Hirschegg, January 17th, 2011

PANDA at FAIR : physics goals and experimental overview

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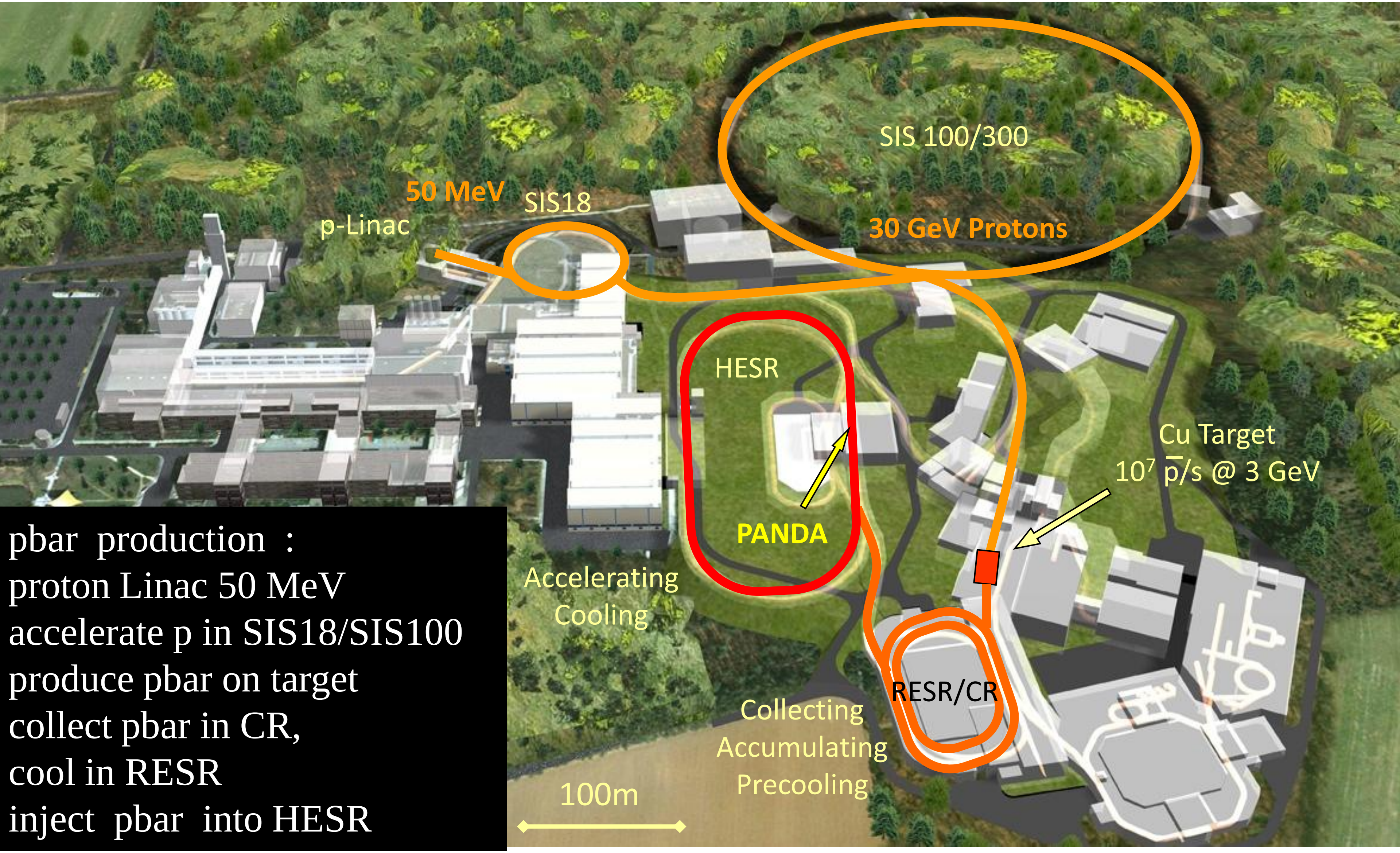
antiProton ANnihilation at DArmstadt

Experiment performed at FAIR facility, at GSI, in Darmstadt, Germany

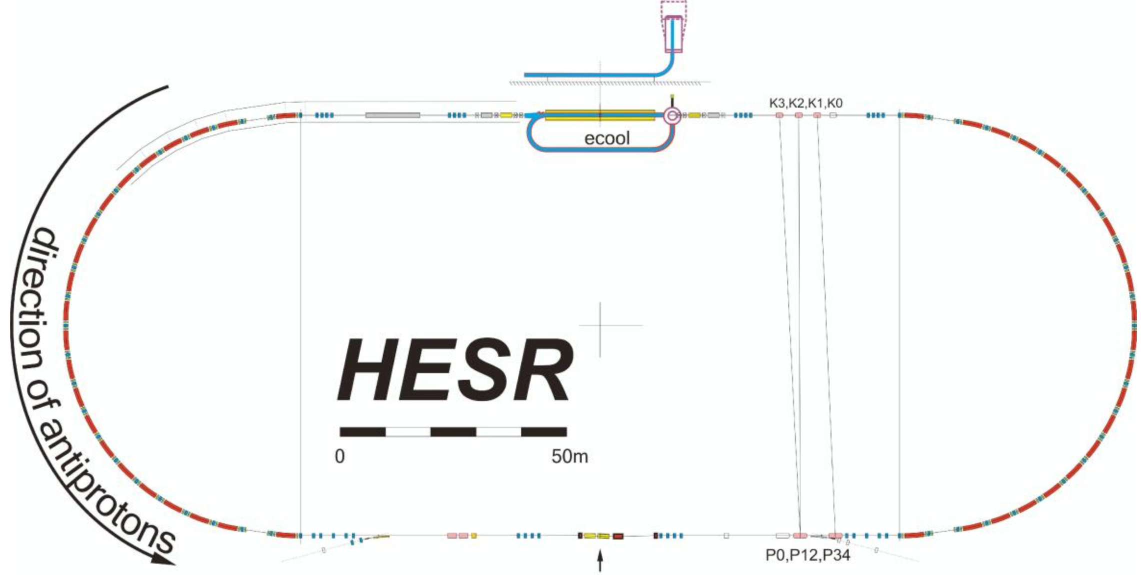
A very high intensity $\bar{p}$ beam with momentum from 1.5 GeV/c up to 15 GeV/c on a proton fixed target (or nuclear target)
average interaction rate 20 MHz

$\sqrt{s}$ from 2.25 up to 5.46 GeV

It will continue and extend the successful physics program performed in the past at facilities like LEAR at Cern and the antiproton accumulator ring at Fermilab



pbar production :
proton Linac 50 MeV
accelerate p in SIS18/SIS100
produce pbar on target
collect pbar in CR,
cool in RESR
inject pbar into HESR



Effective target thickness (pellets): 4×10^{15} cm^{-2} **Beam radius at target (rms): 0.3 mm**		
	High Resolution Mode	High Luminosity Mode
Momentum range	1.5 – 8.9 GeV/c	1.5 – 15 GeV/c
# antiprotons	10^{10}	10^{11}
Peak luminosity	2×10^{31} cm^{-2}s^{-1}	**2×10^{32} cm^{-2}s^{-1}**
Momentum spread (rms)	**$\Delta p/p \sim 3\times10^{-5}$**	$\Delta p/p \sim 1\times10^{-4}$
Beam cooler	Electron ≤ 8.9 GeV/c	Stochastic ≥ 3.8 GeV/c

PHYSICS GOALS

- QCD bound states :
  - Charmonium ;
  - Open charm ;
  - Exotic states (hybrids,glueballs,oddballs,multiquark,molecules) ;
  - Strange and charm baryons : spectroscopy of excited states ;
- Non–perturbative QCD dynamics :
  - $p\bar{p}$ production cross sections of charm and strange baryons and their spin correlations ;
- Hadrons in nuclear medium
- Hypernuclear Physics
- Form factors and electromagnetic processes
- Electroweak physics :
  - CP-violation in charm mesons, charm baryons, hyperons
  - charm rare and forbidden decays

QCD bound states

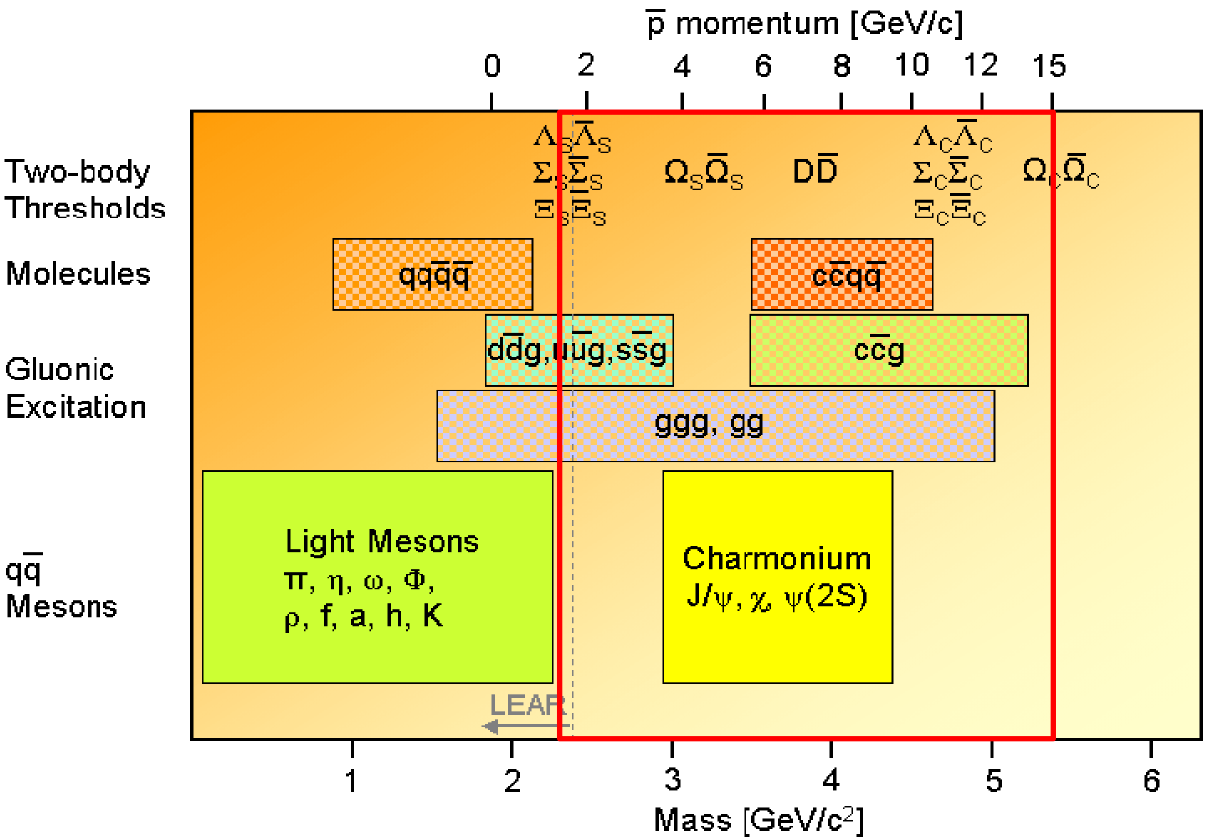
Possible investigation of states in the mass range 2.25 – 5.47 GeV

$p\bar{p}$ experiments can access IN FORMATION all J^{PC} states, not just 1^{--} like in $e^+e^- \rightarrow$ possibility of measuring mass and width of states very precisely with energy scan and thanks to $\delta p/p \sim 10^{-5}$ of the PANDA beam (energy resolution : 50 KeV)

Very high luminosity $\rightarrow$ relatively high statistics in rare decay channels

QCD bound states

Possible investigation of states in the mass range 2.25 – 5.47 GeV



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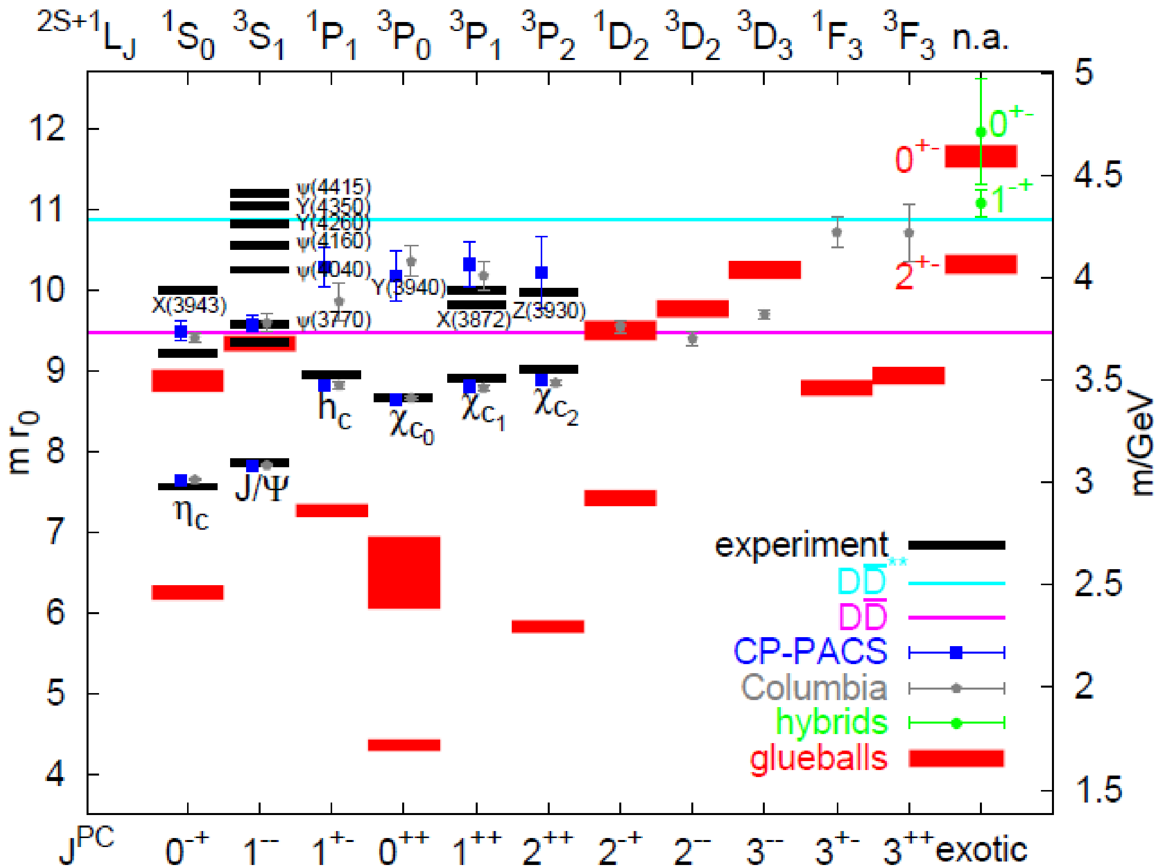
QCD bound states

Charmonium-like states below $D\bar{D}$ threshold



G. S. Bali, Int.J.Mod.Phys. A21 (2006) 5610-5617

States well established but width and mass of some of them (η_c , $\eta_c(2S)$, h_c) still have large errors. More precise measurements are needed to better compare with theory.

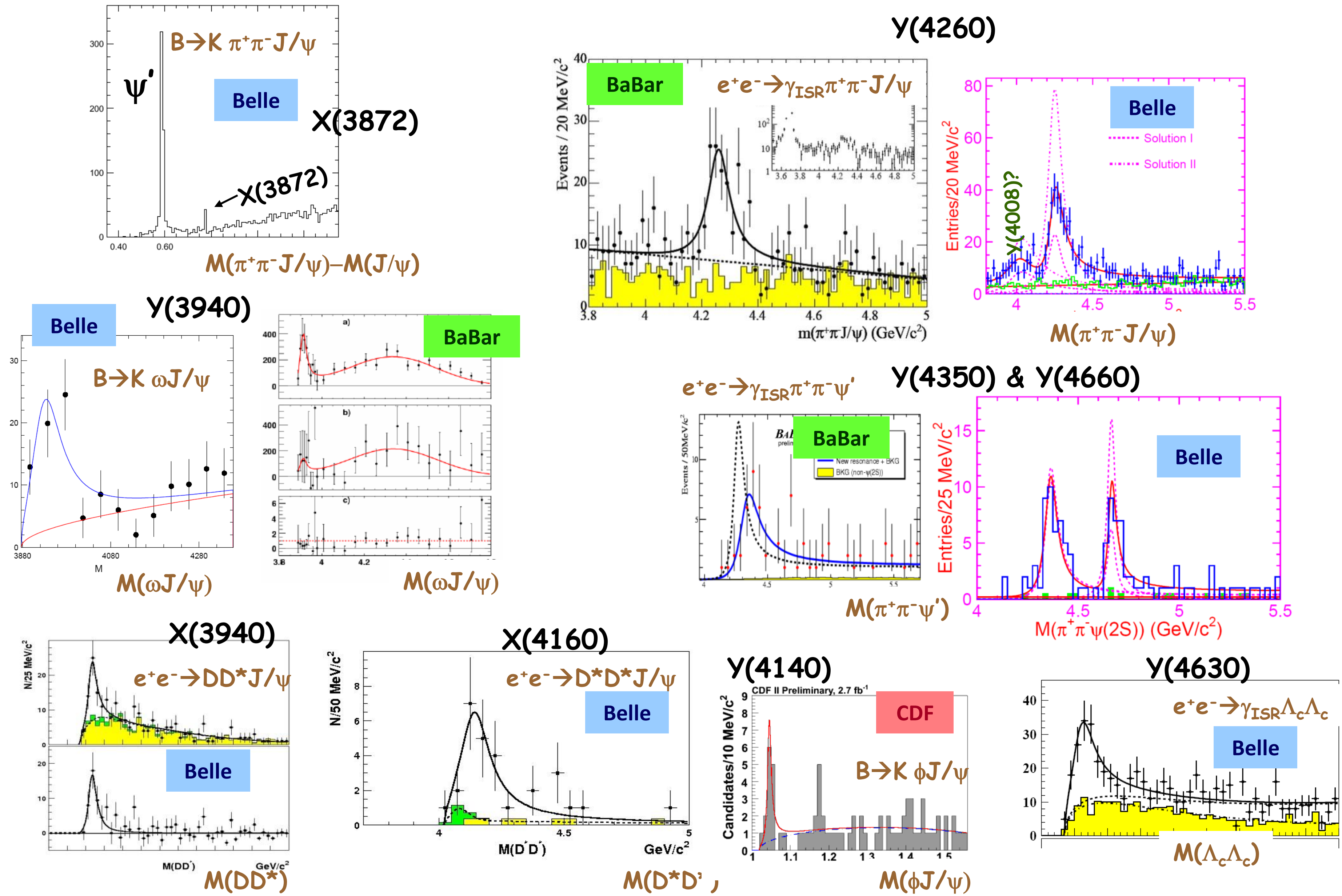
Charmonium-like states above $D\bar{D}$ threshold

state	decay	J^{PC}
X(3872)	$J/\psi\ \pi^+ \pi^-$	1^{++} or 2^{-+}
X(3940)	$J/\psi\ X$	?
X(3945) [or Y(3940)]	$J/\psi\ \omega$	$?^{?+}$
$X(4050)^{\pm}$	$\chi_{c1}\ \pi^+$	?
X(4140)	$J/\psi\ \phi$	$?^{?+}$
X(4160)	$J/\psi\ X$	?
$X(4250)^+$	$\chi_{c1}\ \pi^+$	?
X(4260) [or Y(4260)]	$J/\psi\ \pi^+ \pi^-$	1^{--}
X(4350)	$J/\psi\ \phi$	$?^{?+}$
X(4360) [or Y(4360)]	$\psi(2S)\ \pi^+ \pi^-$	1^{--}
$X(4430)^+$ [or Z(4430)]	$\psi(2S)\ \pi^+$	?
X(4660)	$\psi(2S)\ \pi^+ \pi^-$	1^{--}

cannot be ccbar!!

Besides the ψ excited states, since the discovery of the X(3872) in 2003 a large number of charmonium-like states have been observed, not predicted by potential model. Their quantum numbers mostly unknown, their interpretation still debated

Charmonium-like states above $D\bar{D}$ threshold

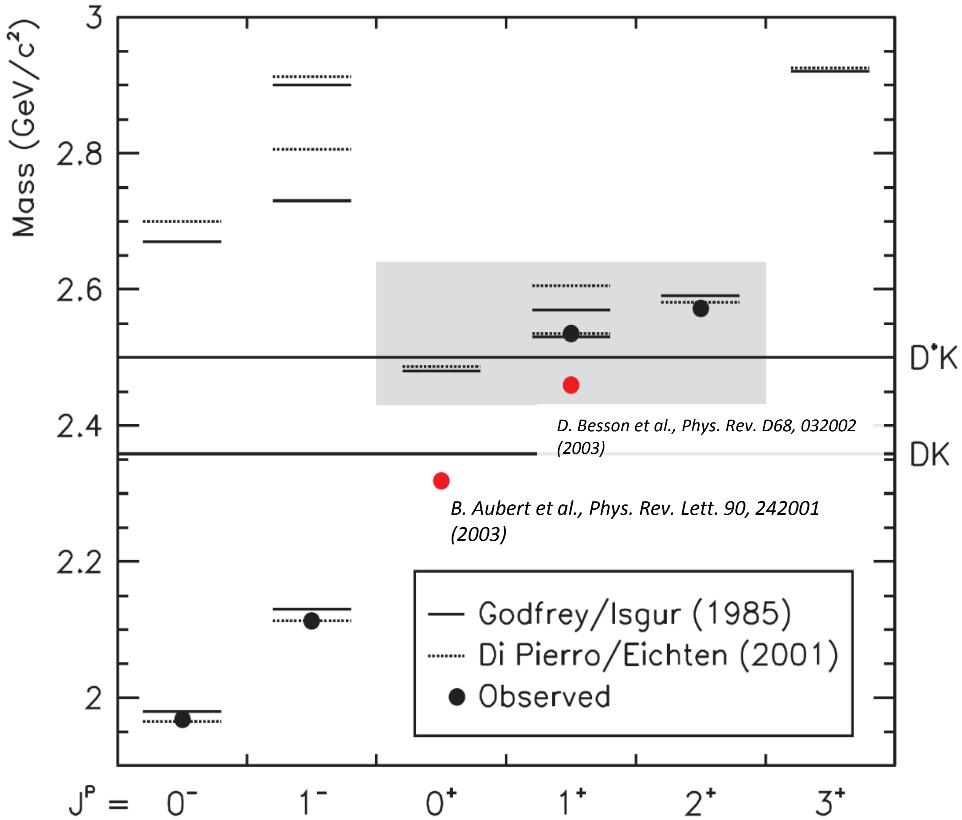


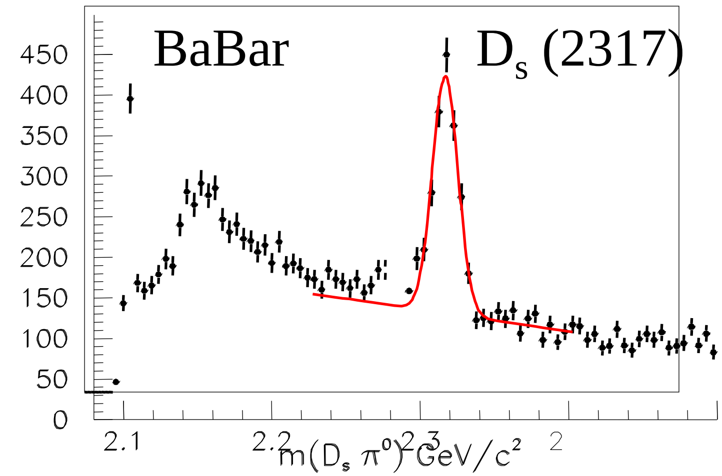
QCD bound states : open charm states

$D_s(2317) \rightarrow D_s \pi^0$ $\Gamma < 3.8$ MeV , $J^P = 0^+$

$D_s(2460) \rightarrow D^*_s(2112) \pi^0$ $\Gamma < 3.5$ MeV , $J^P = 1^+$

not predicted by the quark model





width of these states important to discriminate among different models

QCD bound states : open charm states

$D_s(2317) \rightarrow D_s \pi^0$ $\Gamma < 3.8$ MeV

$D_s(2460) \rightarrow D^*_s(2112) \pi^0$ $\Gamma < 3.5$ MeV

It is possible to measure the width of these states in reactions like

$p\bar{p} \rightarrow D_s(2317)\ \bar{D}_s$

↳ inclusive (missing mass)
or exclusive in $D_s \pi^0$

exploit very good beam momentum for excitation function measurement near threshold and width extraction.
Resolution possible down to 100 KeV

QCD bound states : exotic states

States not $q\bar{q}$ nor qqq.
Meson states with J^{PC} = 0^{--} , 0^{+-} , 1^{-+} , 2^{+-} , 3^{-+} etc. are certainly exotic. Various possibilities of investigation of exotics in $\bar{p}$anda hybrids, glueballs, multiquarks, molecules.

Hybrids : $q\bar{q}g$ states

non-charm hybrids candidates : π_1 , h_2

Experiment	Exotic	J^{PC}	Mass $[MeV/c^2]$		Width $[MeV/c^2]$		Decay
E852	$\pi_1(1400)$	1^{-+}	1359	$^{+16}_{-14}$ $^{+10}_{-24}$	314	$^{+31}_{-29}$ $^{+9}_{-66}$	$\eta\pi$
Crystal Barrel	$\pi_1(1400)$	1^{-+}	1400	$\pm20\pm20$	310	±50 $^{+50}_{-30}$	$\eta\pi$
Crystal Barrel	$\pi_1(1400)$	1^{-+}	1360	±25	220	±90	$\eta\pi$
Obelix	$\pi_1(1400)$	1^{-+}	1384	±28	378	±58	$\rho\pi$
E852	$\pi_1(1600)$	1^{-+}	1593	±8 $^{+29}_{-47}$	168	±20 $^{+150}_{-12}$	$\rho\pi$
E852	$\pi_1(1600)$	1^{-+}	1597	±10 $^{+45}_{-10}$	340	$\pm40\pm50$	$\eta'\pi$
Crystal Barrel	$\pi_1(1600)$	1^{-+}	1590	±50	280	±75	$b_1\pi$
Crystal Barrel	$\pi_1(1600)$	1^{-+}	1555	±50	468	±80	$\eta'\pi$
E852	$\pi_1(1600)$	1^{-+}	1709	$\pm24\pm41$	403	$\pm80\pm115$	$f_1\pi$
E852	$\pi_1(1600)$	1^{-+}	1664	$\pm8\pm10$	185	$\pm25\pm28$	$\omega\pi\pi$
E852	$\pi_1(2000)$	1^{-+}	2001	$\pm30\pm92$	333	$\pm52\pm49$	$f_1\pi$
E852	$\pi_1(2000)$	1^{-+}	2014	$\pm20\pm16$	230	$\pm32\pm73$	$\omega\pi\pi$
E852	$h_2(1950)$	2^{+-}	1954	±8	138	±3	$\omega\pi\pi$

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QCD bound states : exotic states , charm hybrids

Charm hybrids candidates in the range 3-5 GeV : likely to be narrow, since open charm decays are forbidden or suppressed below the $D\overline{D}^*_J$ threshold

(a)	m($c\bar{c}$g), 1^{-+}	Group
	4 390±80±200	MILC97
	4 317±150	MILC99
	4 287	JKM99
	4 369±37±99	ZSU02

(b)	m($c\bar{c}$g,1^{-+})- m($c\bar{c}$,1^{--})	Group
	1 340±80±200	MILC97
	1 220±150	MILC99
	1 323±130	CP-PACS99
	1 190	JKM99
	1 302±37±99	ZSU02

Charm Hybrid masses (a) and mass differencies (b)from quenched LQCD

Examples of channels that PANDA can investigate

$$p\bar{p} \rightarrow \tilde{\eta}_{c0,1,2}\eta \rightarrow \chi_{c1}\pi^0\pi^0\eta$$

$$p\bar{p} \rightarrow \tilde{h}_{c0,1,2}\eta \rightarrow J/\psi\pi^0\pi^0\eta$$

$$p\bar{p} \rightarrow \tilde{\psi}\eta \rightarrow J/\psi\omega[\pi^0 \text{ or } \eta]$$

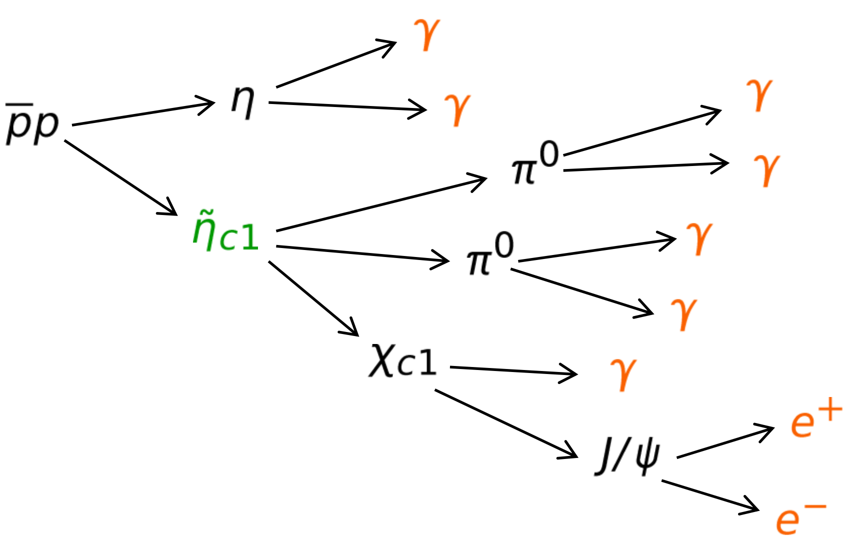
$$p\bar{p} \rightarrow [\tilde{\eta}_{c0,1,2}, \tilde{h}_{c0,1,2}, \tilde{\chi}_{c1}]\eta \rightarrow DD^\star\eta$$

QCD bound states : exotic states , charm hybrids

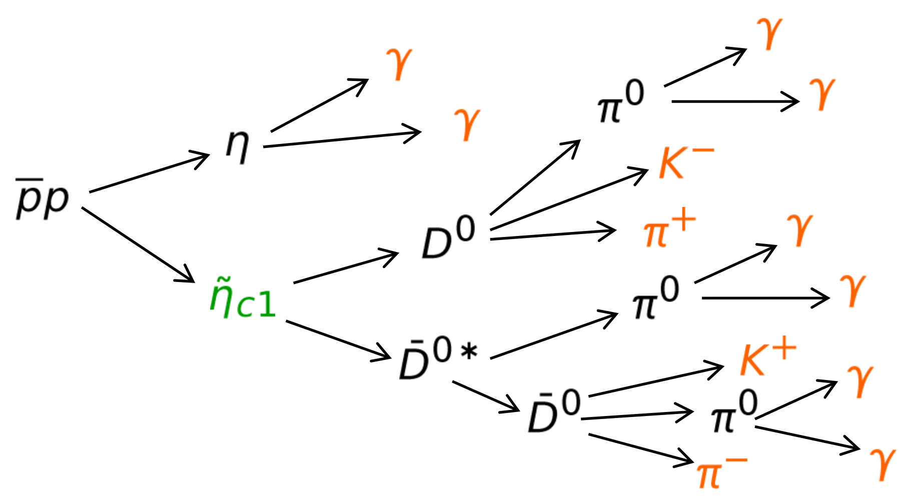
From LQCD calculations, $\tilde{\eta}_{c1}$ with m ~ 4.3GeV/c^2, $J^{PC} = 1^{-+}$

Reconstruction possible in PANDA in exclusive channels like

$\bar{p}p \rightarrow \tilde{\eta}_{c1}\eta \rightarrow \chi_{c1}\pi^0\pi^0\eta$

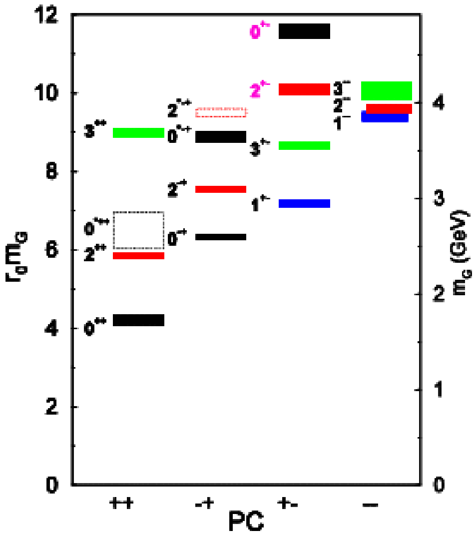


$\bar{p}p \rightarrow \tilde{\eta}_{c1}\eta \rightarrow D^0\bar{D}^{0*}\eta$



thanks to the good calorimeter (γ identification) and detector charged particle identification

QCD bound states : exotic states , glueballs



LQCD theoretical predictions

Decay channels

$\phi\phi$ and $\phi\eta$

preferred for glueball masses < 3.6 GeV

or

$J/\psi\ \eta$ and $J/\psi\ \phi$

for masses > 3.6 GeV

Oddballs should be narrower states (they don't mix with ordinary meson states) and therefore more easily detectable.

LEAR investigated glueball low mass region in $p\bar{p}$ collisions at rest, at Cern in the '90s. is a unique opportunity to study also higher mass states.

QCD bound states : exotic states , glueballs

Examples of possible decay channels in PANDA

Light glueballs , $f_2(2000 – 2500)$:

$p\bar{p} \rightarrow \phi\phi$

$p\bar{p} \rightarrow \phi\eta$

$p\bar{p} \rightarrow K^*\bar{K}^*$

$p\bar{p} \rightarrow \rho\rho$

Heavy oddballs, $b_{0,2}(4000–5000)$:

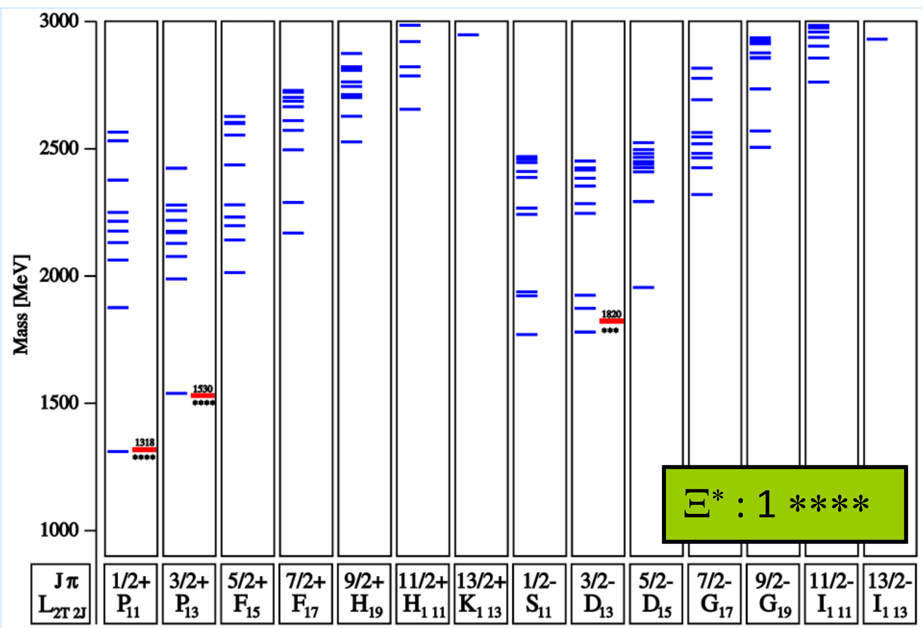
$p\bar{p} \rightarrow DD^* \eta$

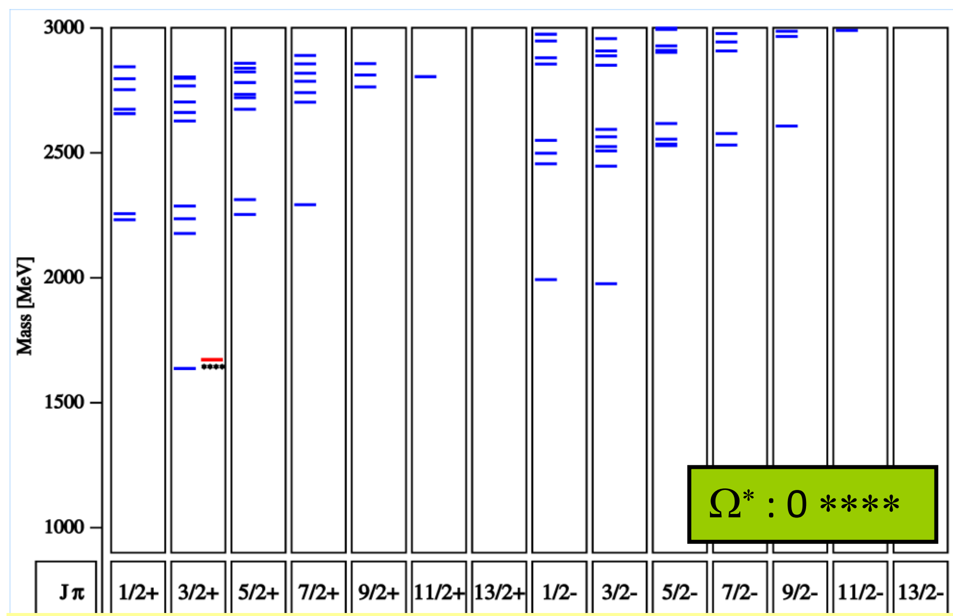
$p\bar{p} \rightarrow DD^* \pi^0$

QCD bound states : spectroscopy of excited states of strange and charm baryons

Little is known of excited states of Λ , Σ and even less of Ξ and Ω.
Do they follow the SU(3) predictions ?

Charm baryons, exotic baryons with hidden charm.



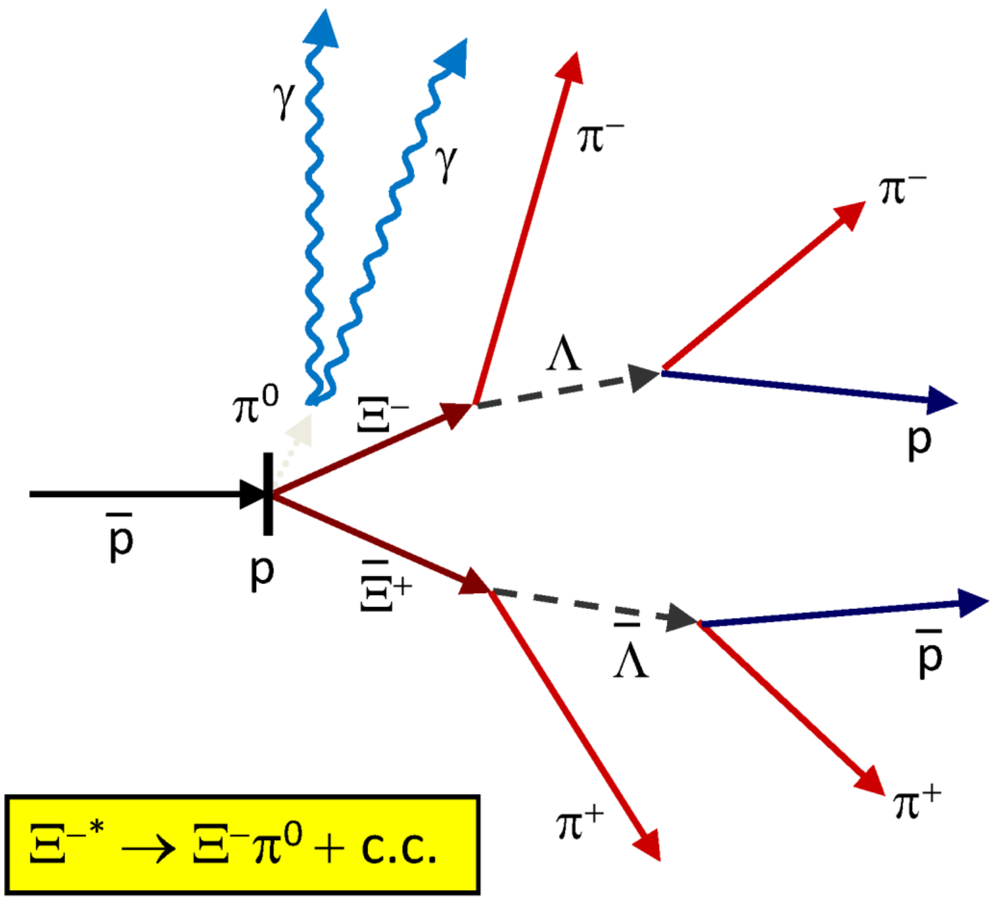


U. Löring, B.Ch. Metsch, H.R. Petry, Eur. Phys. J A 10 (2001) 447

In PANDA : $\bar{p}p \rightarrow \Lambda\bar{\Lambda}, \bar{\Lambda}\Sigma, \Lambda\bar{\Sigma}, \Sigma\bar{\Sigma}, \Xi\bar{\Xi}, \Omega\bar{\Omega}, \Lambda_c\bar{\Lambda}_c, \Xi_c\bar{\Xi}_c, \Omega_c\bar{\Omega}_c$

Characteristic event topology of $\Xi\Xi^*$ and $\Omega\Omega^*$ events.

~μb cross section for $\Xi\bar{\Xi}$ ~10^7 Ξ /day produced with full luminosity

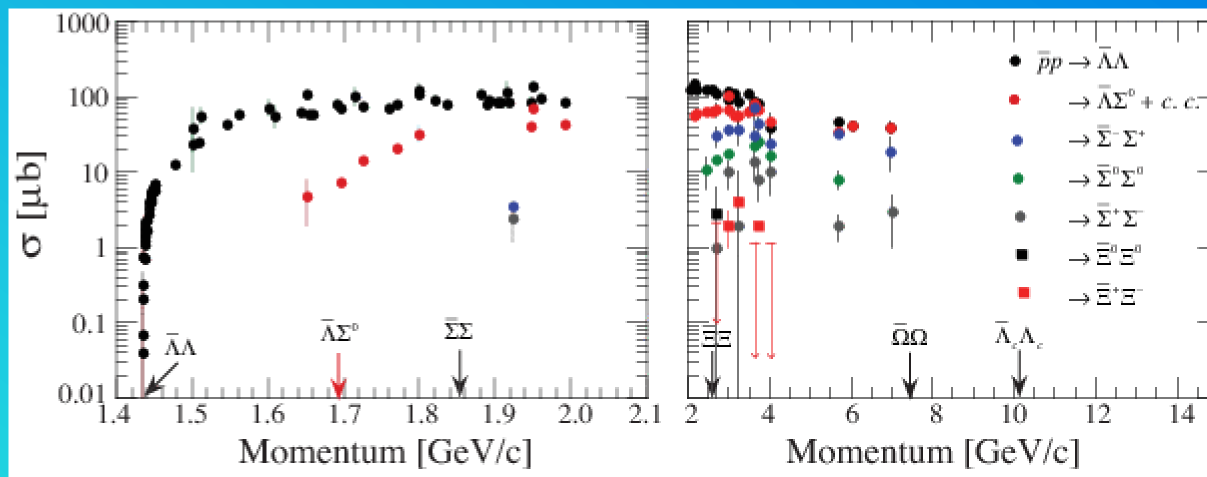


Non perturbative QCD dynamics in baryon sector

Essentially no data exist on production cross section of

$$p\bar{p} \rightarrow \text{(strange baryon) (strange antibaryon)}$$

above 2 GeV/c $\bar{p}$ momentum.



Energy region just transition between parton-parton scattering at high momentum transfer, and hadron-hadron degrees of freedom description used at lower energies.

PANDA can measure that with high statistics and also the production cross section of $p\bar{p} \rightarrow \Lambda_c \bar{\Lambda}_c$

Non perturbative QCD dynamics in baryon sector

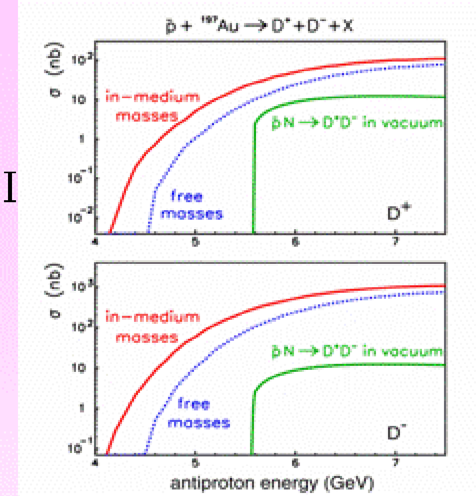
The self-analysing decay of hyperons (for instance : $\Lambda \rightarrow p\,\pi^-$) gives acces to the spin variables $\rightarrow$ possibility of studying the elicity correlations of the baryons in production.

Hadrons in nuclear medium

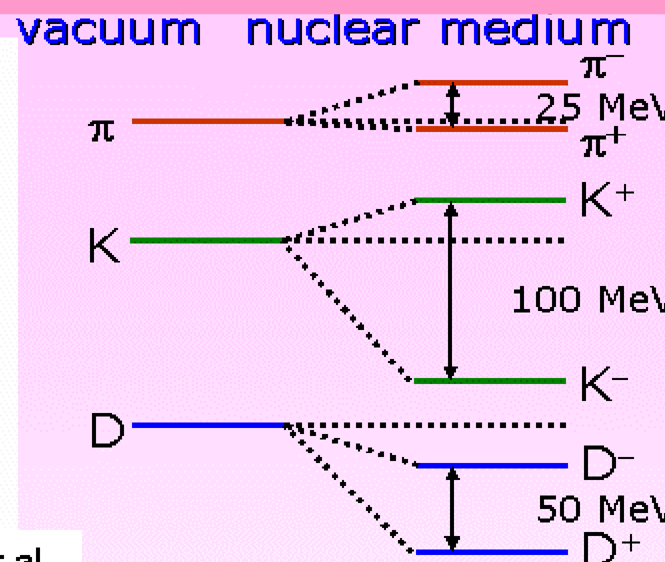
Mass shifts caused by potential in nuclear matter

ρ, ω, ϕ : substantial shifts predicted.
Experimental goal of HADES at GSI

cc mesons sensitive only to gluon condensate in nuclei due to heavy c mass → predicted only 5–10 MeV mass reduction for J/ψ and η_c but 40 MeV for χ_{cJ}, 100 MeV for ψ' and 140 MeV for $\psi(3770)$



Calculation: A. Sibirtsev et al., Eur. Phys. J A6 (1999) 351



Hayaski, PLB 487 (2000) 96
Morath, Lee, Weise, priv. Comm

D–Mesons: theoretical predictions on size of mass splitting depending on the model. Important to measure experimentally

high intensity $\bar{p}$ beam up to 15 GeV/c opens up the possibility of :

- study of nuclear bound states with slow K^- or $\bar{\Lambda}$ produced inside nuclei
- study of mass shifts of charmonium states, produced in nuclei and decaying into leptons or γ
- study of production yield of $D\bar{D}$ pairs produced below threshold in nuclei. Increase of cross section due to increased phase space
- dependence of all above on nucleus size
- study of the possible effect of the opening, in nuclei, of the $D\bar{D}$ decay channel to states normally below threshold like $\psi(3770)$, ψ', χ_{c2}

Hadrons in nuclear medium

	η_c	J/ψ	$\chi_{c\,0,1,2}$	$\psi(3686)$	$\psi(3770)$
Expected Mass shift	-5 MeV to -8 MeV	-7 MeV to -10 MeV	-40 MeV to -60 MeV	-100 MeV to -130 MeV	-120 MeV to -140 MeV
Observation through	$\gamma\,\gamma$	$e^+e^-/\mu^+\mu^-$	$J/\psi\ \gamma$	$e^+e^-/\mu^+\mu^-$	$e^+e^-/\mu^+\mu^-$

Predicted rates at $L = 10^{32}\ \text{cm}^{-2}\text{s}^{-1}$: few 10 … few 100 events/day

S.H. Lee, nucl-th/0310080

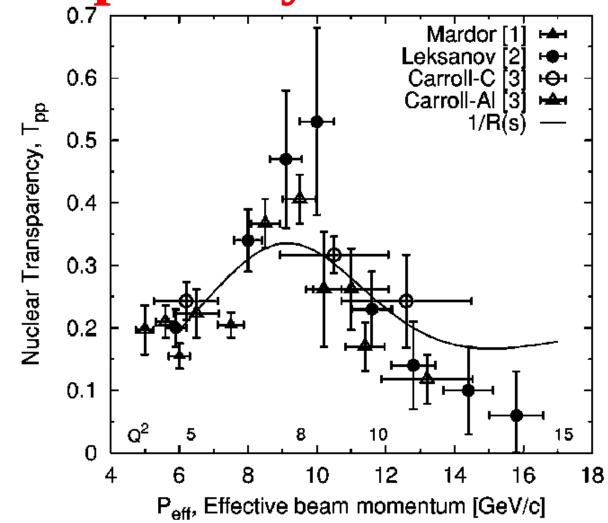
In $\bar{p}$anda possibility to study color transparency

Study of scattering at high energies and fixed large angles :

$\bar{p}N \rightarrow \pi\pi\ ,\ K\bar{K}\ ,\ \bar{p}N$

compared to

$\bar{p}A \rightarrow \pi\pi\ (A-1)^*\ ,\ K\bar{K}\ (A-1)^*\ ,\ \bar{p}N\ (A-1)^*$



Transparency ratio for pp scattering at large angles at BNL (2004)

Hypernuclear physics

In hypenuclei one (or more) Λ substitute one (or more) nucleon. A whole new set of states can exist containing an extra degree of freedom : strangeness.

The lighter single strangeness (Λ–hypernuclei) energy levels are predicted in the frame of the shell model, where the Λ particle is subject to an effective single particle potential. Heavier Λ–hypernuclei and $\Lambda\Lambda$–hypernuclei are described by more complicated models.

Experimental situation : ~35 Λ–hypernuclei established since 50 years ago
Only 6 $\Lambda\Lambda$–hypernuclei

- 1963: Danysz et al. ${}^{10}_{\Lambda\Lambda}Be$ (emulsion)
- 1966: Prowse ${}^{6}_{\Lambda\Lambda}He$ (emulsion, Dalitz criticises the interpretation)
- 1991: KEK-E176 ${}^{13}_{\Lambda\Lambda}B$ (or ${}^{10}_{\Lambda\Lambda}Be$, emulsion counter hybrid experiment)
- 2001: BNL-E906 ${}^{4}_{\Lambda\Lambda}H$
- 2001: KEK-E373 ${}^{6}_{\Lambda\Lambda}He$
- 2001: KEK-E373 ${}^{10}_{\Lambda\Lambda}Be$

$$\Xi^- + {}^{12}C \rightarrow {}^{6}_{\Lambda\Lambda}He + {}^{4}He + t$$

$$ {}^{6}_{\Lambda\Lambda}He \rightarrow {}^{5}_{\Lambda}He + p + \pi^-$$

Hypernuclear physics

produce $\Xi^-\ \bar{\Xi}$ at threshold in $p\bar{p} \rightarrow \Xi^-\bar{\Xi}$

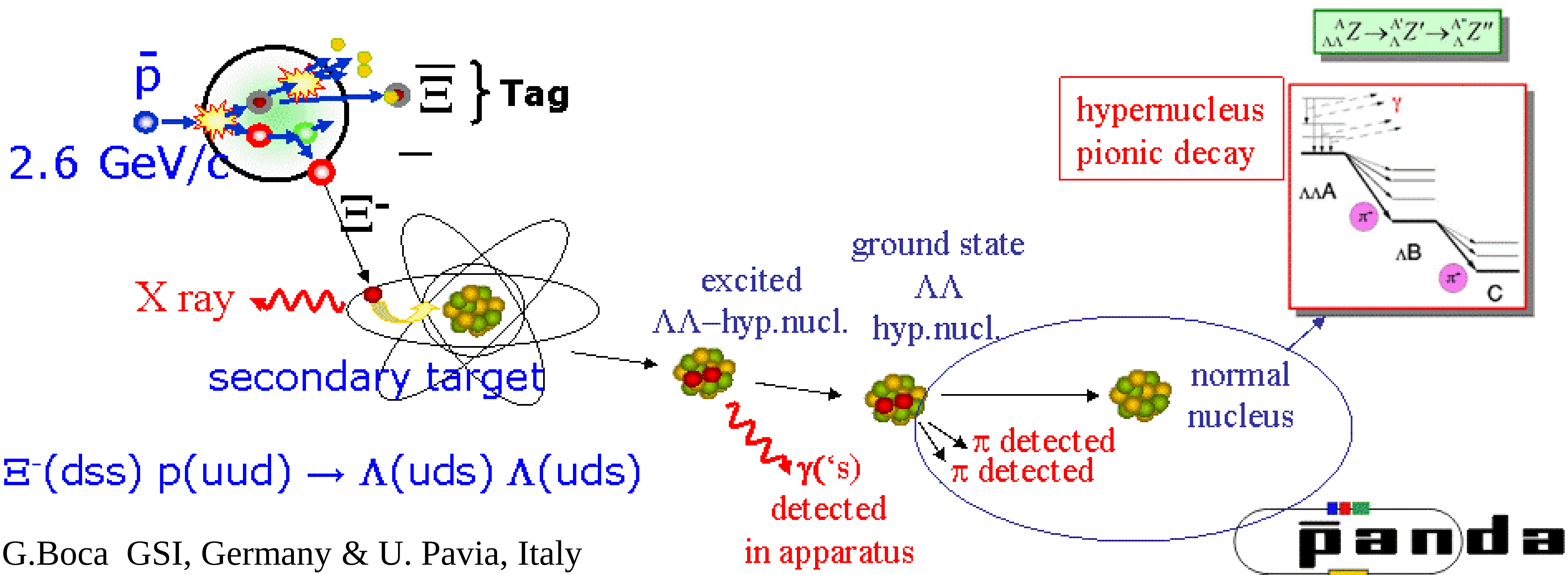
use a secondary target where Ξ^- is captured in a hyperatom and then interacts in nucleus

$\Xi^- + {}^{A}Z \rightarrow {}^{A+1}_{\Lambda\Lambda}(Z-1)^* \rightarrow {}^{A+1}_{\Lambda\Lambda}(Z-1) + \gamma$('s) detected in apparatus

$\rightarrow {}^{A+1}(Z+1) + \pi^-\pi^-$

detect γ with high resolution germanium detector in coincidence with tag.

${}^{A+1}_{\Lambda\Lambda}(Z-1)$ subequently decays via pionic cascade into normal nucleus.



Ξ^-(dss) p(uud) → Λ(uds) Λ(uds)

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Structure of the nucleon and form factors

Timelike proton form factors studied in $p\bar{p} \rightarrow e^+ e^-$, $\mu^+\mu^-$

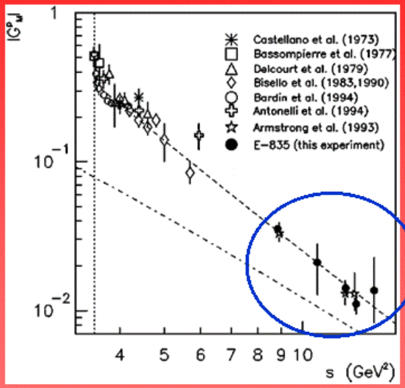
To first order QCD :

E, P ≡ energy, momentum antiproton in cms

$$\frac{d\sigma}{d\cos\theta^*} = \frac{\pi\alpha^2}{8EP}[|G_M|^2(1+\cos^2\theta^*) + \frac{4m_p^2}{s}|G_E|^2(1-\cos^2\theta^*)]$$

θ* ≡ scattering angle lepton in cms

Several measurements were made in the past at low Q^2 (up to ~ 15 GeV^2) :

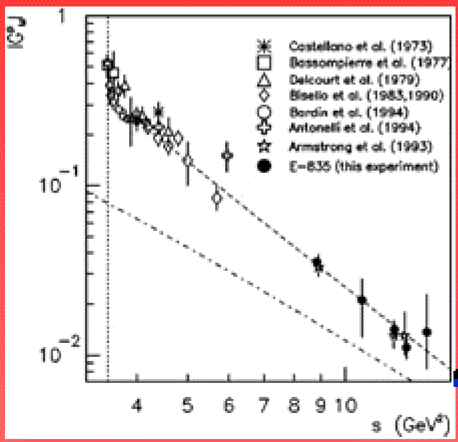


at high Q^2 only E760 and E835 up to Q^2~15 GeV^2 but due to low statistics measured only $|G_E|$ and $|G_M|$ under assumption $|G_E| = |G_M|$

Structure of the nucleon and form factors

in
PANDA :

possibility of measuring form factors
from threshold up to 29 GeV^2 !



29 GeV^2

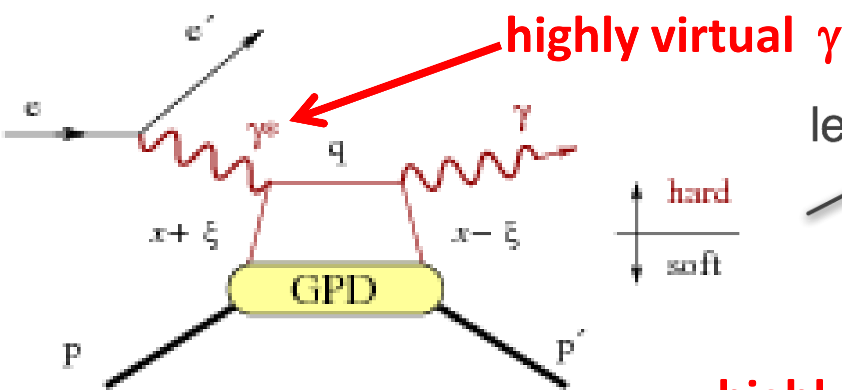
much wider angular acceptance and higher statistics

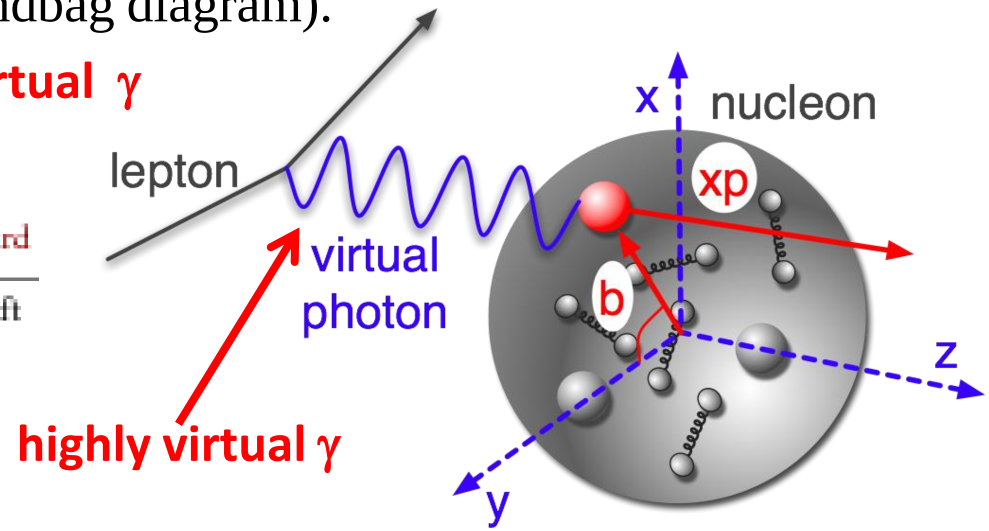
possibility of measuring $|G_E|$ and $|G_M|$ separately

Structure of the nucleon and form factors

GPDs, GDAs, TDAs

In recent years, the Generalized Parton Distributions theoretical framework has been developed on firm QCD basis and used in certain kinematical ranges (highly virtual photo exchange). In such case factorization of the soft part and hard part of the interaction can be performed (handbag diagram).



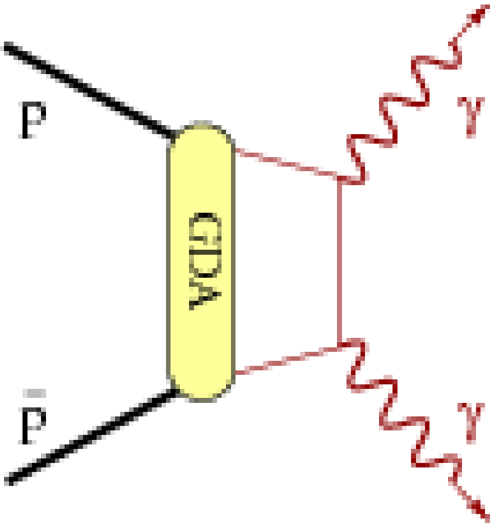


- Functions of 3 variables
    - parton momentum fraction x
    - skewedness ξ
    - 4-momentum transfer t
- 4 (chirality conserving) quark GPDs

GPDs used for instance in $p\, e^{\pm} \rightarrow p\, e^{\pm}$ scattering

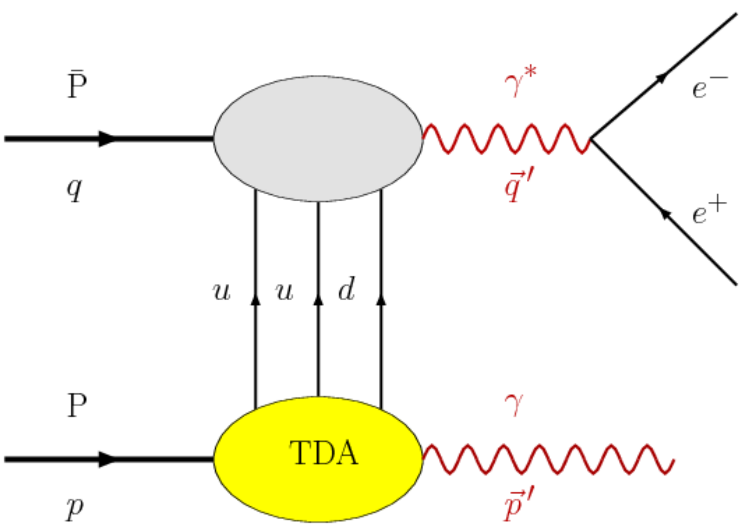
Structure of the nucleon and form factors

GPDs, GDAs, TDAs



For the cross channels like $p\bar{p} \rightarrow \gamma\gamma$, $\gamma\gamma^*$ the factorization ansatz seems still valid (not proven yet theoretically) but only at intermediate energies

Instead of GPDs, Generalized Distribution Amplitudes (GDAs) are used.



In a complementary theoretical approach Transition Distibution Amplitudes (TDAs) are used to describe the transition of a proton into a (virtual) photon.

Structure of the nucleon and form factors

In PANDA calculations based on the GDAs or TDAs framework can be used to compare the differential cross sections of

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

All channels are very challenging because of the low cross section

$\rightarrow$ very good γ detection required !

PANDA will achieve that with an excellent EM calorimetry.

Electroweak physics

CP violation measurement possible for hyperons and the Λ_c in the self-analysing non-leptonic decay (for instance : $\Lambda \to p\,\pi^-$)

$$dP/d\cos\theta = ½\,(1 + P\alpha\cos\theta)$$

where P is the polarization of the hyperon. If CP is conserved $\alpha_\Lambda = -\alpha_{\bar{\Lambda}}$

CP asimmetry parameter

$$\mathcal{A} = (\alpha_\Lambda + \alpha_{\bar{\Lambda}})/(\alpha_\Lambda - \alpha_{\bar{\Lambda}})$$

PDG 2010 : $\mathcal{A}_\Lambda = 0.012 \pm 0.021$

PANDA with 580 evt/s can improve this limit and can also measure asymmetry for $\Xi^0 \to \Lambda\pi^0$, $\Xi^- \to \Lambda\pi^-$, $\Lambda^+_c \to \Lambda\pi^+$

CP violation and mixing measurement in the charm sector in $p\bar{p} \to D\bar{D}$ possible with flavour tagging.

Charm rare decays and lepton flavour violation :

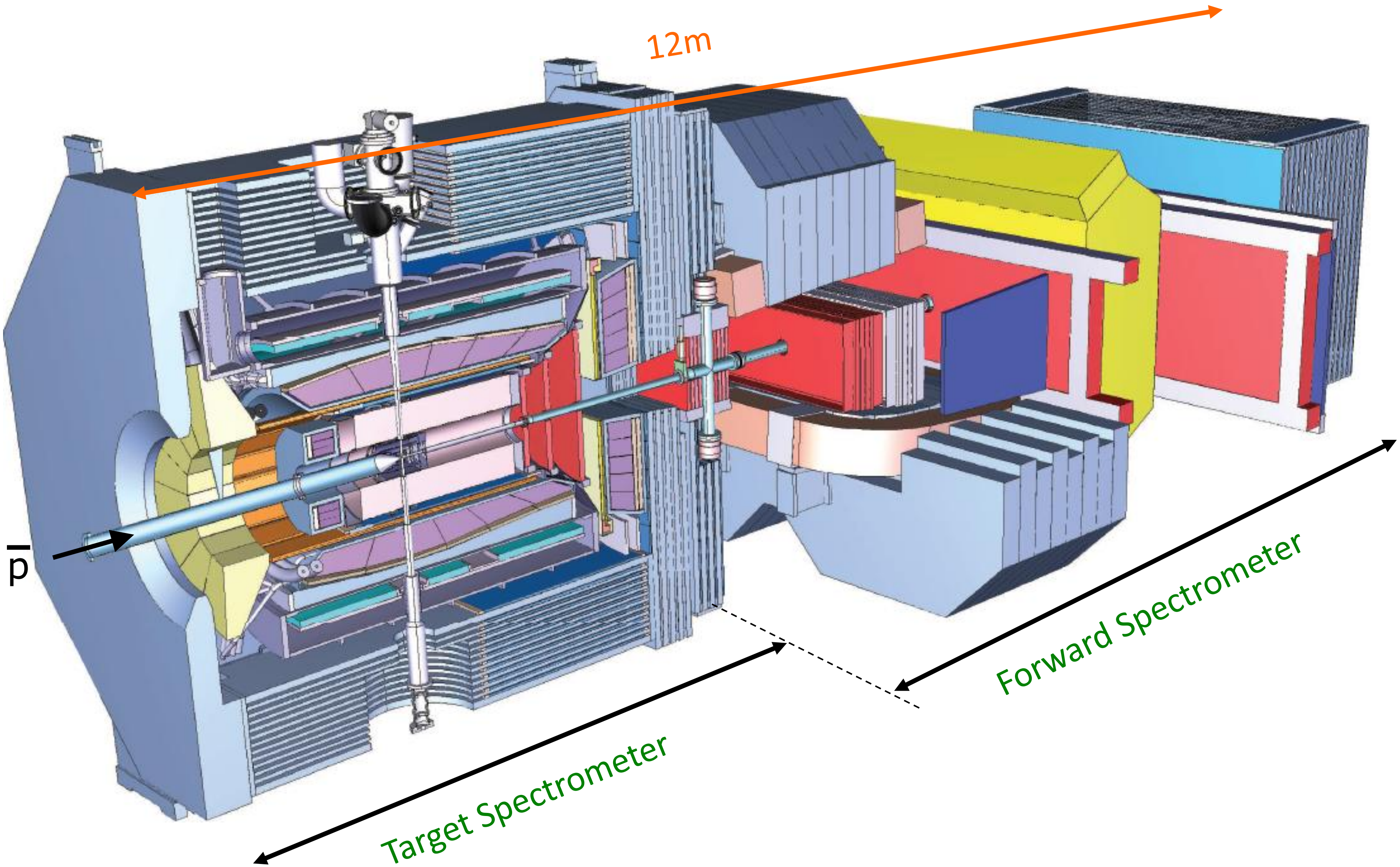
$D^0 \to \mu\, e$; $D^\pm \to \mu\, \pi\, e$ with flavour tagging.

The $\bar{p}$anda detector

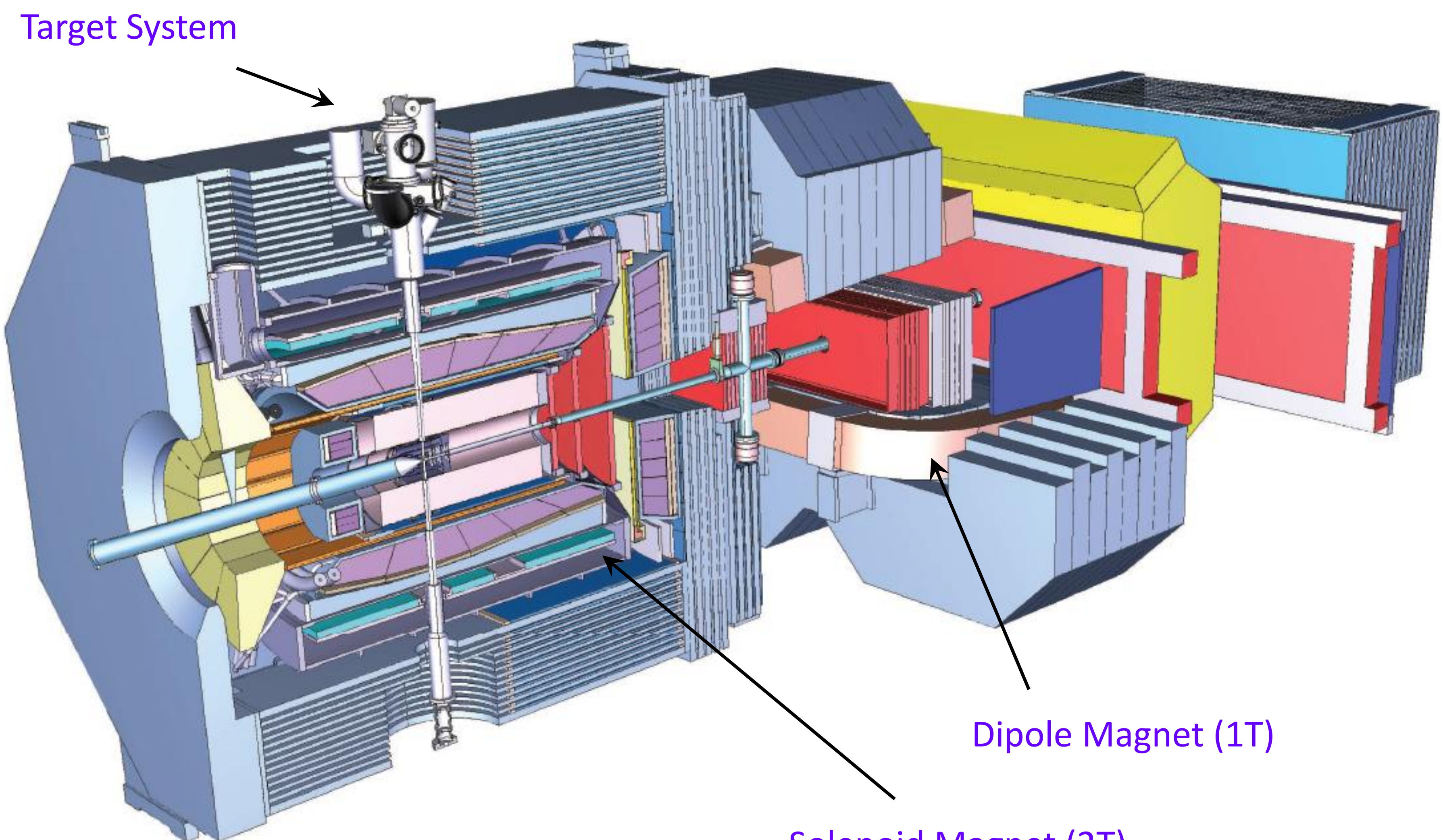
Detector requirements

1. 4π acceptance
2. high rate capability (average interaction rate 20 MHz)
3. excellent tracking capabilities, momentum resolution 1%
4. Vertexing capabilities for D, K_s , hyperons
5. good PID (e, μ, π, K, p) → *Čerenkov, ToF, dE/dx*
6. γ detection up to 10 GeV → *PWO crystal calorimeter*
7. flexible and modular design (for hypernuclear physics)
8. continuous data acquisition, intelligent software trigger

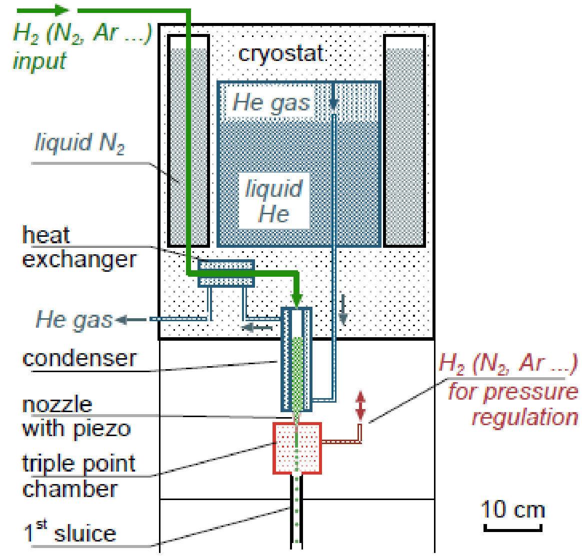
PANDA detector

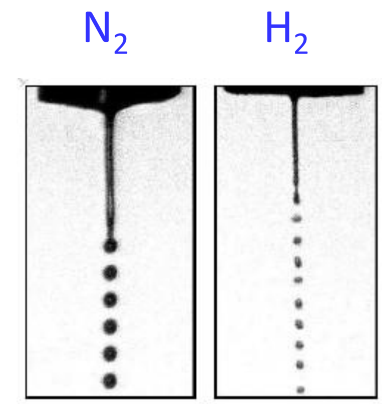


G.Boca GSI, Germany & U. Pavia, Italy


Target System
Dipole Magnet (1T)
Solenoid Magnet (2T)

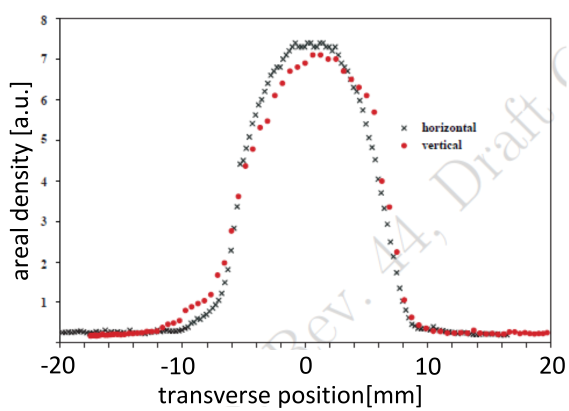
- **Requirements**
  - Proton Target
  - 5 x 10^{15} cm^{-2} for maximum luminosity



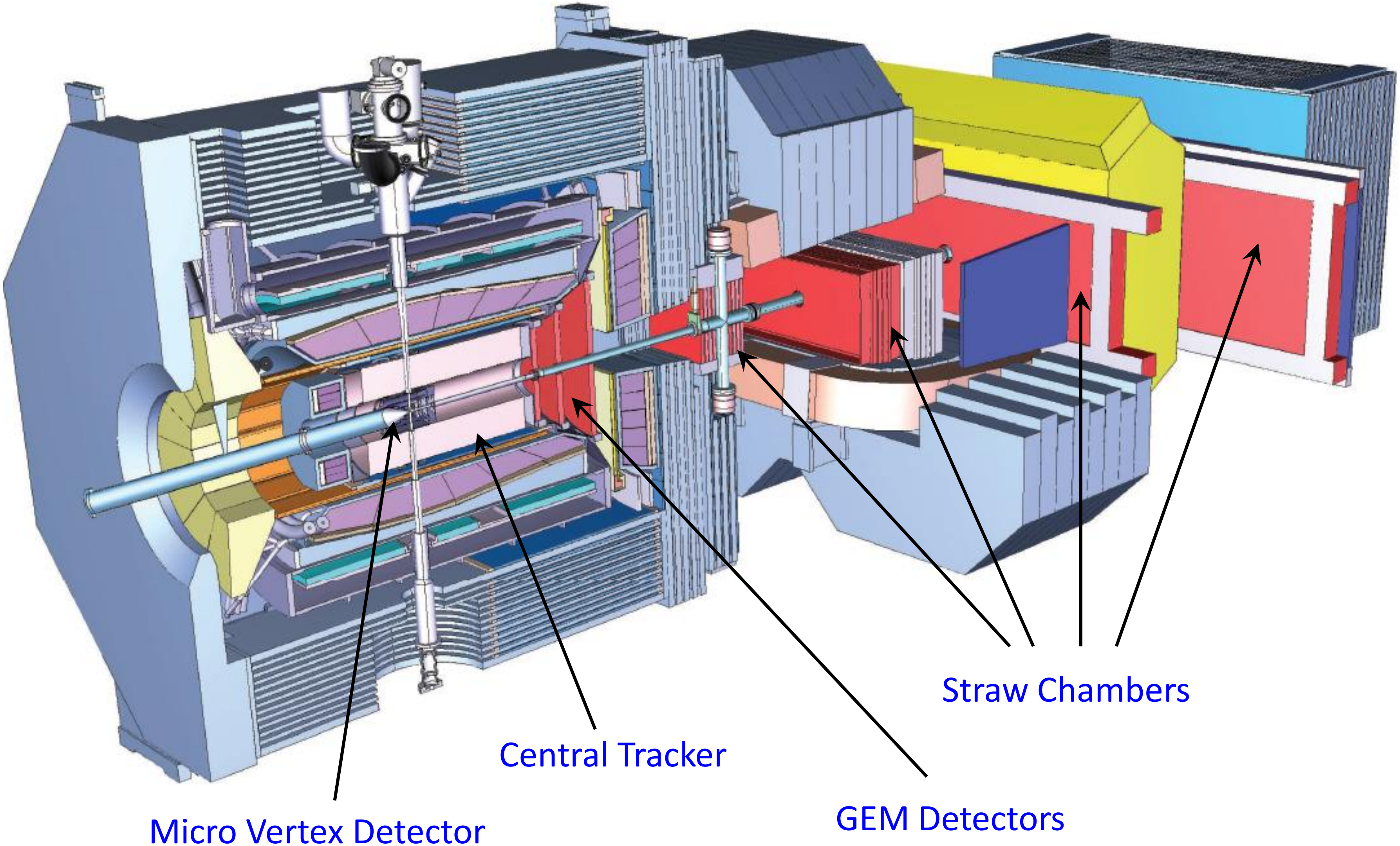


- **Pellet Target**
  - Frozen droplets ∅ 20μm
  - also possible: D_2, N_2, Ne, ...
  - Status: ρ ~ 5 x 10^{15}

- **Cluster Jet Target**
  - Dense gas jet
  - also D_2, N_2, Ne, ...
  - Status: ρ ~ 8 x 10^{14}



G.Boca GSI, Germany & U. Pavia, Italy

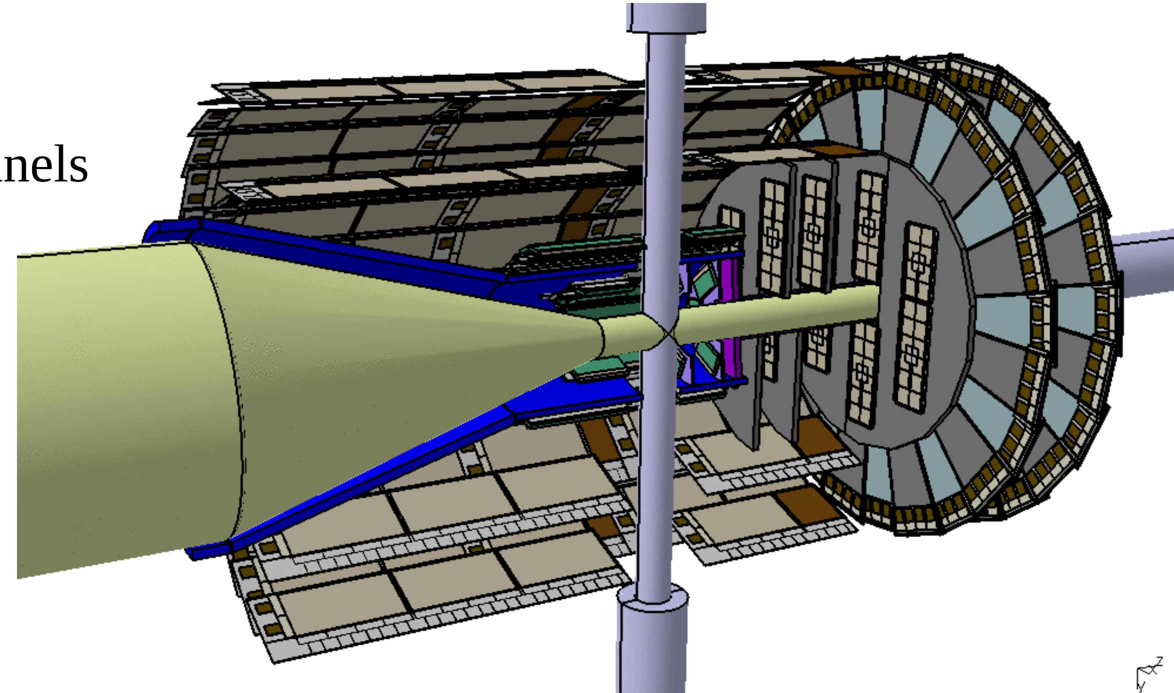

Straw Chambers
Central Tracker
GEM Detectors
Micro Vertex Detector

Micro Vertex Detector

- 4 barrels and 6 disks
- Inner layers:
  hybrid pixels (100x100 μm^2)
  - 140 module, 12M channels
- Outer layers:
  silicon strip detectors
  - double sided strips
  - 400 modules, 200k channels
- Mixed forward disks
- Continuous readout

Requirements

- $c\tau(D^{\pm}) \sim 312\ \mu m$
  $c\tau(D_s^{\pm}) \sim 147\ \mu m$
- Vertex resolution ~ 50 μm

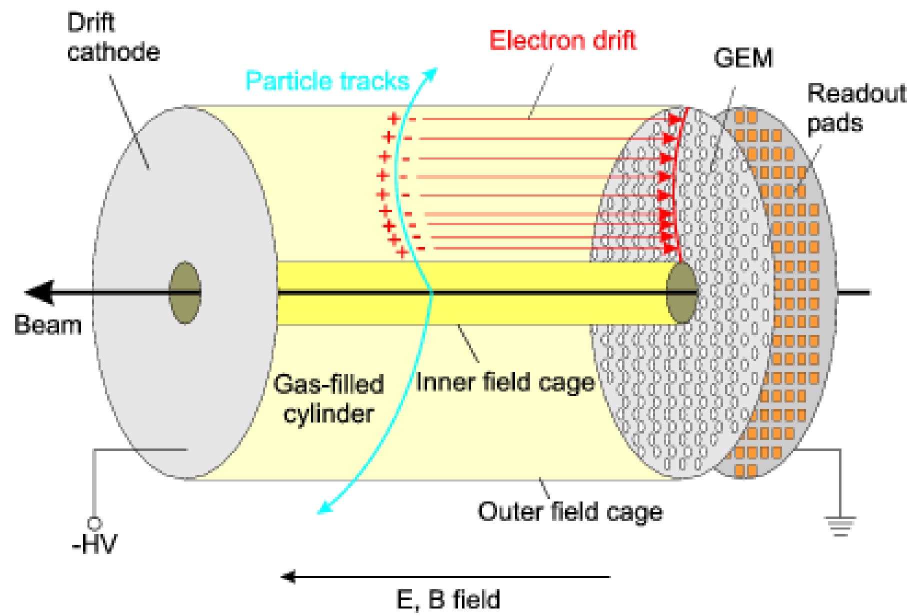


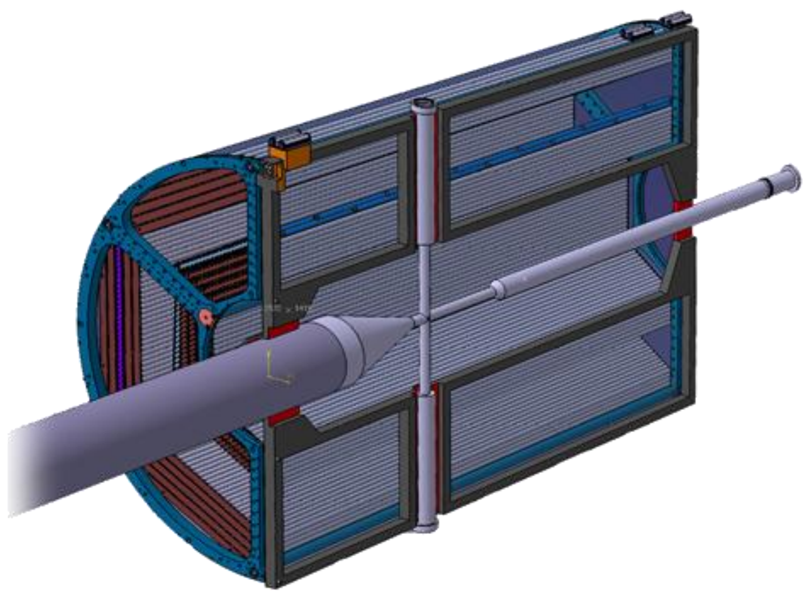
- Design figures:
  - $\sigma_{r\varphi} \sim 150\mu m$, $\sigma_z \sim 1mm$
  - $\delta p/p \sim 1\%$ (with MVD)
  - Material budget ~ 1% X_0

2 Alternatives:

- **Time Projection Chamber**
  - Continuous sampling
    GEMs readout plane
    (Ion feedback suppression)
    Online tracklet finding

- **Straw Tube Tracker**
  - about 4000 straws
  - 27 µm thin mylar tubes, 1 cm Ø
  - Stability by 1 bar overpressure





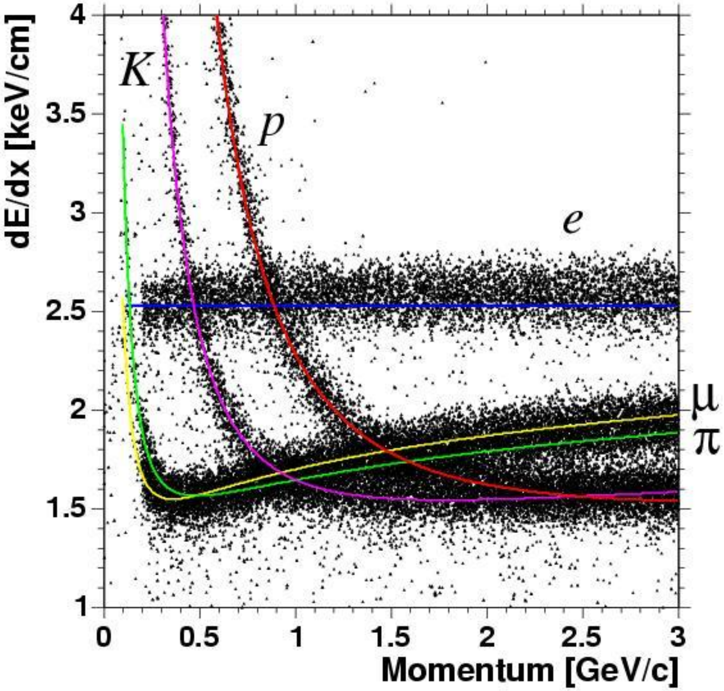
PANDA PID Requirements

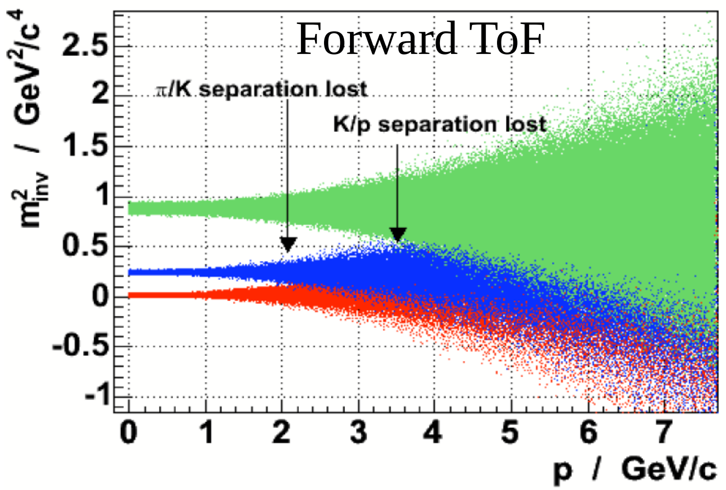
- Particle identification essential tool
- Momentum range 200 MeV/c – 10 GeV/c
- Different processes for PID needed

PID Processes

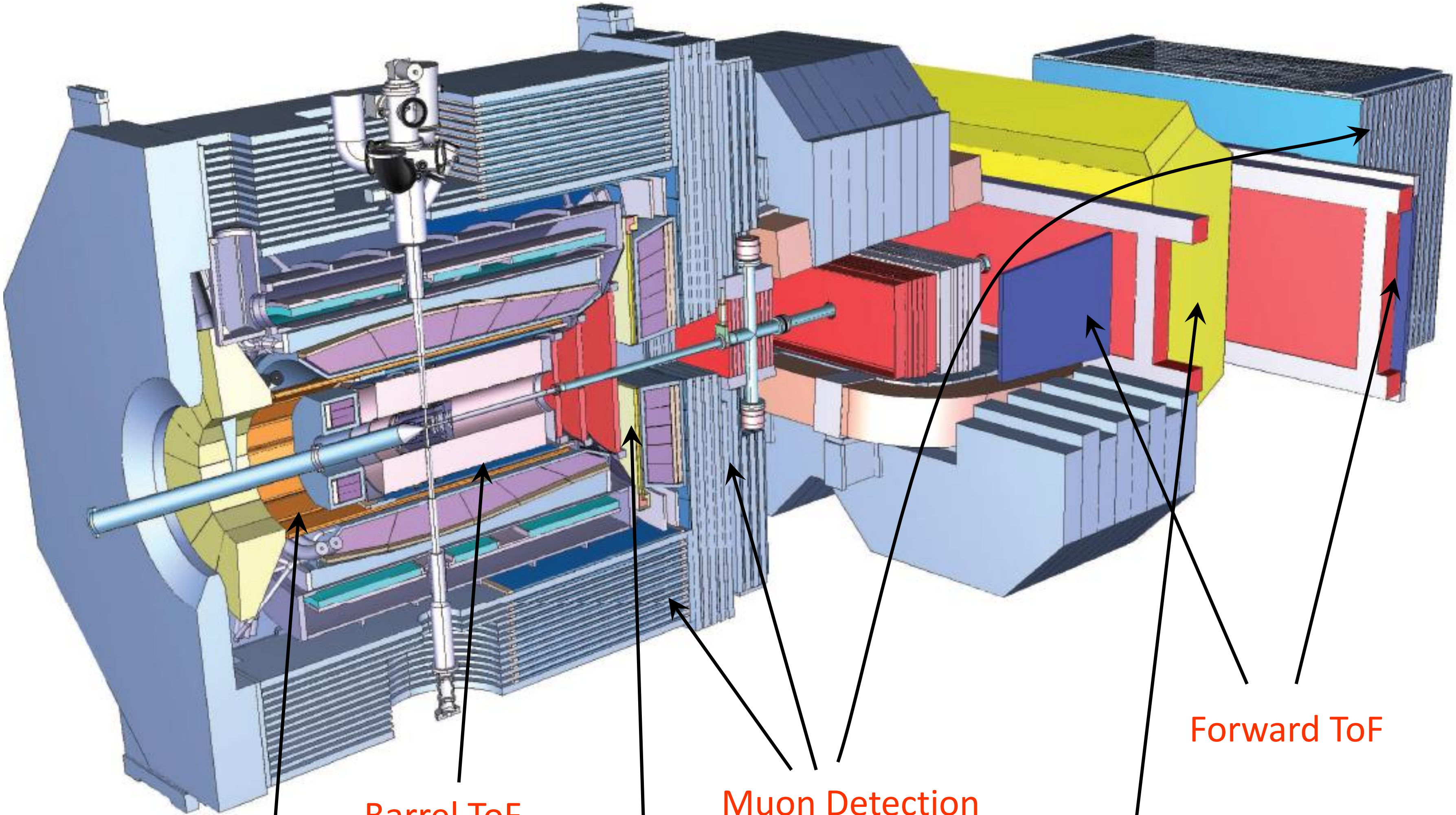
- Čerenkov radiation: p > 1 GeV
  Radiators: quartz, aerogel, C_4F_{10}
- Energy loss: p < 1 GeV
  Good accuracy with TPC,
  Stt system dE/dx under study
- Time of flight:
  needs a start detector
- Electromagnetic showers:
  EMC for e and γ

dE/dx of TPC

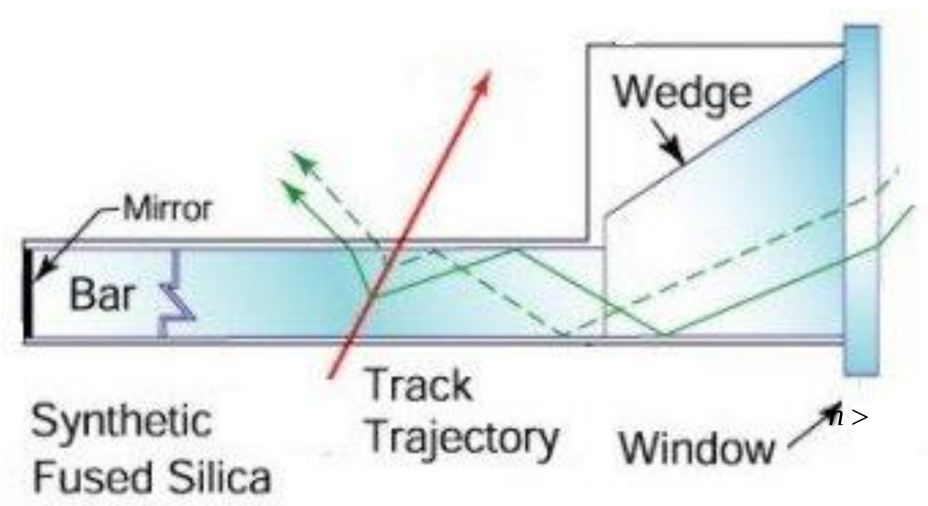


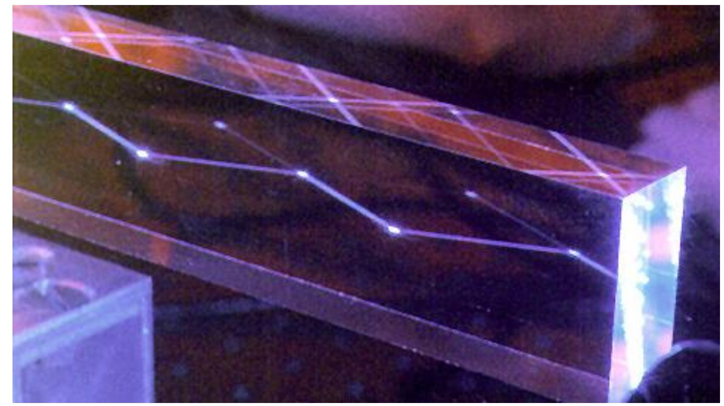


panda detector



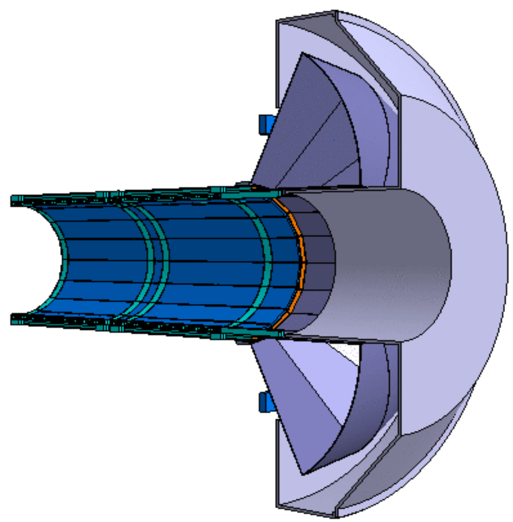
DIRC = Detection of Internally Reflected Cherenkov Light

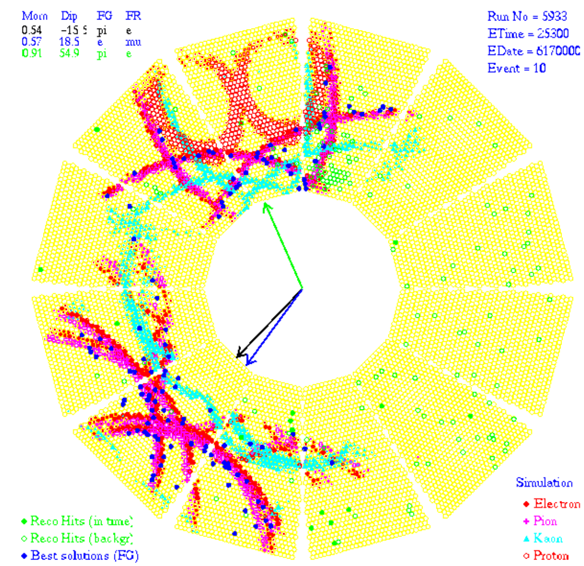




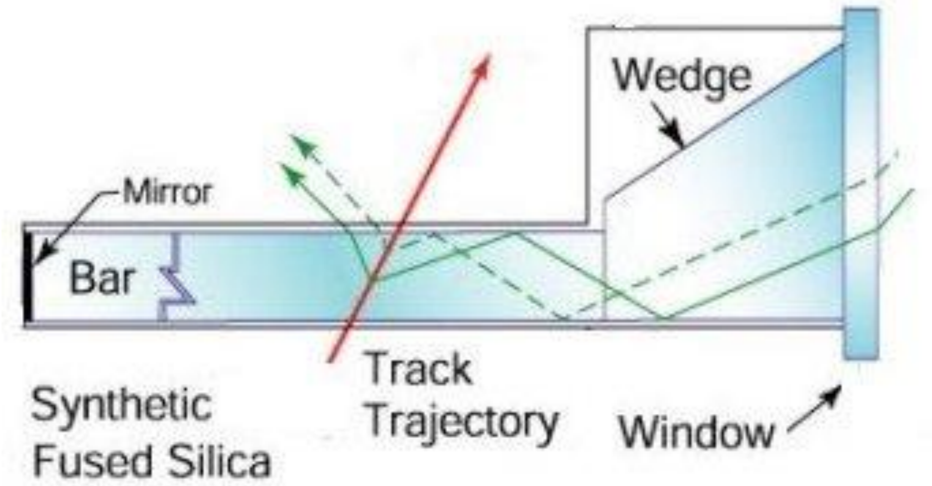
BaBar like DIRC

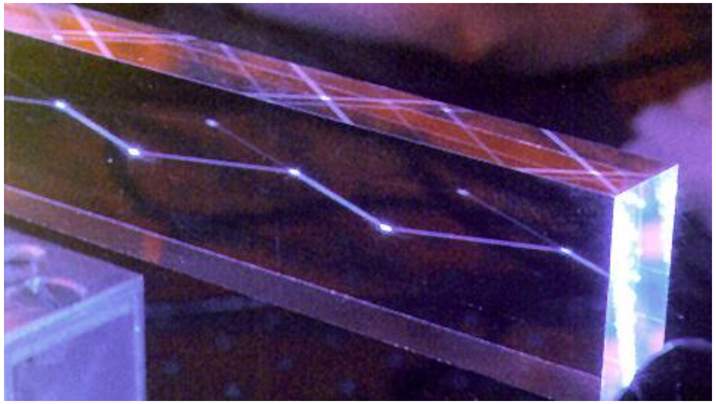
- Pin hole focusing
- Large water tank
- Readout with PMTs (BaBar 11000, PANDA 7000)





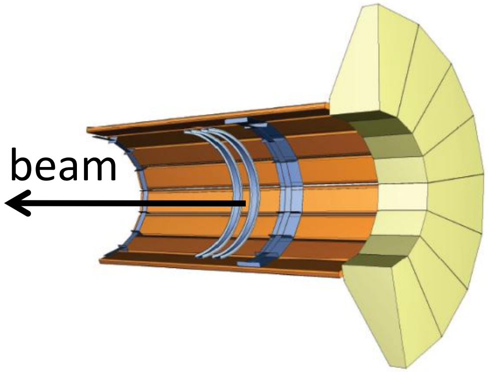
DIRC = Detection of Internally Reflected Cherenkov Light



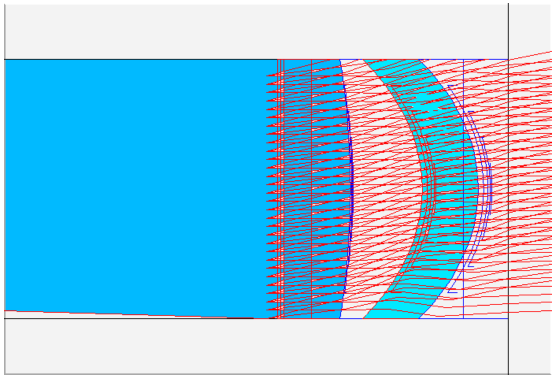


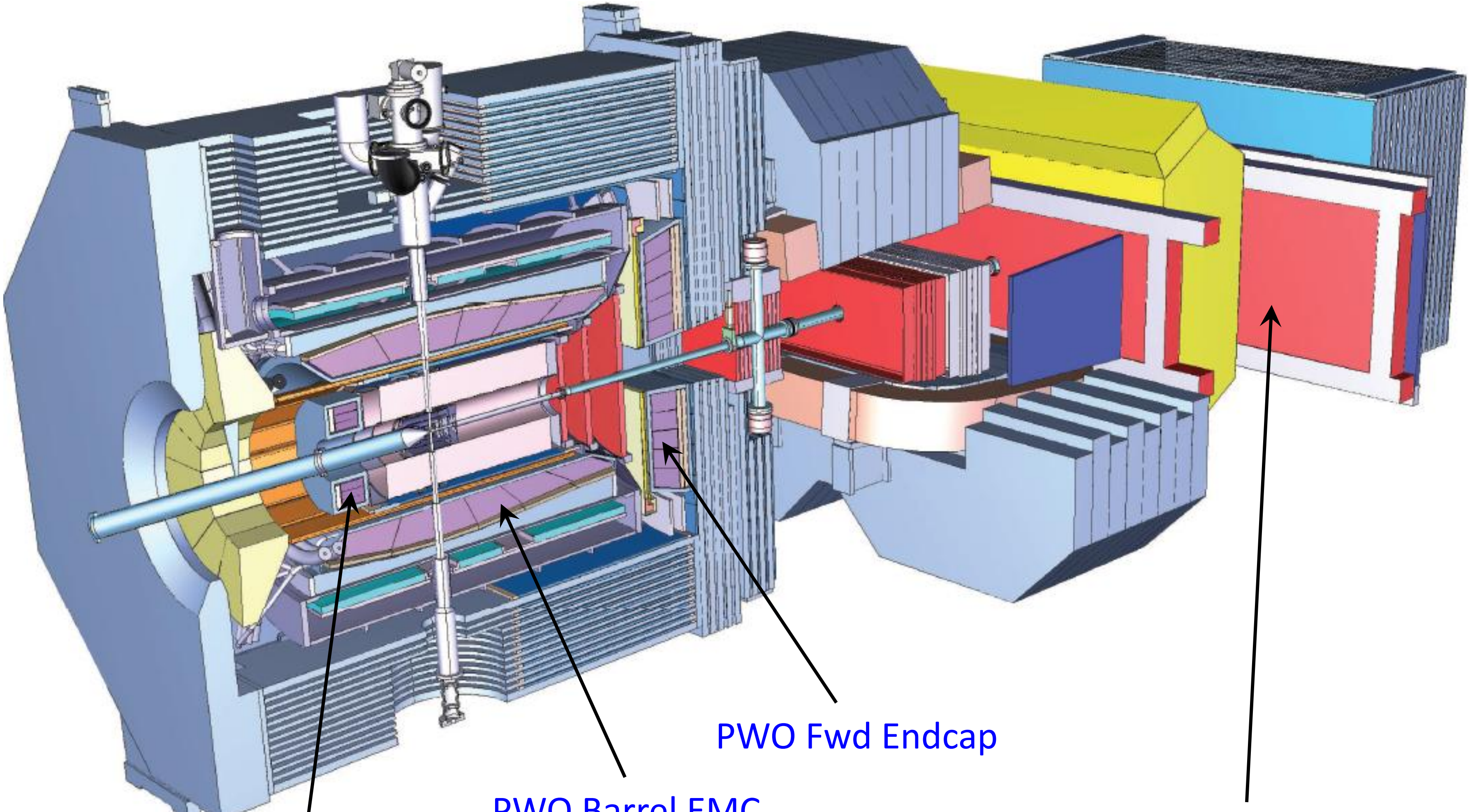
PANDA DIRC

- Lens focussing
- shorter radiator
- no water tank
- compact pixel readout
  (CP-PMTs or APDs)



Lens Focussing

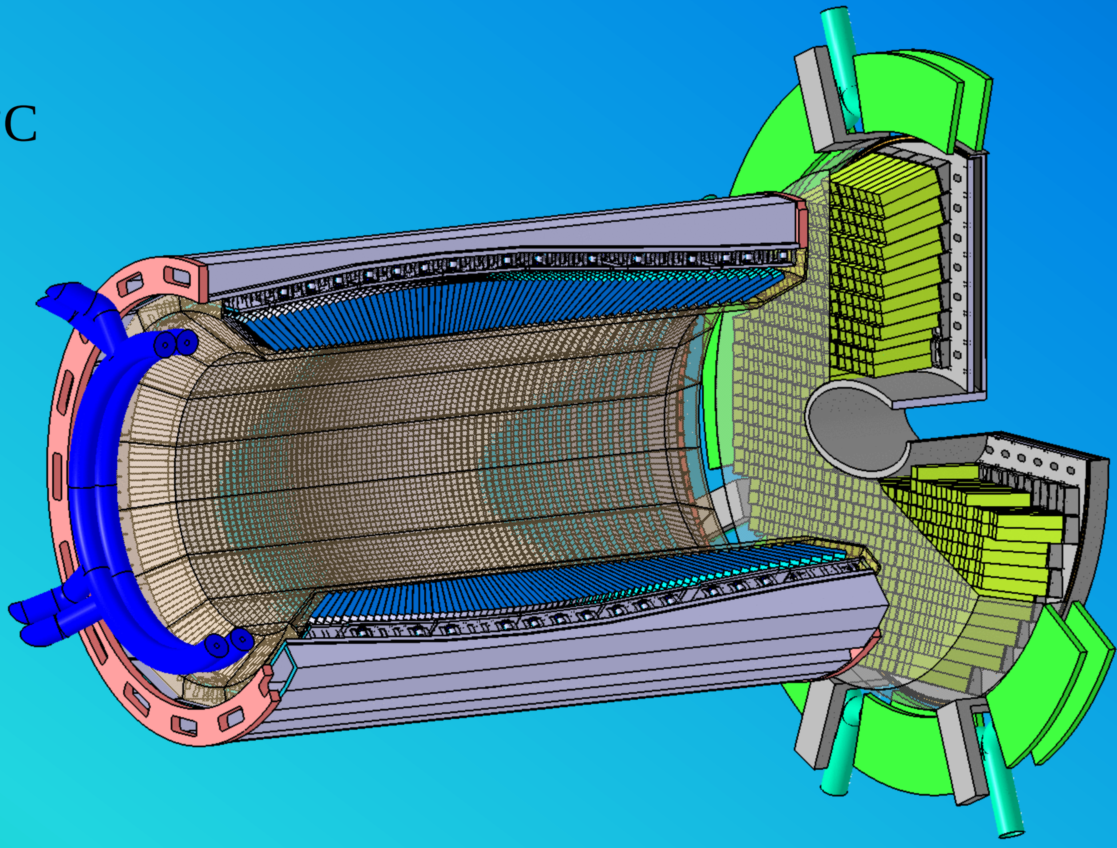



PWO Fwd Endcap
PWO Barrel EMC
Forward EM Calorimeter
PWO Backward Endcap

PANDA PWO Calorimeters

- PWO is dense and fast
- Increase light yield:
  - improved PWO II
  - operation at -25°C
- Challenges:
  - temperature stable to 0.1°C
  - control radiation damage
  - low noise electronics
- Delivery of crystals started

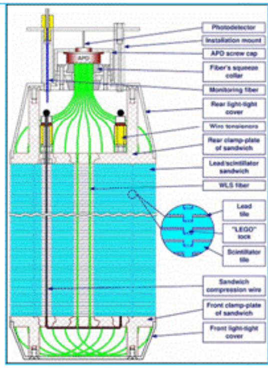
Forward Endcap
- 4000 PWO crystals
- High occupancy in center
- LAAPD readout

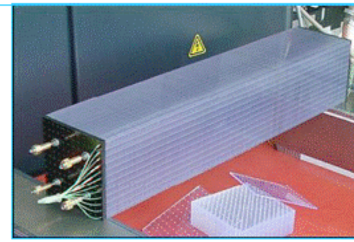


Barrel Calorimeter
- 11000 PWO Crystals
- LAAPD readout, 2 x 1cm^2
- $\sigma(E)/E \sim 1.5\%/\sqrt{E}$ + const.

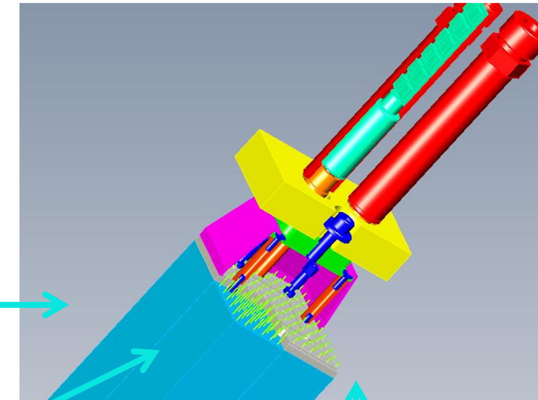
Shashlyk forward calorimeter

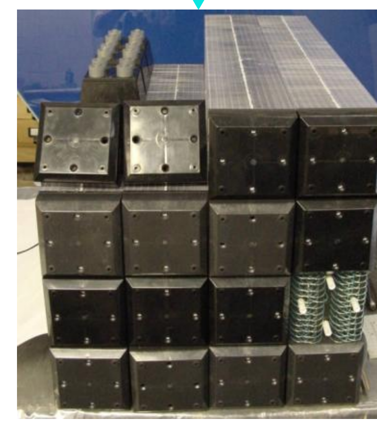
Forward : Shashlyk modules composed of lead absorbers and scintillators

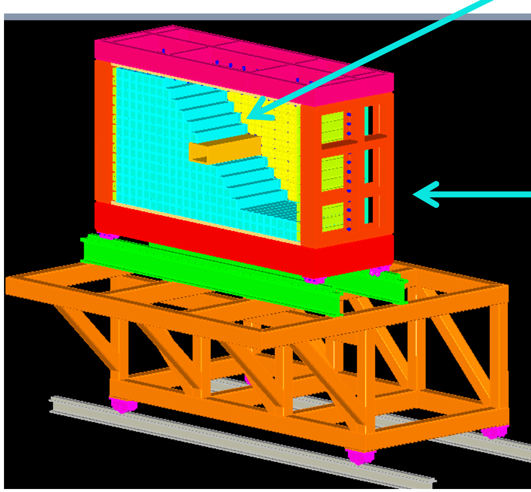


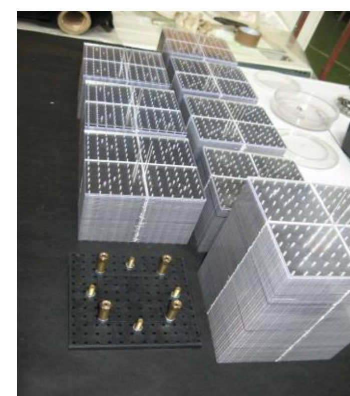


$$\frac{\sigma(E)}{E} = (1.96 \pm 0.1)\% \oplus \frac{(2.74 \pm 0.05)\%}{\sqrt{E[GeV]}}$$









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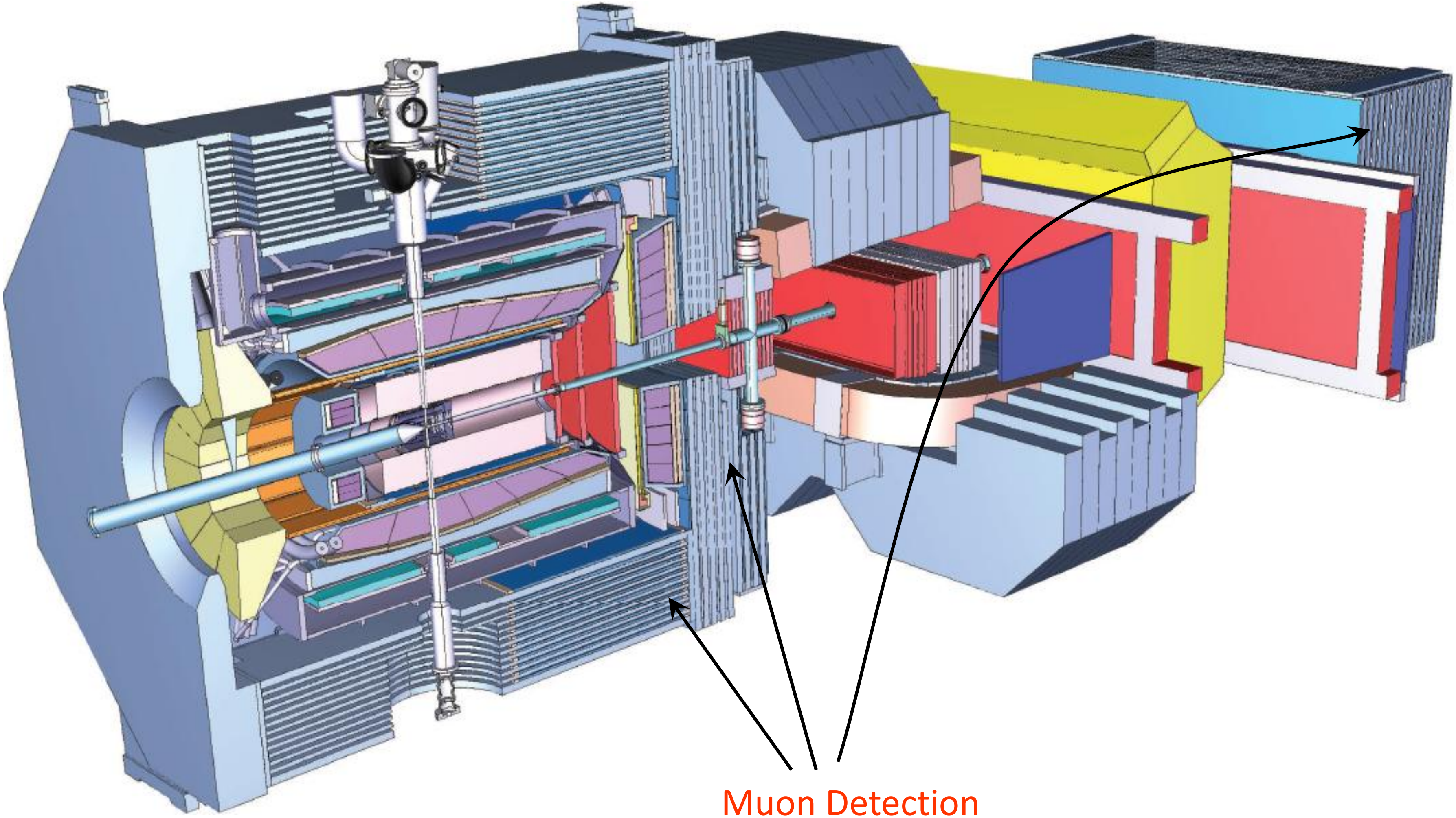
panda detector

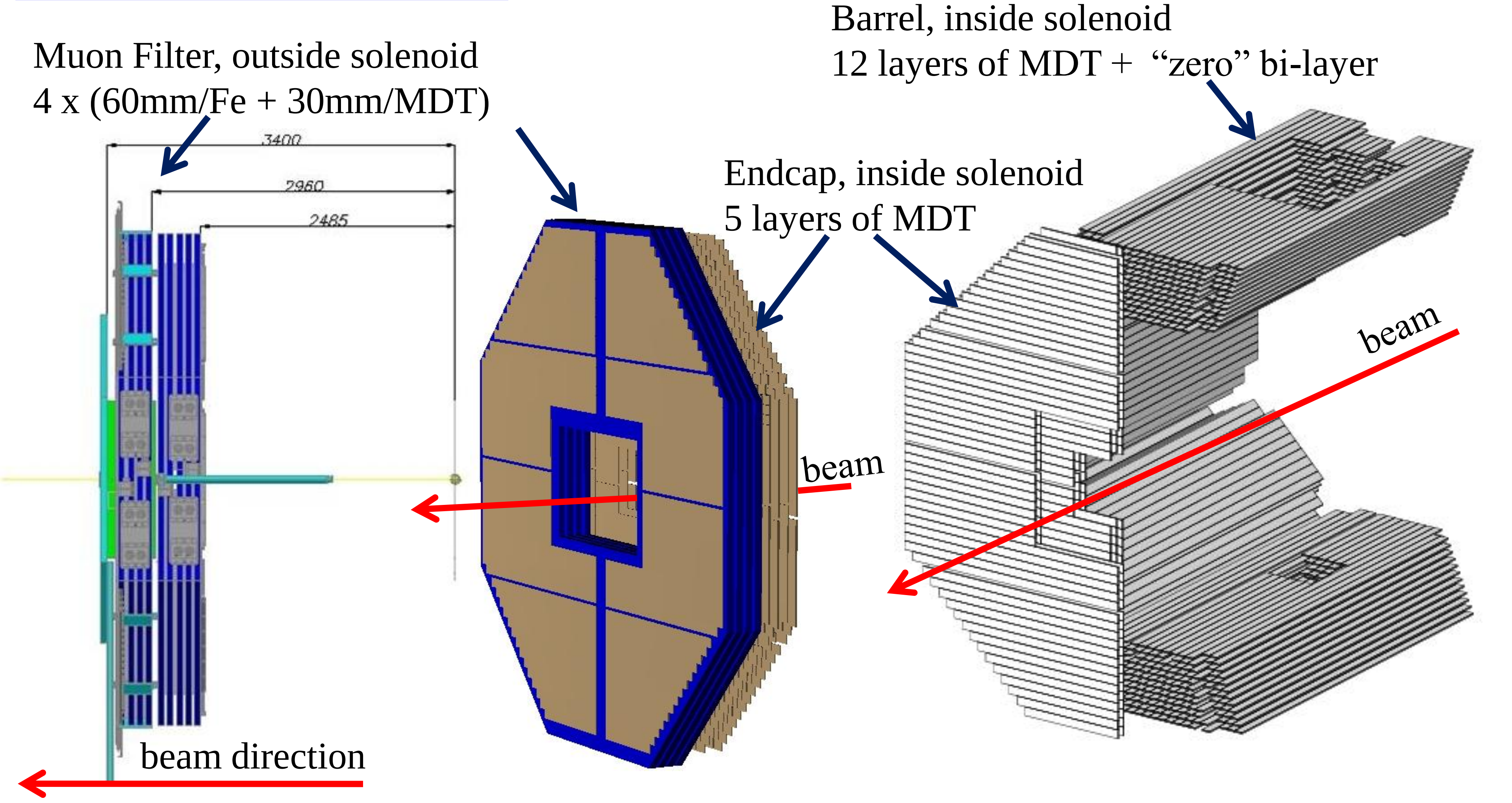


G.Boca GSI, Germany & U. Pavia, Italy

Proportional tubes : anode signal and induction signal on 1 cm strips

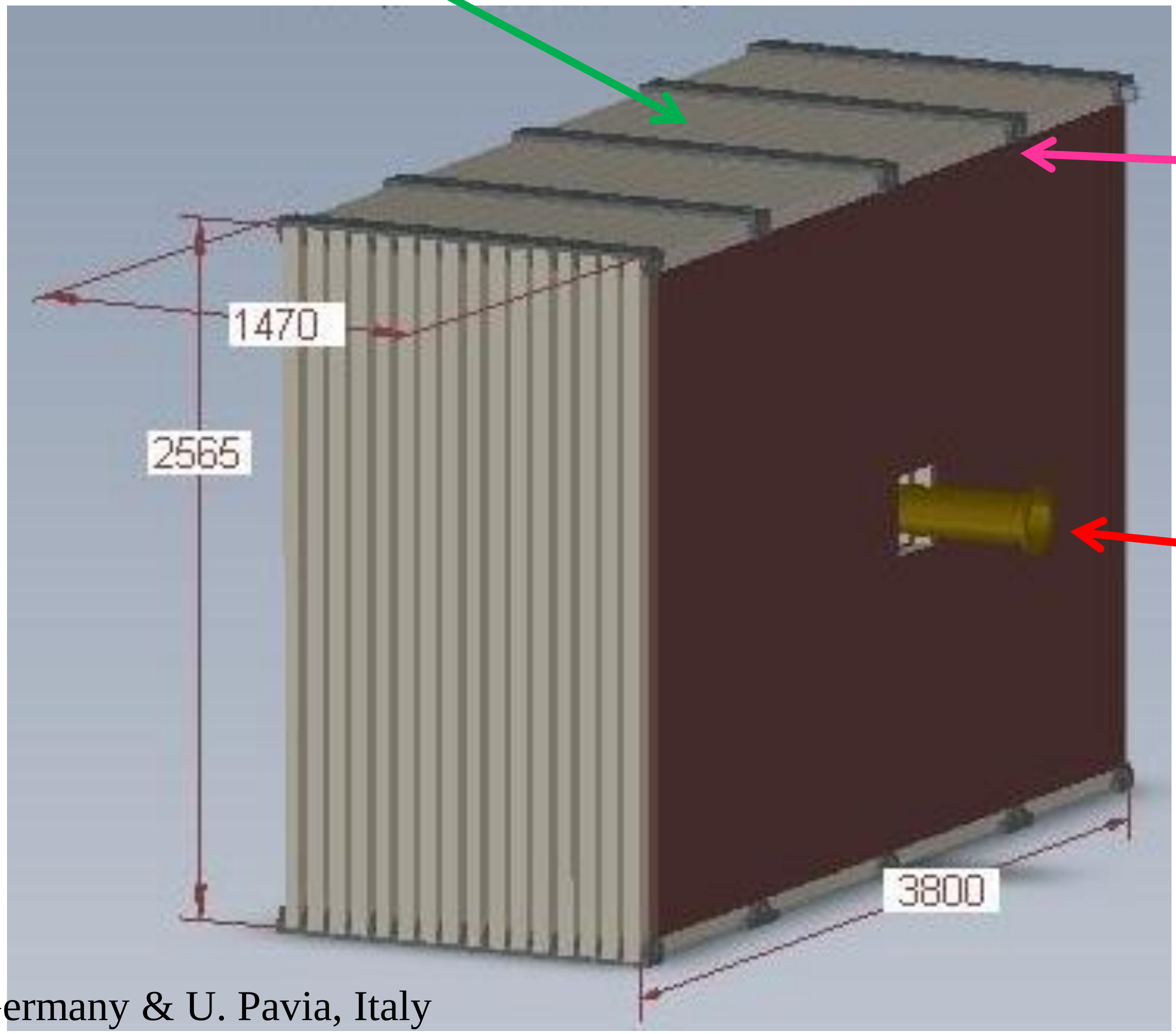
Outside the solenoid
"Muon Filter", 4 layers

Inside the solenoid
Barrel: 12 layers inside the yoke + 1 bi-layer ("zero" bi-layer) in before iron
Endcap: 5 layers + "zero" bi-layer before iron



Forward Muon System

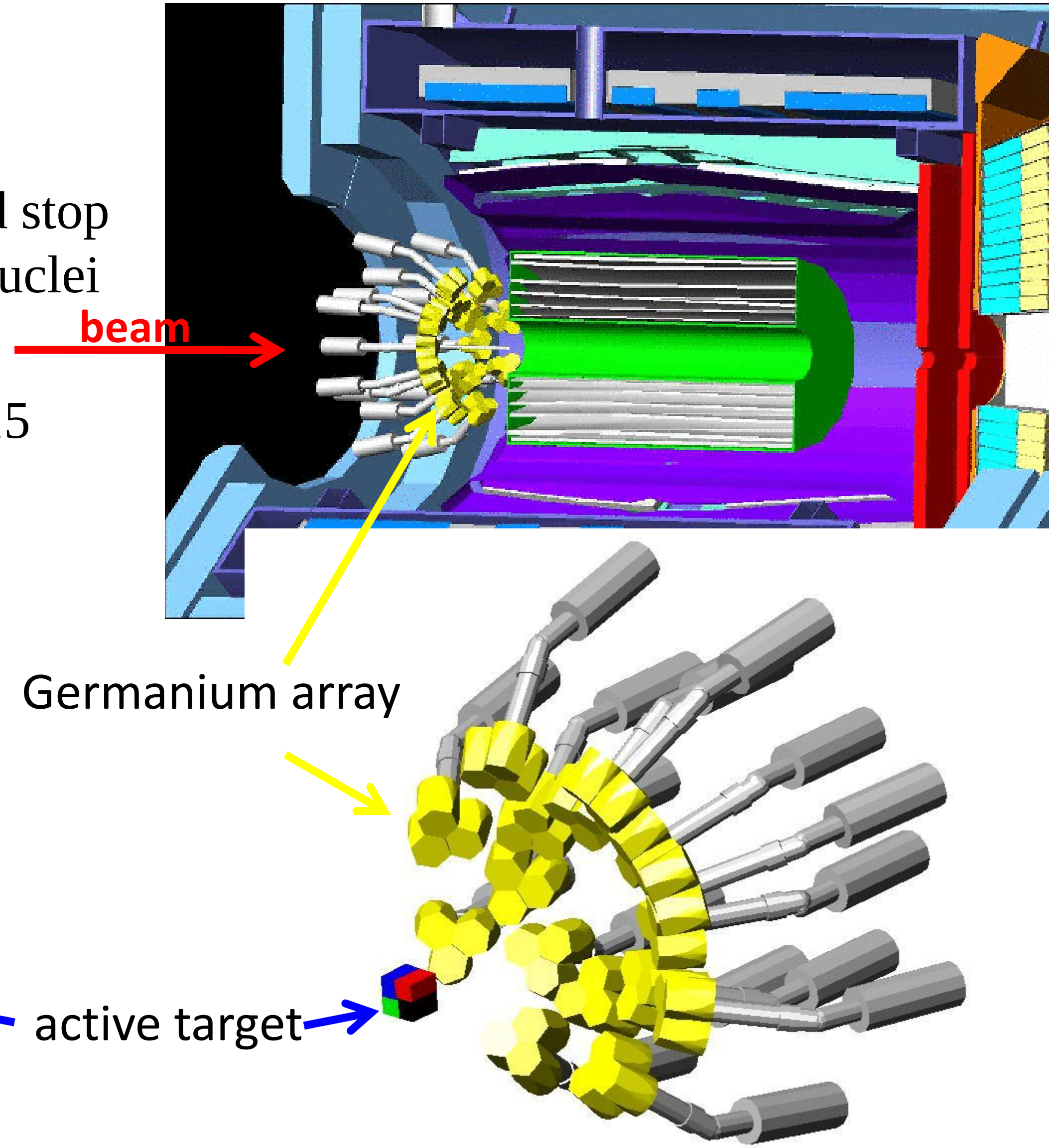
“zero” bi-layer + 16 x(60mm/Fe + 30mm/MDT)

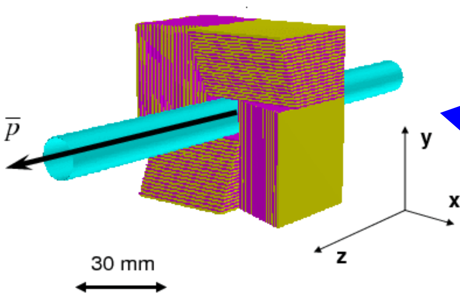


Hypernuclear Detector

- Active silicon target to produce and stop the $\Xi\bar{\Xi}$ pair and detect the hypenuclei decay products
- Germanium γ array detector, with 15 clusters of 3 gemanium

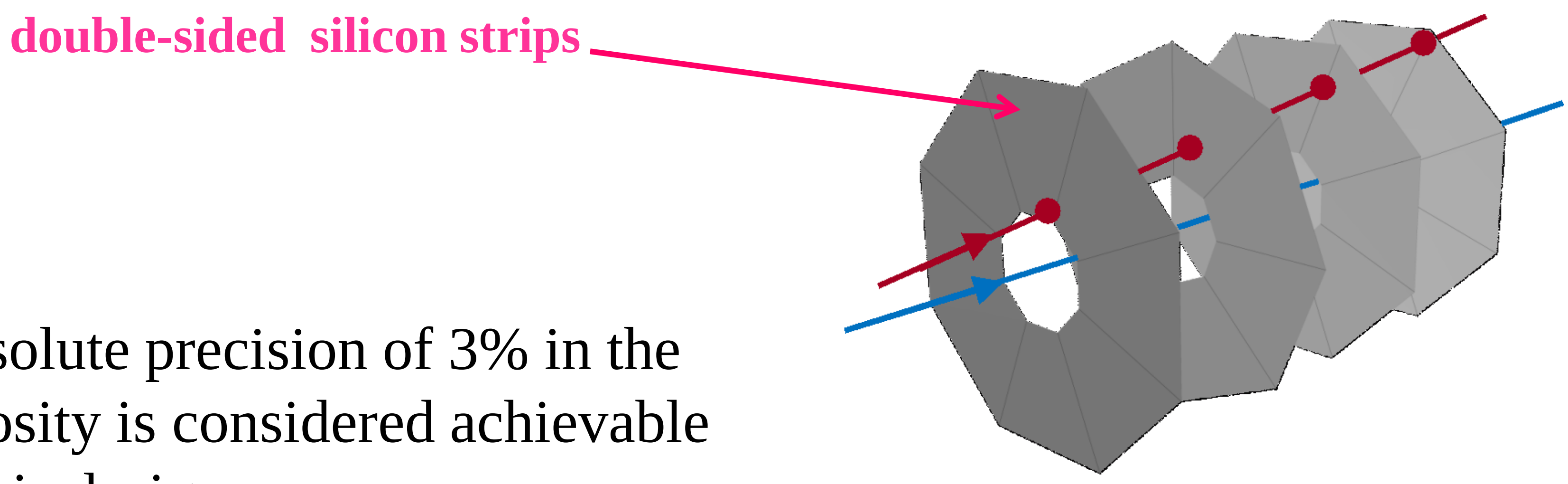
Forseen 2 KeV γ enery resolution, 1.3 MeV π energy resolution





Luminosity Monitor, concept design

- measure the $p\bar{p}$ elastic cross section for total cross section determination
- 4 planes of 8 silicon trapezoids located ~ 10–12 m downstream the interaction point; distance between two consecutive planes : 10 cm;
- each sensor is strips of 150/300 μm ; 45 degree stereo angle;
- angle coverage ~ 3 mrad to 8 mrad;
- second plane rotated by 22.5 degrees.



An absolute precision of 3% in the luminosity is considered achievable with this design.

DAQ

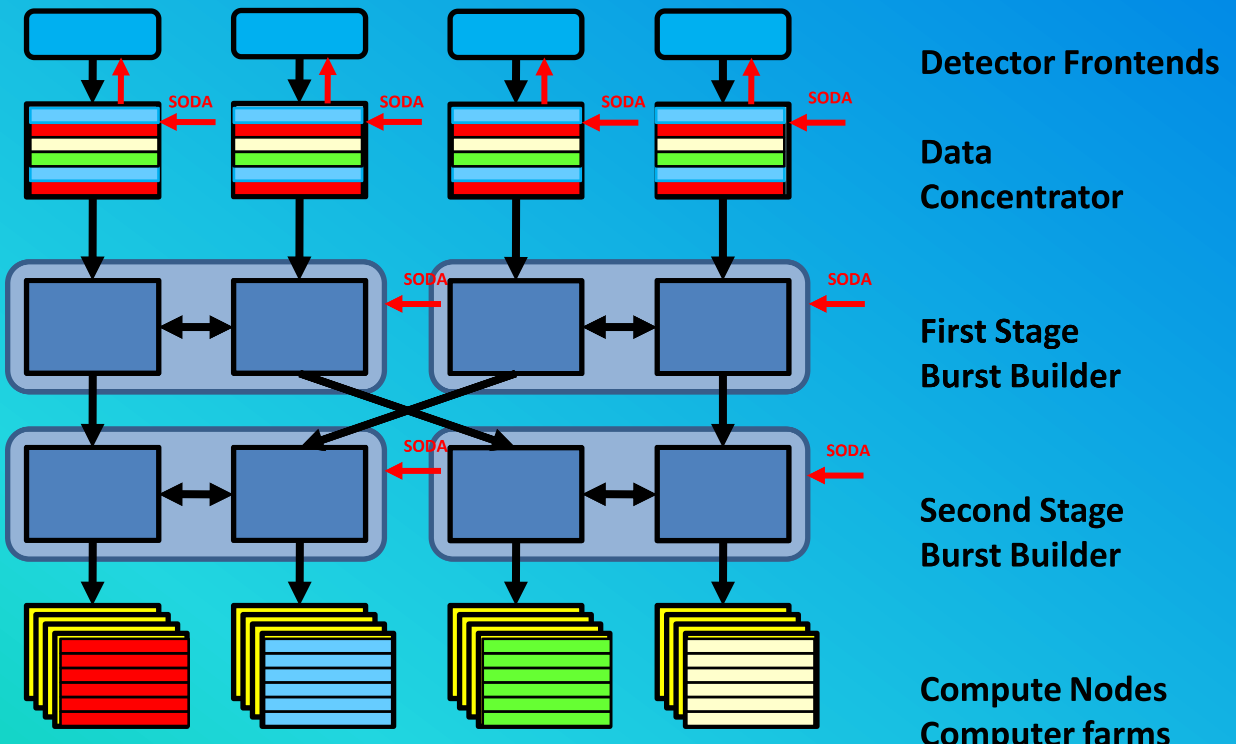
- no hardware trigger, continuous data taking ;
- flexibility required to select different physics channels;
- average interaction rate $2x10^7$;
- average required bandwidth 120 – 140 GB/s;
- signals detected autonomously by each sub-detector and preprocessed, time stamp is associated to each hit bunch;
- data concentrators receive hits from subdetectors, provide point-to-point communication via optical links, buffering and online manipulation ;
- programmable computing nodes (FPGA, Digital Signal Processors) perform data feature extraction, association of data fragments to events, event selection;
- necessary a precise time distribution system (SODA).

DAQ

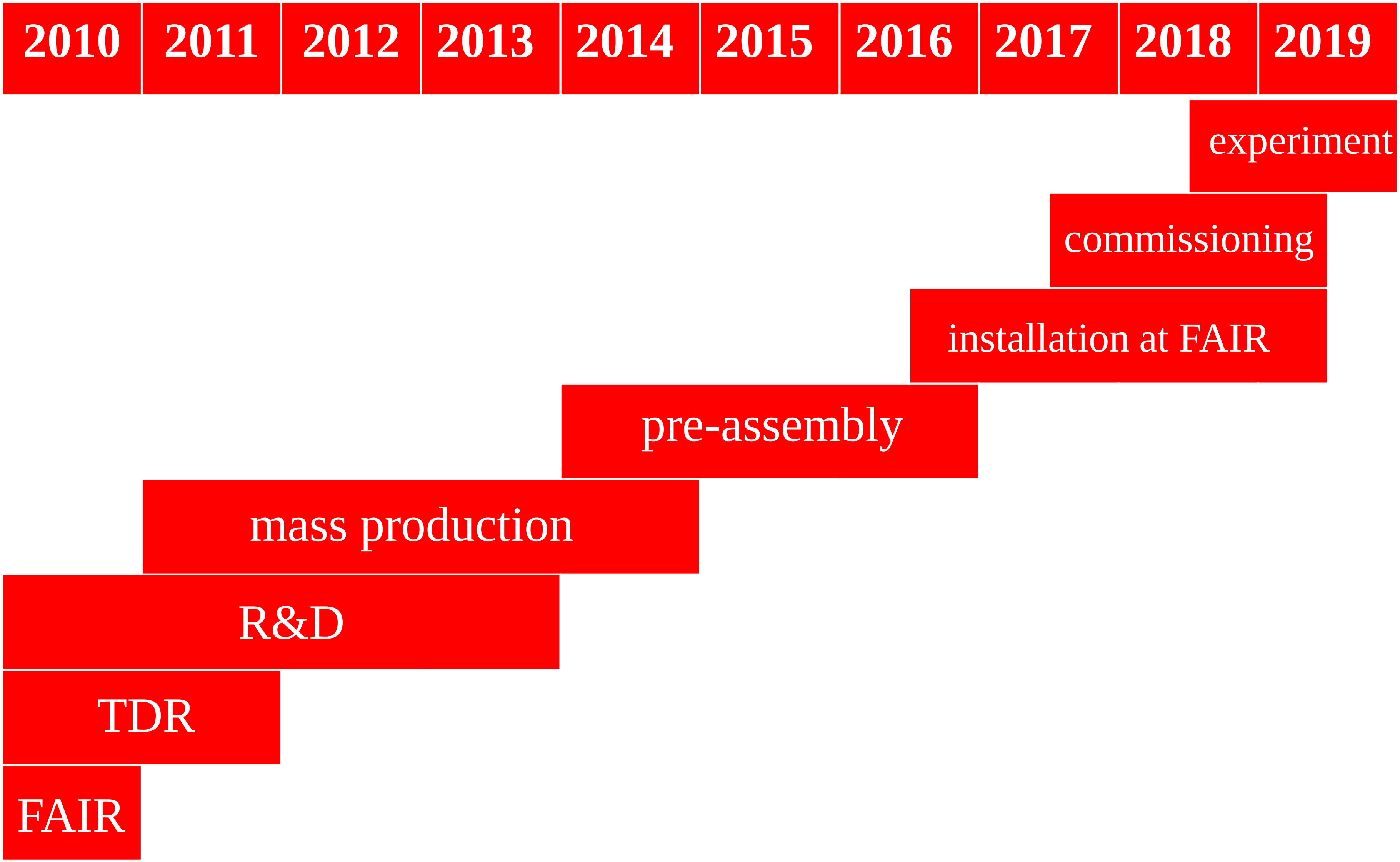
Technically challenging but feasible; a lot of thinking and ideas already done, discussion is very well advanced on possible option available now and in the next few years.

1000 data sources

SODA – time distribution system



Timescale of $\bar{\text{p}}$anda



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IHEP Beijing
U Bochum
IIT Bombay
U Bonn
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U & INFN Brescia
U & INFN Catania
JU Cracow
TU Cracow
IFJ PAN Cracow
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JINR Dubna (LIT,LPP,VBLHE)
U Edinburgh
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TSL Uppsala
U Uppsala
U Valencia
SMI Vienna
SINS Warsaw
TU Warsaw

Conclusions

Don’t you feel you want to join

$\bar{p}$anda

?

Special thanks to K. Götzen for his help with many of the pictures.