma_{BW} = \frac{2J+1}{4}\frac{\pi}{k^2}\frac{B_{in}B_{out}\Gamma_R^2}{(E-M_R)^2+\Gamma_R^2/4}$

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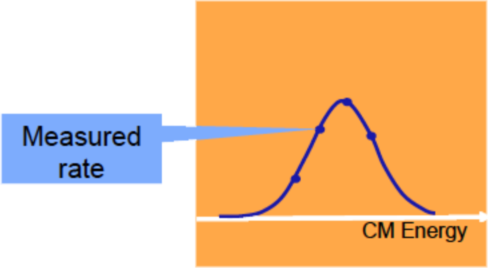
The production rate of a certain final state ν



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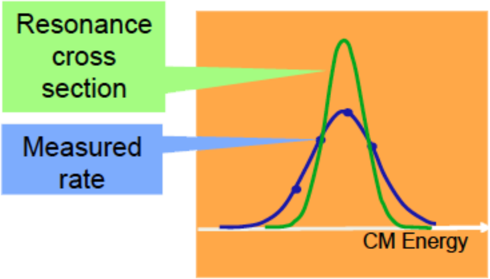
The production rate of a certain final state ν is a convolution of the BW cross section



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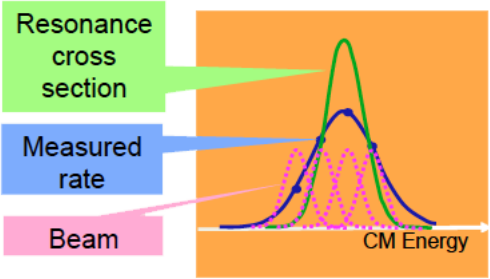
The production rate of a certain final state ν is a convolution of the BW cross section and the beam energy distribution function $f(E, \Delta E)$:
$\nu = \mathcal{L}\{\epsilon \int dE\, f(E, \Delta E) \sigma_{BW}(E) + \sigma_b\}$



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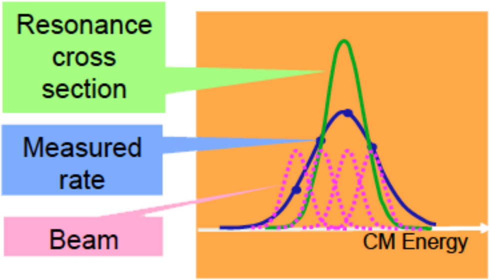
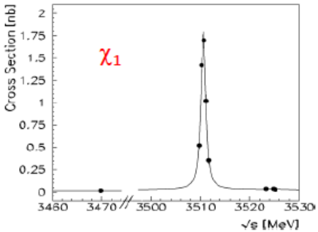
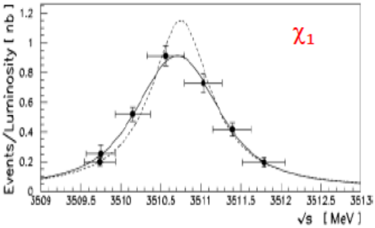
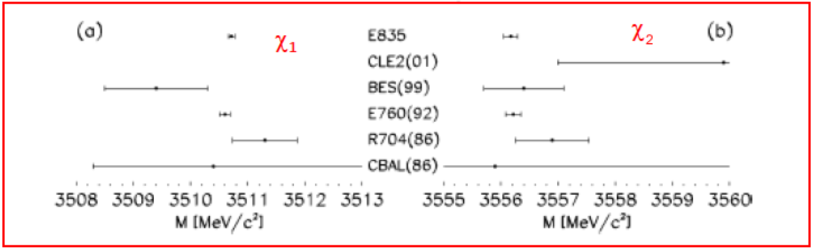


The resonance mass M_R, total width Γ_R and product of branching ratios into the initial and final state $B_{in}B_{out}$ can be extracted by measuring the formation rate for that resonance as a function of the center of mass energy E.

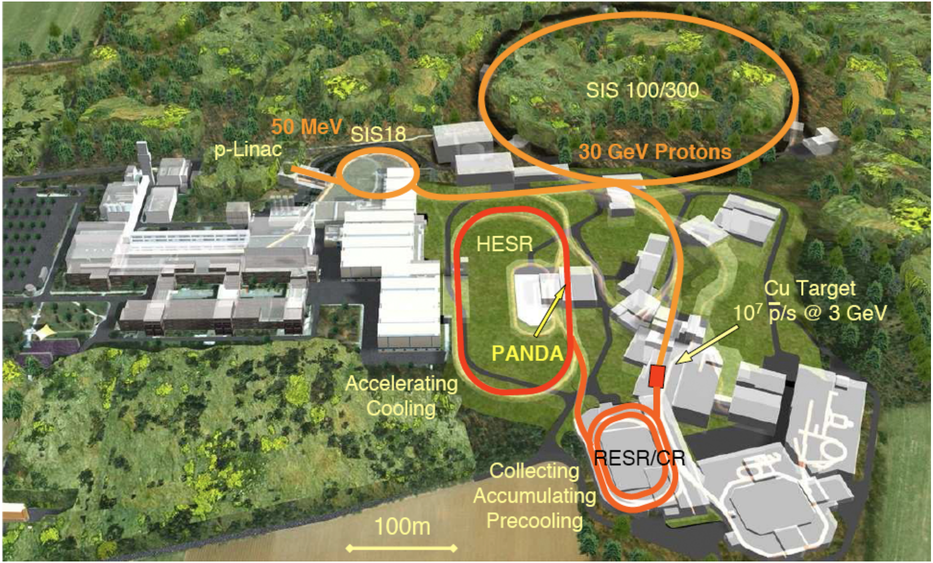
Examples: χ_{c1} and χ_{c2} scans in Fermilab E835





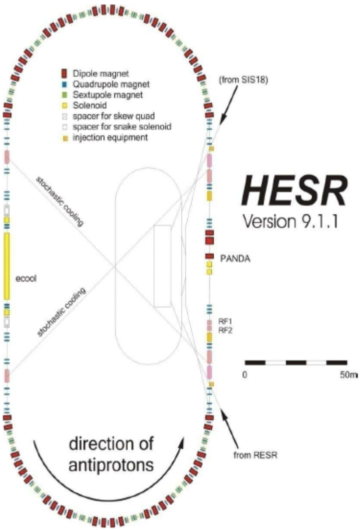


Facility for Antiproton and Ion Research



* The discussion about the RESR construction is ongoing

High Energy Storage Ring (HESR)



- $\bar{P}$ beam momentum: 1.5 - 15 GeV/c
- Internal target
- Antiproton production rate: $2 \cdot 10^7$/sec
- N_{stored} = up to $1 \cdot 10^{11} \bar{p}$

High resolution mode

- Electron cooling
- $\delta p/p \sim 10^{-5}$
- $L = 10^{31} cm^{-2} s^{-1}$

High luminosity mode

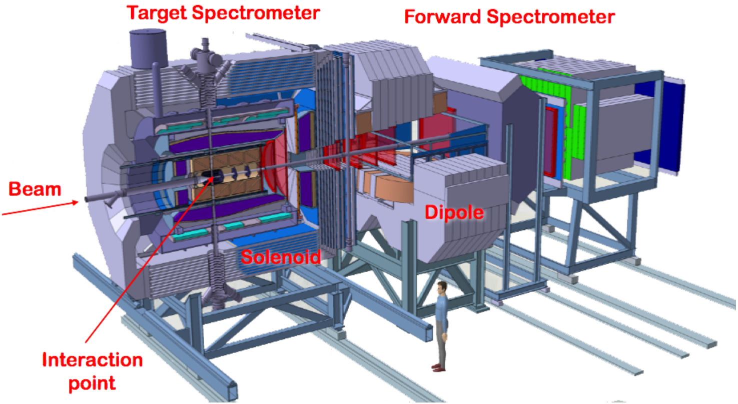
- Stochastic cooling
- $\delta p/p \sim 10^{-4}$
- $L = 2 \cdot 10^{32} cm^{-2} s^{-1}$

* with RESR

Detector Requirements

- 4π acceptance
- High rate capability: $2{\cdot}10^7 s^{-1}$ interactions
- Excellent tracking capabilities, Momentum resolution $\sim 1\%$
- Vertexing capabilities for D, K_s, hyperons
- Continuous data acquisition
- Good PID (e, μ, π, K, p)
- γ detection up to 10 GeV

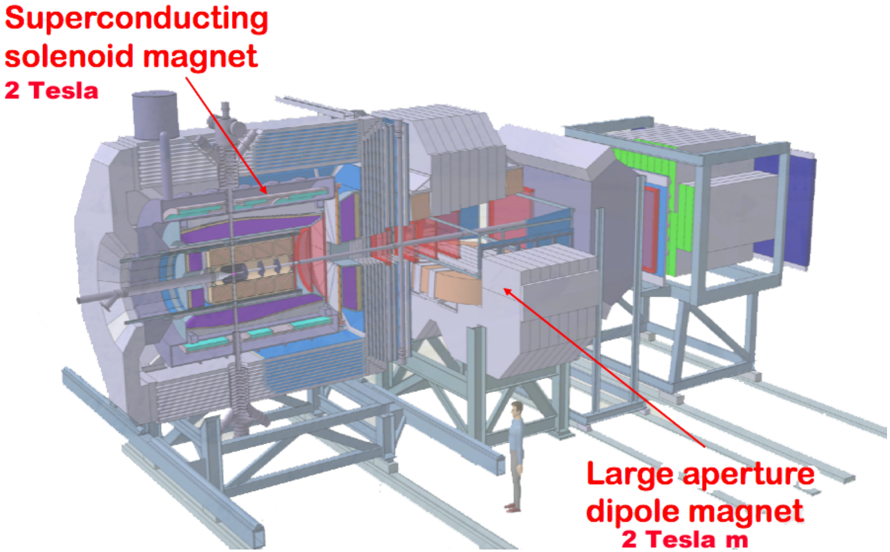
Anti-Proton ANnihilation at DArmstadt - $\bar{P}$ANDA Detector



Target Spectrometer: will be arranged in three parts: the barrel covering angles between 22° and 140°, the forward end cap extending the angles down to 5° and 10° in the vertical and horizontal planes, respectively, and the backward end cap covering the region between about 145° and 170°.

Forward Spectrometer: will cover all particles emitted in vertical and horizontal angles below ±5° and ±10°, respectively.

Anti-Proton ANnihilation at DArmstadt - $\bar{P}$ANDA Detector



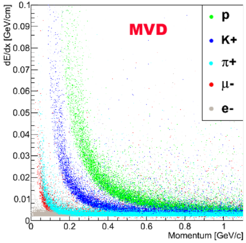
Anti-Proton ANnihilation at DArmstadt - $\bar{P}$ANDA Detector

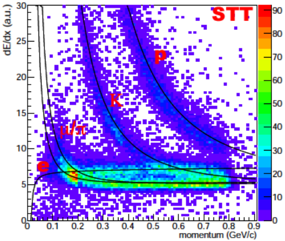
PID requirements

- separate charged π, K, p, e, μ
- momentum range: 200 MeV/c - 10 GeV/c

PID processes

- π, K, p below 1 GeV: energy loss (Micro Vertex Detector, Trackers)
- π, K, p above 1 GeV: Cherenkov (barrel DIRC, disc DIRC, RICH)
- π, K, p up to 4 GeV: Time of Flight (TOF detectors)
- e and γ: electromagnetic showers (EMC); (γ: few MeV to 10 GeV)
- μ: showers (Muon detectors)





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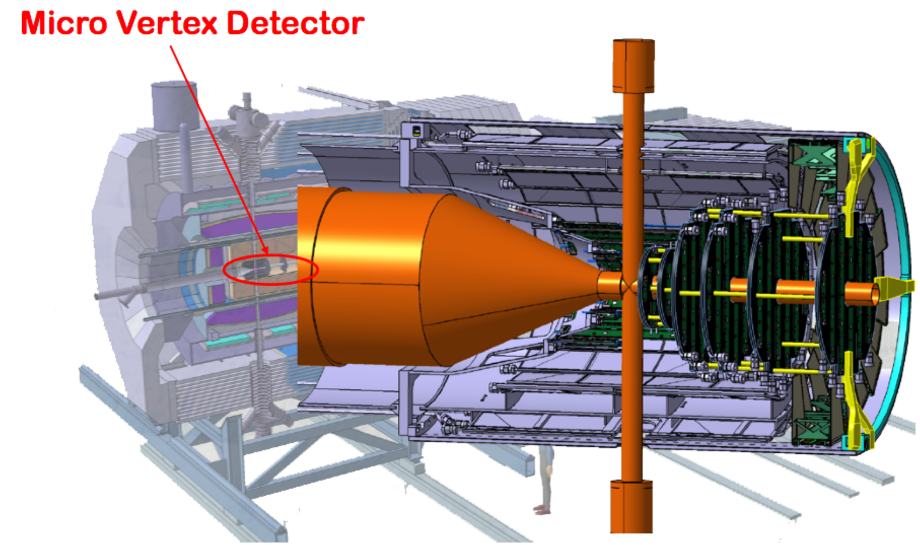

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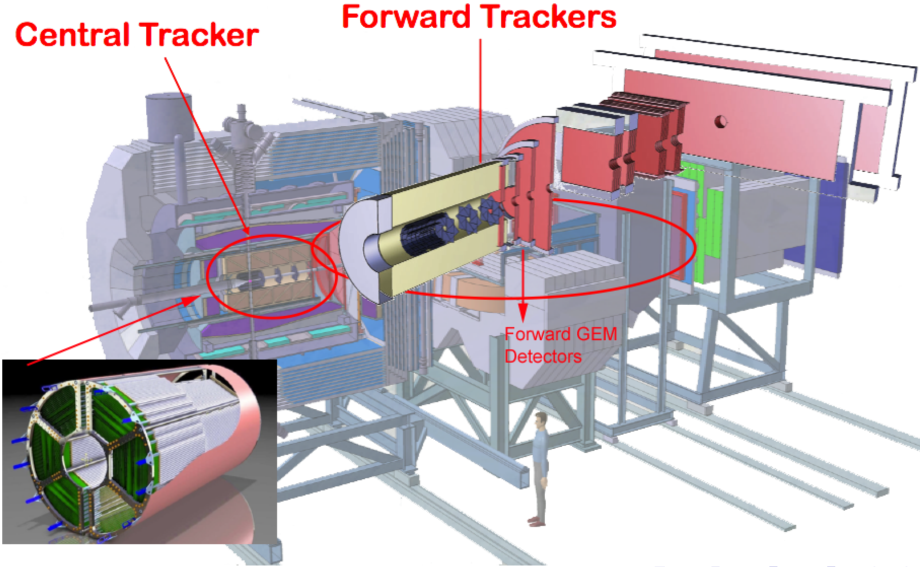

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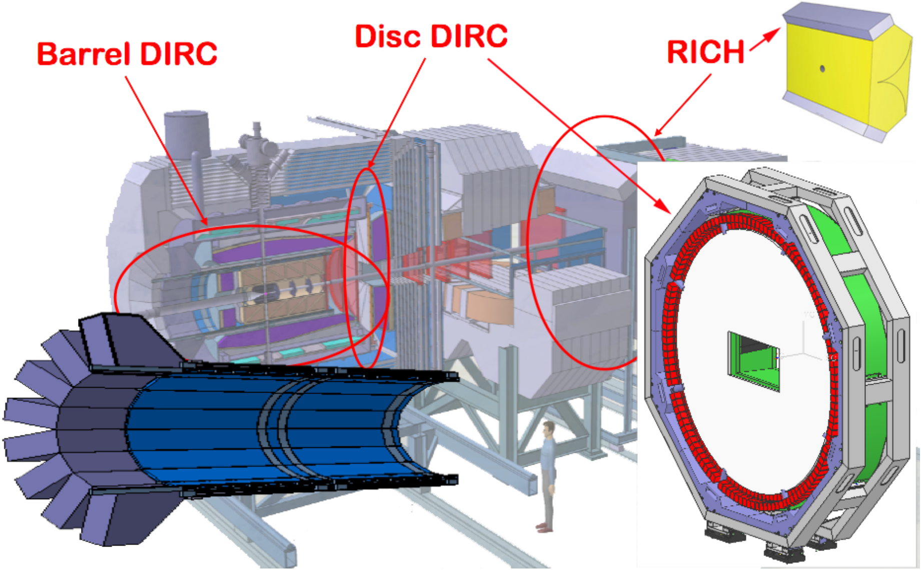

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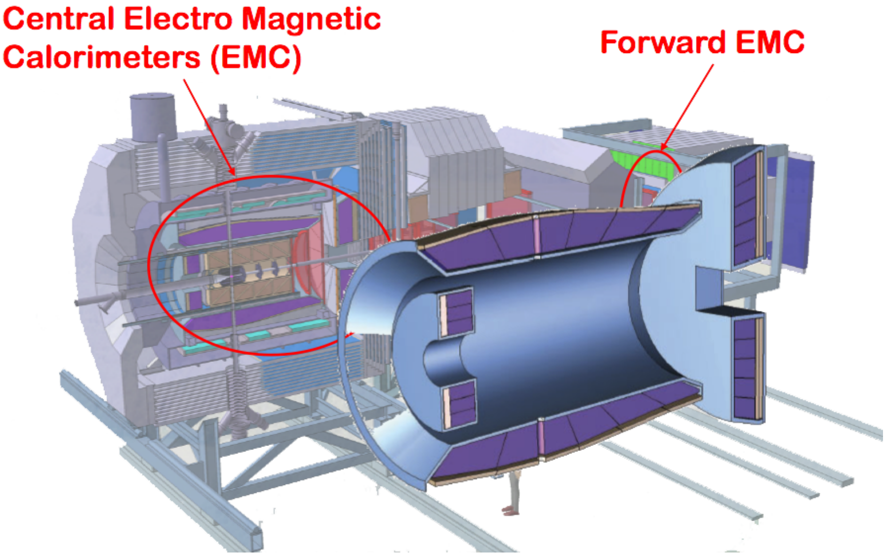

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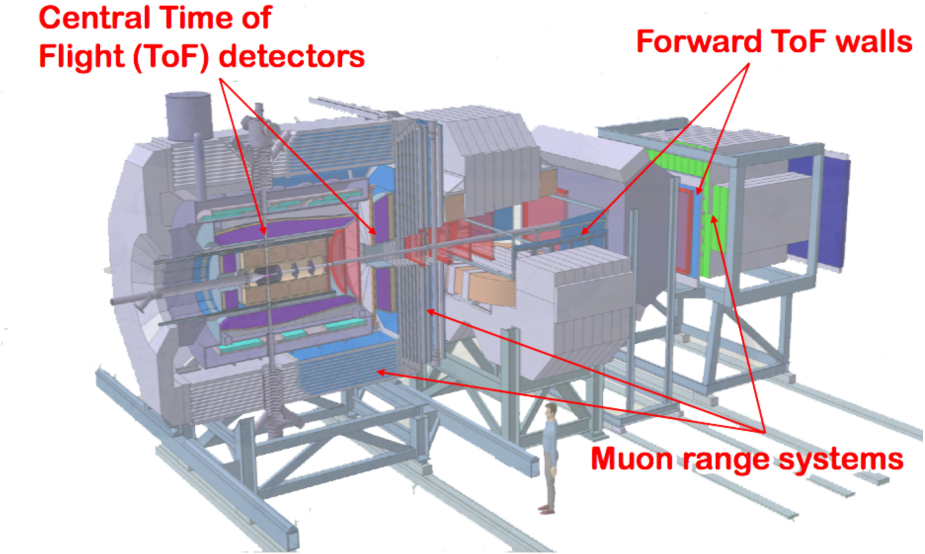
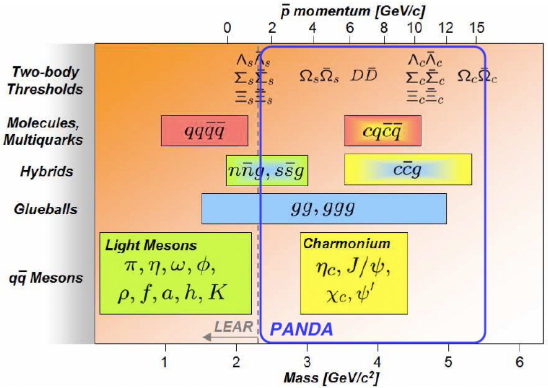
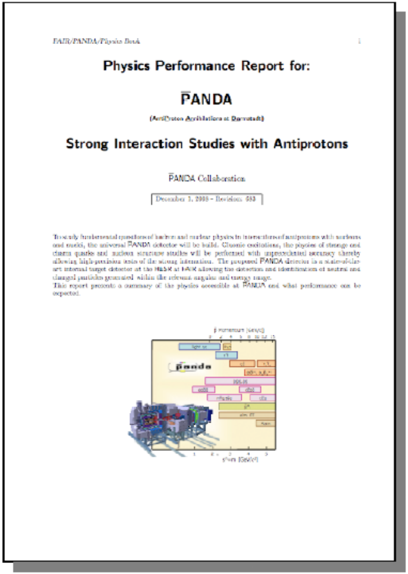




- QCD bound states:
  - Charmonium
  - Exotic excitations
  - Heavy-light systems
  - Strange and charmed baryons
- Hadrons in the nuclear medium
- Hypernuclear physics
- Nucleon structure
  - Generalized distribution amplitudes
  - Drell-Yan
  - Electromagnetic form factors
- Electroweak physics

Physics Performance Report for PANDA



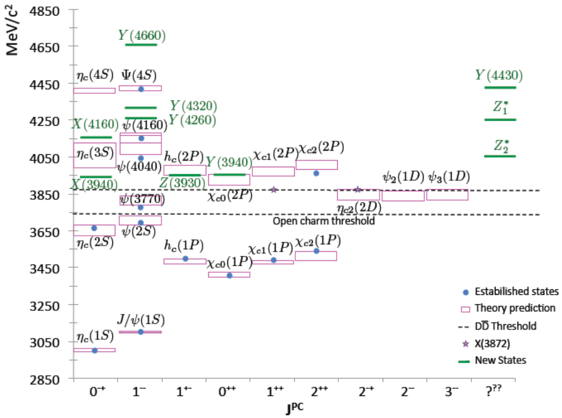
- A big effort has been made to create the PHYSICS PERFORMANCE REPORT FOR PANDA
- Detailed description of the intended scientific program
- More than 20 channels have been studied in detail to determine the experimental sensitivity
- If interested take a look under: http://arxiv.org/abs/0903.3905v1

QCD Bound States

The study of QCD bound states is of fundamental importance for a better, quantitative understanding of QCD.
Particle spectra can be computed within the framework of non-relativistic potential models, effective field theories and Lattice QCD.
Precision measurements are needed to distinguish between the different approaches and identify the relevant degrees of freedom.

- Charmonium
- Exotic excitations
- Heavy-light systems
- Strange and charmed baryons

Charmonium spectroscopy



- Below the $D\bar{D}$ threshold, all expected states have been observed, with properties in good agreement with theory; some precision masses and widths measurements still missing; there are no additional states.

- Many unexpected states have been reported above the $D\bar{D}$ threshold, seemingly too many with $J^{PC} = 1^{--}$.
Several exotic hypotheses about their nature: tetraquarks, hadronic molecules, hybrids, glueballs, hadro-quarkonia.

- These result mainly from Belle and *BABAR* , with significant contributions also from CDF, D0, CLEO, LHCb, ATLAS, CMS and BES

Charmonium at $\bar{P}$ANDA

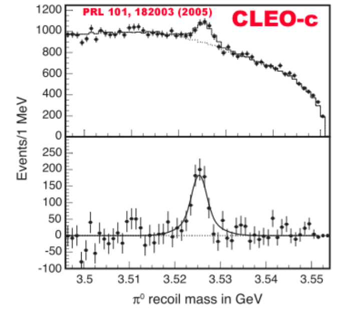
- At $2 \cdot 10^{32} cm^{-2} s^{-1}$ accumulate 8 pb^{-1}/day (assuming 50% overall efficiency). It means $10^4 - 10^7$ $(c\bar{c})$ states/day.
- Total integrated luminosity 1.5 fb^{-1}/year (at $2 \cdot 10^{32} cm^{-2} s^{-1}$, assuming 6 months/year data taking).
- Improvements with respect to Fermilab E760/E835:
  - Up to ten times higher instantaneous luminosity.
  - Better beam momentum resolution $\Delta p/p = 10^{-5}$ (GSI) vs $2 \cdot 10^{-4}$ (FNAL)
  - Better detector (higher angular coverage, magnetic field, ability to detect hadronic decay modes.)
- Fine scans to measure masses to $\sim$ 100 KeV and widths to $\sim$ 10%
- Explore entire region below and above open charm threshold, finding missing states and understanding newly discovered states
- Decay channels: - $J/\psi + X$; $J/\psi \to e^+e^-$, $J/\psi \to \mu^+\mu^-$
  - $\gamma\gamma$
  - hadrons
  - $D\bar{D}$
- Get a complete picture of the dynamics of the $c\bar{c}$ system.

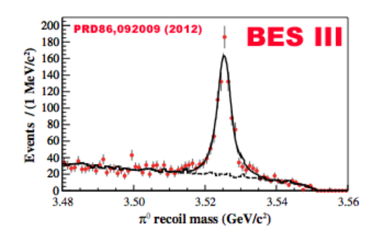
Charmonium below and above the $\bar{D}D$ threshold

- Thanks to high beam momentum resolution and high luminosity we can make accurate measurement of all the eight states below the $\bar{D}D$ threshold

- Thanks to high-statistic and small-step scans of the entire energy region accessible at GSI we can identify all missing states above the open charm threshold and confirm the ones for which we only have a weak evidence.

The CLEO experiment was able to find the h_c signal in $\psi(2S)$ decay by means of an exclusive analysis (where the $\psi(2S)$ decay mode is isospin violating): $e^+e^- \to \psi(2S) \to \pi^0 h_c \to \gamma\gamma\gamma\eta_c$
The width and the BF were not measured. PRL 95, 102003 (2005)

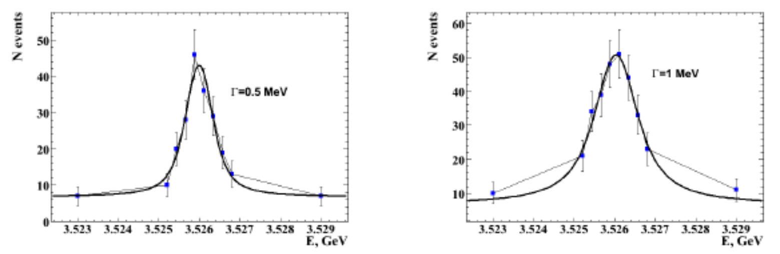




In 2012 a similar analysis was done by the BESIII experiment, with higher statistic. PRD 86,092009 (2012)
-m_{h_c}=3525.31±0.11±0.4 MeV/c^2
-$\Gamma(h_c)$=0.70±0.28±0.22 MeV/c^2

$h_c(1^1P_1)$ at $\bar{P}$ANDA

Thanks to the precise HESR momentum definition, widths of known states can be precisely measured with an energy scan.

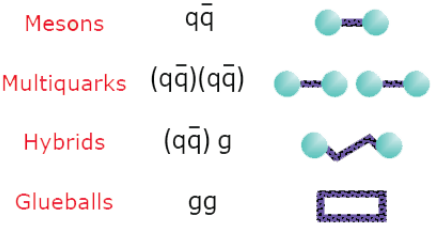


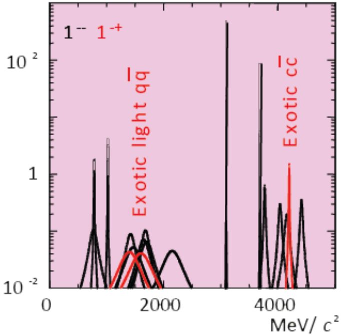
- $h_c \rightarrow \eta_c\gamma \rightarrow \phi\phi\gamma \rightarrow 4K\gamma$
- Energy scan of 10 values around the h_c mass
- Width upper limit is 1 MeV
- Each point represents a 5 day data taking in high luminosity mode

$\Gamma_{R,MC}$ [MeV]	$\Gamma_{R,reco}$ [MeV]	$\Delta\Gamma_R$ [MeV]
1	0.92	0.24
0.75	0.72	0.18
0.5	0.52	0.14

Exotic hadrons

The QCD spectrum is much richer than that of the quark model as the gluons can also act as hadron components. The identification of exotic states is an important key to understand hadron spectrum and the process of mass generation.



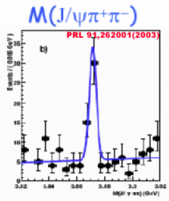


- Spin exotic quantum numbers J^{PC} are powerful signature of gluonic hadrons.
- In the light meson spectrum exotic states overlap with conventional states.
- In the $c\bar{c}$ meson spectrum the density of states is lower and the exotics can be resolved unambiguously.

X(3872)

In 2003, Belle discovered a new signal in $B^+ \to XK^+$ where $X \to J/\psi\pi^+\pi^-$.
Phys. Rev. Lett. 91, 262001 (2003)

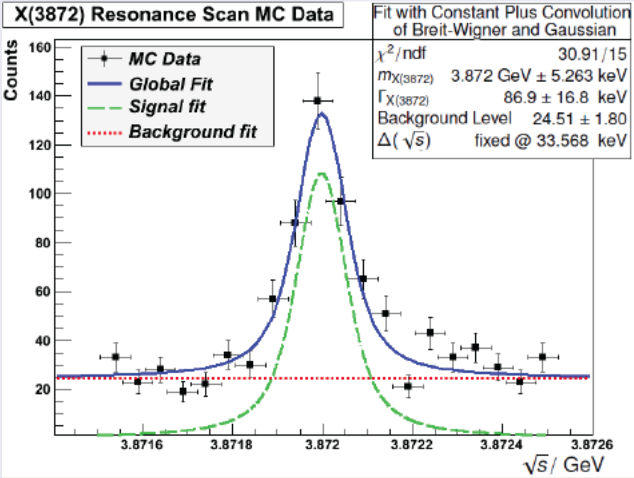
PDG12	X(3872)
Mass	(3871.68 ± 0.17) MeV/c^2
Width	< 1.2 MeV (90% C.L.)



- LHCb arXiv:1302.6269 (2013) dipion angular analysis in $X \to J/\psi\pi^+\pi^-$ favours $J^{PC} = 1^{++}$
- No charged partners found, doesn't decay to $\chi_{c1}\gamma$ or $J/\psi\eta_c$

- X(3872) is puzzling:
  - Similar to charmonium, ie: narrow state decaying to $J/\psi\pi^+\pi^-$
  - DD^{*0} molecule?
  - tetraquark 4-quark bound state?
  - Glueball gluon bound state or charmonium-gluon hybrid?

X(3872) at $\bar{P}$ANDA



- The narrow width of X(3872) can be precisely determined with an energy scan.
- Input parameters:
  - m= 3.872 GeV/c^2
  - Γ=1 MeV
- Mass Resolution: $\sim$ 5 KeV/c^2
- Width precision: $\sim$ 10-20%
- Each data point 2 days data taking, only statistical errors are included

Y(4260)

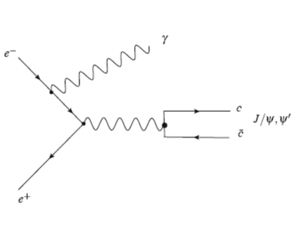
It is the first of the Y states. It has been discovered by *BABAR* in Initial state radiation, for this reason the quantum numbers are $J^{PC} = 1^{--}$.

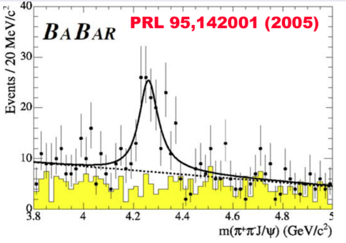
Phys. Rev. Lett. 95, 142001 (2005)

The Y(4260) appears to represent an overpopulation of the expected $J^{PC} = 1^{--}$ states. The absence of open charm production speaks against it being a conventional $c\bar{c}$ state.

The QCD string model predict that the Y(4260) is the lowest charmonium hybrid.

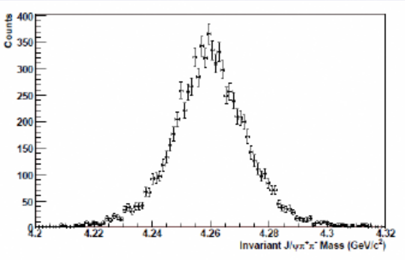
Phys. Rev. D 77, 054025 (2008)

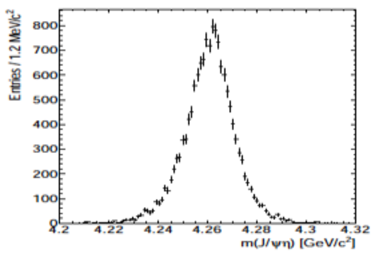




Y(4260) at $\bar{P}$ANDA

$p\bar{p} \to Y(4260) \to J/\psi\pi^+\pi^-; J/\psi\eta$





σ =13.4 MeV

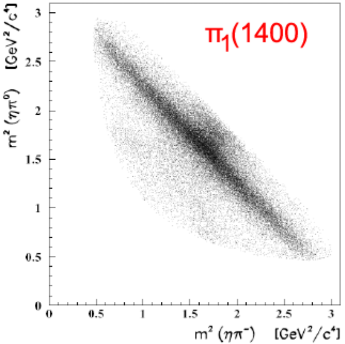
Efficiency=33%

σ =18 MeV

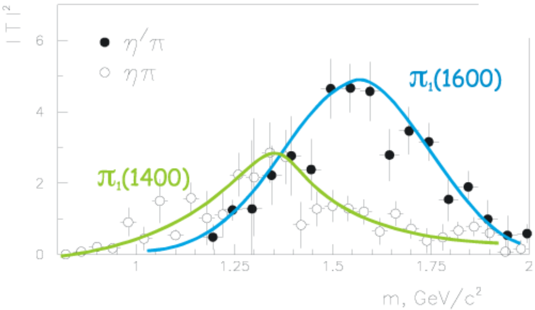
Efficiency=18.8%

Hybrids and glueballs

- Hybrids candidates: $\pi_1(1400)$ and $\pi_1(1600)$ with $J^{PC} = 1^{-+}$
  S.U.Chung [E852 Collaboration], Phys Lett D 65, 072001 (2002)



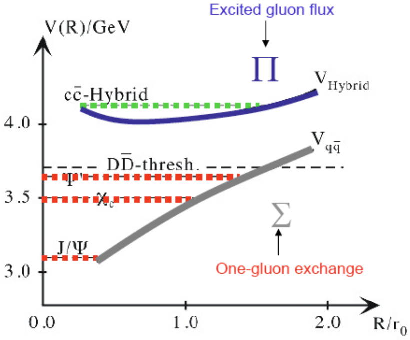
Crystal Barrel Collaboration - A.Abele
Phys Lett B423, 175 (1998)



VES Collaboration - G.M.Beladidze,
Phys Lett B 313, 276 (1993)

Charmonium Hybrids

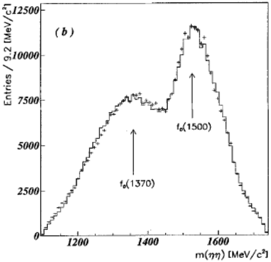
- The charmonium hybrids predictions come from different theoretical models: bag model, flux tube model, constituent gluon model and LQCD.
- Three of the lowest charmonium hybrids have exotic J^{PC}: 0^{+-}, 1^{-+}, 2^{+-}. The mixing with nearby $c\bar{c}$ states is excluded.
- The charmonium hybrids are predicted in the range mass: 4.2 - 4.5 GeV/c^2.
- Charmonium hybrids expected to be much narrower than light hybrids (open charm decays is forbidden or suppressed below DD^{**} threshold).
- Cross sections for formation and production of charmonium hybrids are similar to normal $c\bar{c}$ states ($\sim$ 100-150 pb).



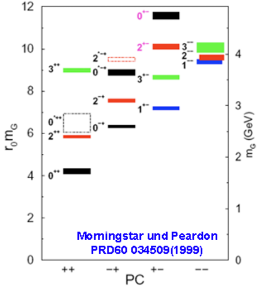
- Narrow state at 1500 MeV/c^2 seen by Crystal Barrel best candidate for glueball ground state ($J^{PC} = 0^{++}$)
- Non exotic gg/ggg-system are complicated to be identified (mixing with the nearby $\bar{q}q$ states).
- Detailed predictions of mass spectrum from LQCD.

C.Amsler et al., [Crystal Barrel], Phys Lett B 342, 433 (1995)

- Exotic heavy glueballs:
  - m(0^{+-})=4140(50)(200) MeV
  - m(2^{+-})=4340(70)(230) MeV
- Width unknown but there is a good probability to see glueballs in charm channels

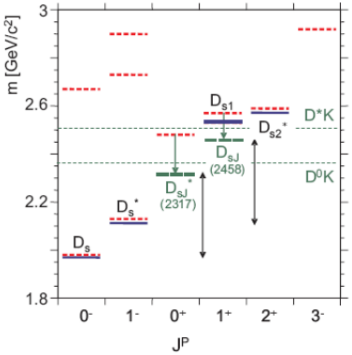


Crystal Barell Collaboration
C. Amsler, Phys Lett B 355 (1995)

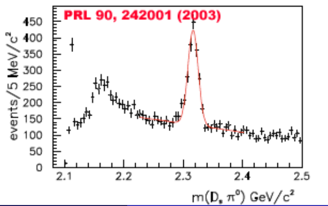


Heavy light system - Open charm Physics - $D_{s0}^{*}(2317)$

- New narrow states D_{sJ} recently discovered at B factories do not fit theoretical calculations.
- At full luminosity at $\bar{p}$ momenta larger than 6.4 GeV/c $\bar{P}$ANDA will produce large numbers of $D\bar{D}$ pairs.
- Despite small signal/background ratio (5×10^{-6}) situation favourable because of limited phase space for additional hadrons in the same process.



$D_{s0}^{*}(2317)$



BABAR studied the mass spectrum by combining charged particles corresponding to the decay $D_s^+ \to K^+K^-\pi^+$ with π^0 candidates reconstructed from a pair of photons. They observed the $D_{s0}^{*}(2317)$ in the invariant mass distribution $D_s^+\pi^0$

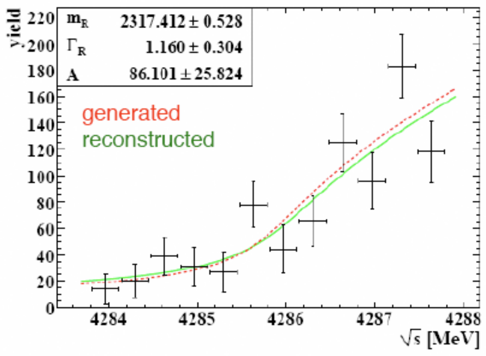
PRL 90,242001 (2003)

PDG12: $m = 2317.8\pm0.6$ MeV/c^2; Width$<$ 3.8 MeV

PANDA

$$\bar{p}p \rightarrow D_s^{\mp} D^*_{s0}(2317)^{\pm}$$
$$D_s^{\pm} \rightarrow \phi\pi^{\pm},\ \phi \rightarrow K^+K^-,\ D^{*\pm}_{s0} \rightarrow \text{anything}$$

14 Days scan close threshold. The selected parameters are:
- $m = 2317.30$ MeV/c^2; Γ=1 MeV/c^2



Output:
$m = 2317.41 \pm 0.53$ MeV/c^2
$\Gamma = 1.16 \pm 0.30$ MeV/c^2

Baryons spectroscopy

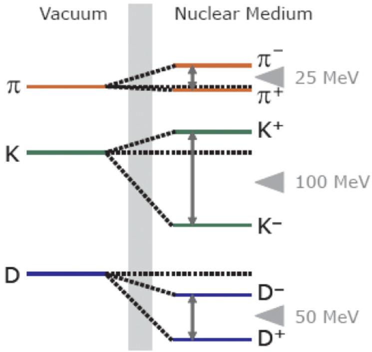
An understanding of the baryon spectrum is one of the primary goals of non-perturbative QCD. In the nucleon sector, where most of the experimental information is available, the agreement with quark model predictions is astonishingly small, and the situation is even worse in the strange baryon sector.

- In $\bar{p}p$ collisions a large fraction of the inelastic cross section is associated to channels with a baryon-antibaryon pair in the final state.
- This opens up the opportunity for a comprehensive baryon spectroscopy program at $\bar{P}$ANDA.
- Example: $\bar{p}p \to \bar{\Xi}\Xi$ cross section up to 2 μb, expect sizable population of excited Ξ states. In $\bar{P}$ANDA these excited states can be studied by analyzing their various decay modes e.g. $\Xi\pi$, $\Xi\pi\pi$, $\Lambda\bar{K}$, $\Sigma\bar{K}$, $\Xi\eta$.
- Ω baryons can also be studied, but cross section lower by approximately two order of magnitude.

Hadrons in Nuclear Matter

One of the fundamental questions of QCD is the generation of MASS.
The light hadron masses are large than the sum of the constituent quark masses.
Spontaneous chiral symmetry breaking seems to play a decisive role in the mass generation of light hadrons. How can we check this?

- Since density increase in nuclear matter is possible a partial restoration of chiral symmetry.
- Evidence for mass changes of pions and kaons has been observed.
- $c\bar{c}$ states are sensitive to gluon condensate:
  - Small (5-10 MeV/c^2 in medium modifications for low-lying $c\bar{c}$ (J/ψ and η_c)
  - Significant mass shifts for excited states: 40, 100, 140 MeV/c^2 for χ_{cJ}, ψ' and $\psi(3770)$ respectively (S.Lee, Phys. Rev. C67, 038202 (2003)).
- D mesons are the QCD analog of the H-atom.
  - chiral symmetry to be studied on a single light quark
  - theoretical calculations disagree in size and sign of mass shift (50 MeV/c^2 attractive - 160 MeV/c^2 repulsive) (Phys. Rev. B487, 96 (2000) - Eur. Phys. J A7, 279 (2000)).



Charmonium in Nuclei

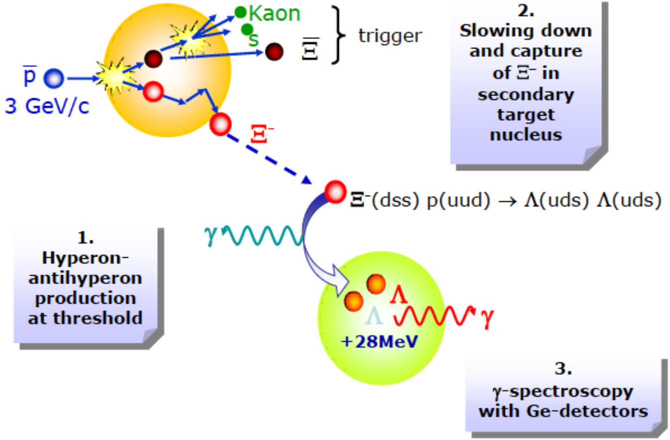
- Measure J/ψ and D production cross section in $\bar{p}$ annihilation on a series of nuclear targets.
- J/ψ nucleus dissociation cross section
- Lowering of the D^+D^- mass would allow charmonium states to decay into this channel, thus resulting in a dramatic increase of width:
  - $\psi(1D)$: 27 MeV $\rightarrow$ 40 MeV
  - $\psi(2S)$: 0.30 MeV $\rightarrow$ 2.7 MeV
- Study relative changes of yield and width of the charmonium states.
- In medium mass reconstructed from dilepton or hadronic decays.

Hypernuclear Physics

Hypernuclei, system where one (or more) nucleon is replaced by one (or more) hyperon(s) (Y), allow access to a whole set of nuclear states containing an extra degree of freedom: strangeness.

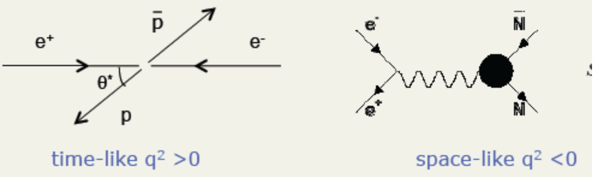
- Probe of nuclear structure and its possible modifications due to the hyperon
- Test and define shell model parameters
- Description in term of quantum field theories and EFT
- Study of the YN and YY forces (single and double hypernuclei)
- Weak decays ($\Lambda \rightarrow \pi N$ suppressed, but $\Lambda N \rightarrow NN$ and $\Lambda\Lambda \rightarrow \Lambda$N allowed: four baryon weak interact)
- Hyperatoms
- Experimentally: in 50 years of study 35 single and 6 double hypernuclei established.

Hypernuclear Physics



- $\bar{p}p \rightarrow \Xi^-\bar{\Xi}^+$ and $\bar{p}n \rightarrow \Xi^-\bar{\Xi}^0$ followed by re-scattering of the Ξ^- within the primary target nucleus.
- After stopping the Ξ^- in an external secondary target, the formed Ξ hypernuclei will be converted into double Λ hypernuclei.

The simplest structure functions of the nucleon are form factors.

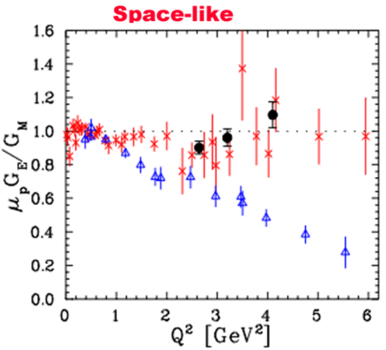


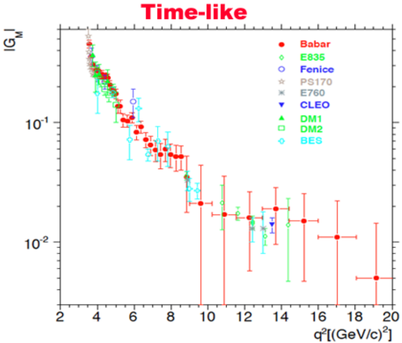
$$\frac{d\sigma}{d\Omega} = \frac{\alpha^2 \beta C}{4s}\left[|G_M(s)|^2 (1+\cos^2\theta^*) + \frac{4m_N^2}{s} |G_E(s)|^2 \sin^2\theta^* \right]$$

Most experiments could not determine $|G_M|$ and $|G_E|$ (the magnetic and electric form factors respectively) separately from the analysis of the angular distributions, but extracted $|G_M|$ using the arbitrary assumption $|G_E| = |G_M|$

Nucleon Form Factor

Existing results on the proton form factor



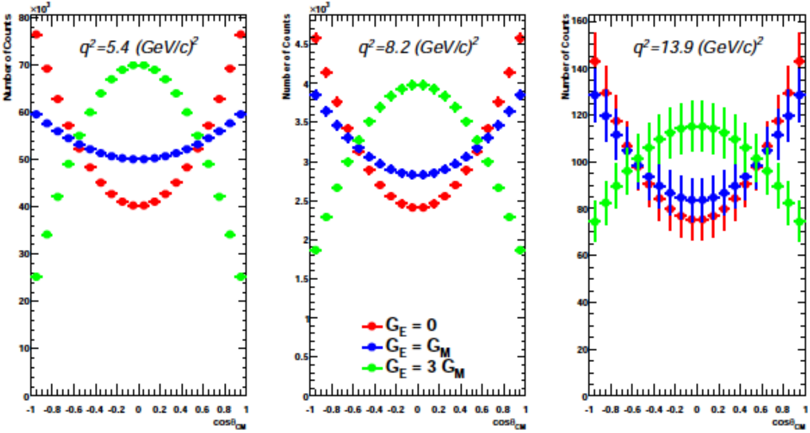


Older Rosenbluth separation data (crosses), most recent JLab Rosenbluth separation data (filled circles), and polarization transfer data (triangles).

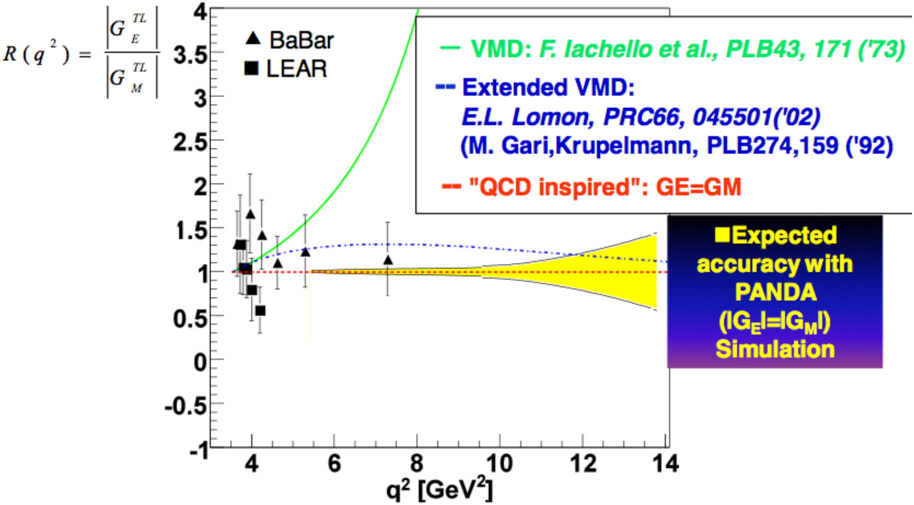
- $|G_E|$ and $|G_M|$ in the time like region can be determined by the reactions $\bar{p}p \rightarrow e^+e^-$
- Presently statistics is limited: no real separation $|G_E|/|G_M|$
- G_E in the time like region is today unknown
- Extraction of the ratio $R = |G_E|/|G_M|$

$\bar{p}p \longrightarrow e^+e^-$ angular distribution

- $\sim$ 120 days, $\mathcal{L}$=2$\times$10^{32} cm^{-2}s^{-1}, $\mathcal{L}_{int}$=2 fb^{-1}
- Statistical errors only
- $R = |G_E|/|G_M|$ will be determined with good precision for q^2 values less than 15 (GeV/c)^2

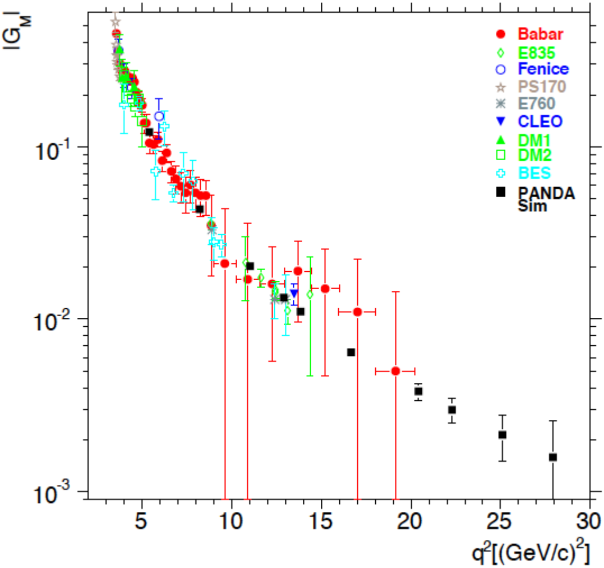


Time-like Form Factor of the proton



Measurement of the $R = |G_E|/|G_M|$ ratio at $\bar{P}$ANDA can be done with unprecedent precision compared to *BABAR* and LEAR.

Time-like Magnetic Form Factor of the proton



$\bar{\mathrm{P}}$ANDA Collaboration

At present ∼500 physicists
from 57 institutions in 17 countries.

Summary and Outlook

The HESR at the GSI FAIR facility will deliver $\bar{p}$ beams of unprecedented quality with momenta up to 15 GeV/c ($\sqrt{s}$ ∼5.5 GeV). This allow $\bar{P}$ANDA to carry out the following measurements:

- QCD bound states: charmonium, exotic excitations, heavy-light systems, strange and charmed baryons
- Non perturbative QCD dynamics
- Hadrons in the nuclear medium
- Hypernuclear physics
- Nucleon structure: generalized distribution amplitudes, Drell-Yan, electromagnetic form factors.
- Electroweak physics

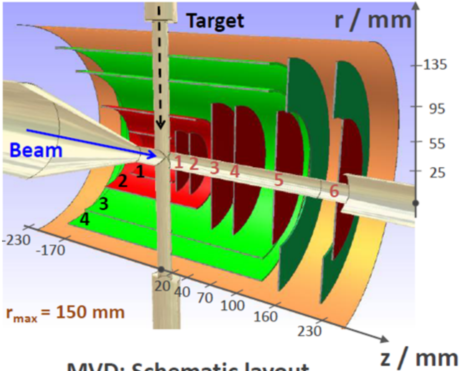
The performance of the detector and the sensitivity to the various physics channels have been estimated reliably by means of detailed Monte Carlo simulations: acceptance, resolution, signal/background

The simulations show that the final states of interest can be detected with good efficiency and that the background situation is under control.

THANKS FOR YOUR ATTENTION

BACKUP SLIDES

The Micro-Vertex Detector



MVD: Schematic layout

Layout

- 6 Forward Disks
- 4 Barrels

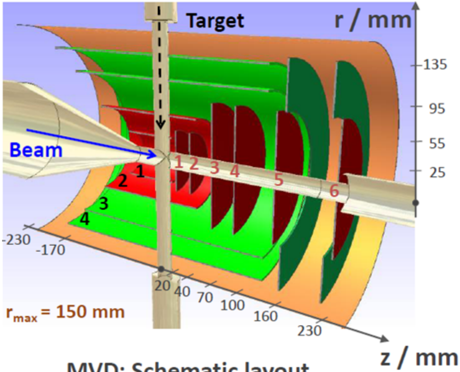
Geometrical Constraint

- Maximum Radius: 15 cm
- Dimension along z: $\pm$ 23 cm

Readout Channels

- $\sim 10^7$ Hybrid Pixels
- $\sim 2 \cdot 10^5$ Double-Side Microstrips

The Micro-Vertex Detector



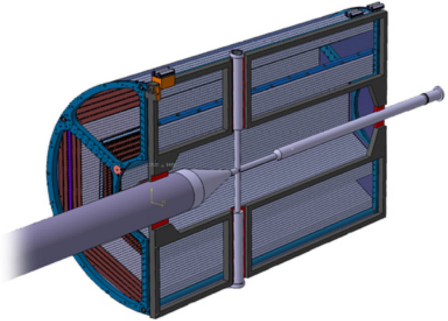
MVD: Schematic layout

Requirements

- Spatial resolution $< 100\ \mu$m
- Momentum resolution $\delta p/p \sim 2\%$
- Time resolution ≤ 10 *ns*
- High rate capability
- No hardware trigger
- Radiation tolerance $\sim 10^{14}\ n_{1\text{MeV eq}}\text{cm}^{-2}$
- Low material budget
- PID by dE/dx

The Straw Tube Tracker

STT Internal radius	15 cm
STT External radius	42 cm
Number of double layers	12
Skew angle double layer 5	$+3^{o}$
Skew angle double layer 6	-3^{o}
Tube wall thickness	30 µm
Tube internal diameter	10 mm
Axial tube length	150 cm
Wire diameter	20 µm
Tube wall material	Al-Mylar
Wire material	Au plated W/Re
Gas mixture	Ar/CO_2 (90/10)
Single tube transparency	$3.7 \times 10^{-4}\ X/X_0$
ρ/φ plane resolution	150µm
z resolution	1 mm



The EMC

	Required performance value		
Common properties			
energy resolution σ_E/E	$\leq 1\,\% \oplus \frac{\leq 2\,\%}{\sqrt{E/\mathrm{GeV}}}$		
energy threshold (photons) E_{thres}	10 MeV (20 MeV tolerable)		
energy threshold (single crystal) E_{xtl}	3 MeV		
rms noise (energy equiv.) $\sigma_{E,noise}$	1 MeV		
angular coverage $\%\,4\pi$	99 %		
mean-time-between-failures t_{mtbf} (for individual channel)	2000 y		
Subdetector specific properties	backward ($\geq 140°$)	barrel ($\geq 22°$)	forward ($\geq 5°$)
energy range from E_{thres} to	0.7 GeV	7.3 GeV	14.6 GeV
angular equivalent of crystal size θ	4°		1°
spatial resolution σ_θ	0.5°	0.3°	0.1°
maximum signal load f_γ ($E_\gamma > E_{xtl}$)	60 kHz		500 kHz
($p\bar{p}$-events) maximum signal load f_γ ($E_\gamma > E_{xtl}$)	100 kHz		500 kHz
(all events) shaping time t_s	400 ns		100 ns
radiation hardness (maximum annual dose $p\bar{p}$-events)	0.15 Gy	7 Gy	125 Gy
radiation hardness (maximum annual dose from all events)	10 Gy		125 Gy

Table 1.1: Main requirements for the $\overline{\text{P}}$ANDA EMC. Rates and doses are based on a luminosity of $L = 2 \cdot 10^{32} cm^{-1} s^{-1}$.