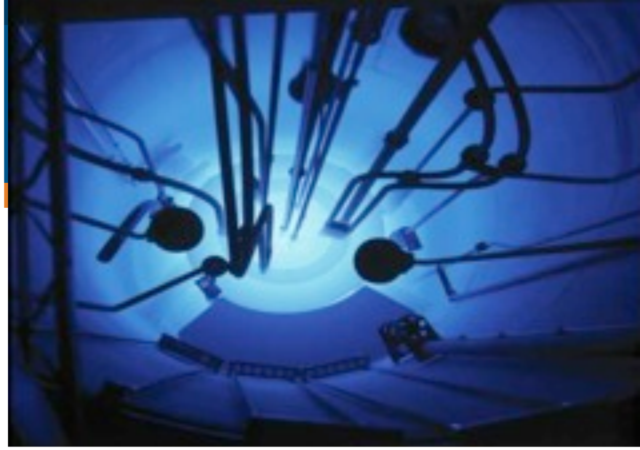



GSI/FAIR Perspectives

Frank Maas, Helmholtz-Institut Mainz, Director

TRANSVERSITY 2011 -
Third International Workshop on Transverse Polarization Phenomena in Hard Scattering
Veli Losinj (Croatia), September 2, 2011

With Trasnparencies from P. Lenisa (PAX), I. Augstin (FAIR)

Overview

FAIR

PANDA@FAIR

unpolarised Drell-Yan: Muons

Electrons?

SSA: polarised Hydrogen Target in PANDA?

PAX-Experiment

doubly polarised Drell-Yan?

(polarised Antiproton beam?)

Electron-Nucleon Collider (ENC)

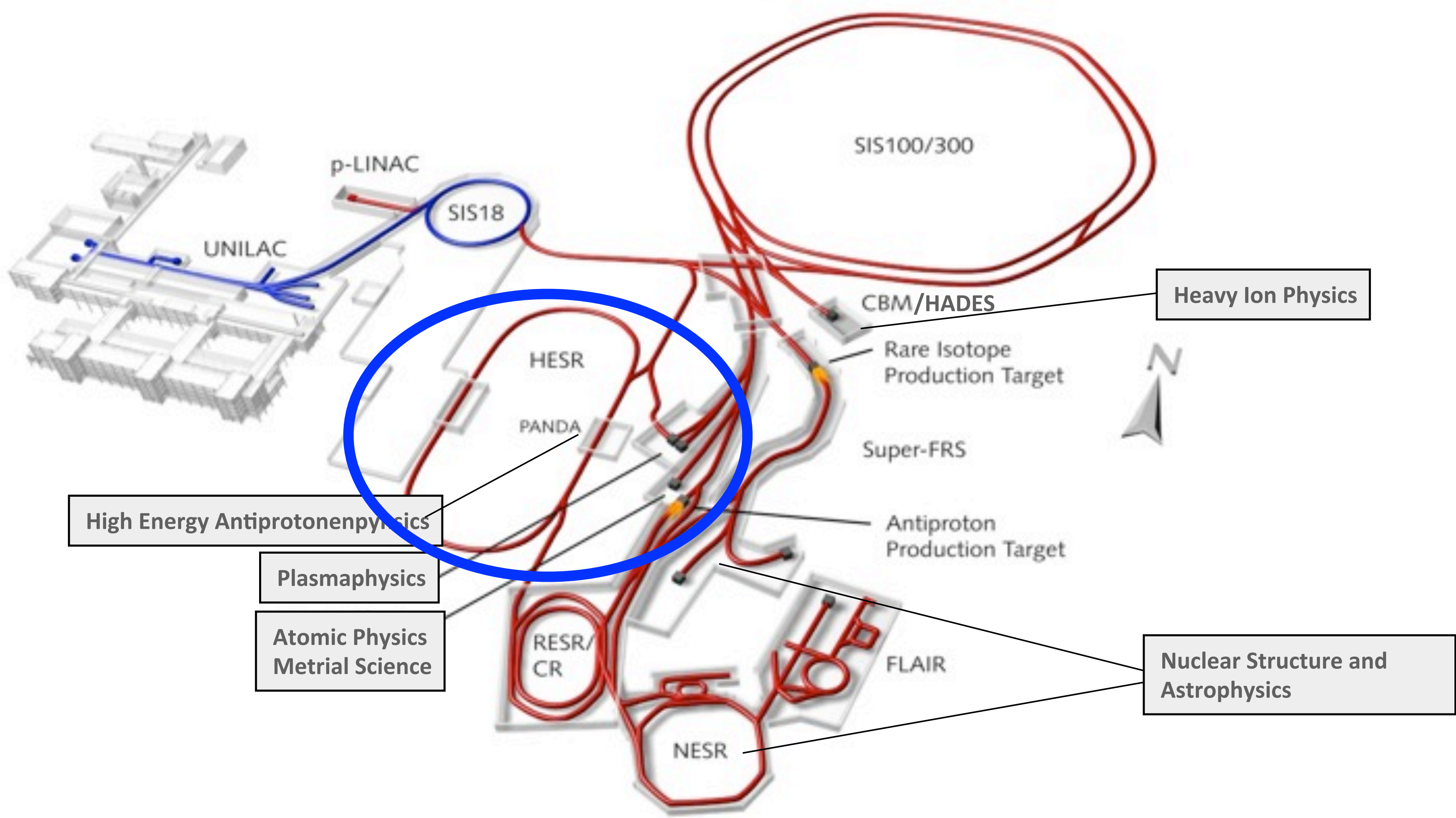
polarised electron-nucleon collider?

at PANDA@HESR@FAIR?

PANDA@FAIR

- unpolarised Drell-Yan: Muons
- unpolarised Drell Yan: Electrons
- SSA: polarised Hydrogen Target in PANDA

FAIR



Budget: 1.03 M€

FAIR in 2017/2018

FAIR

QCD and Strong Interaction: PANDA

panda

QCD and Strong Interaction: PANDA

- Confinement, Glueballs, Hybrids: Hybrid charmonium e.g. decay in 7 photons

- Spectroscopy, Charmonium decays using e.g. $J/\psi \rightarrow e^+e^-/\mu^+\mu^-$
- Charmed mesons: Weak decays in K^0_S and $K^{\pm}$

- Strange Matter, Hypernuclear cascades

- Nucleon Structure: Generalised parton distributions (time like): High energy photons, Electromagnetic form factors: Dilepton pairs, Drell-Yan (unpolarised)

- New Detector development
- New Simulation software development
- New Analysis tool development

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QCD … A

- Confinement, G … ecay in 7 photons
- Spectroscopy, (… -μ-
- Charmed meso
- Strange Matter,
- Nucleon Structu … e): High energy ph … pairs, Drell-Yan
- New Detector d
- New Simulation
- New Analysis to

Physics Performance Report for:

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

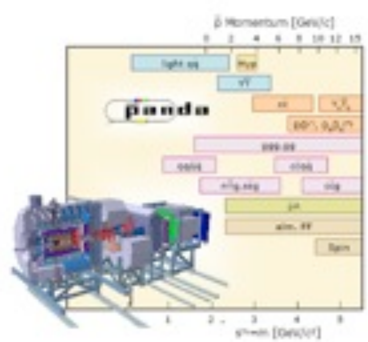
(AntiProton Annihilations at Darmstadt)

Strong Interaction Studies with Antiprotons

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

February 13, 2009 - Revision: 810

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.



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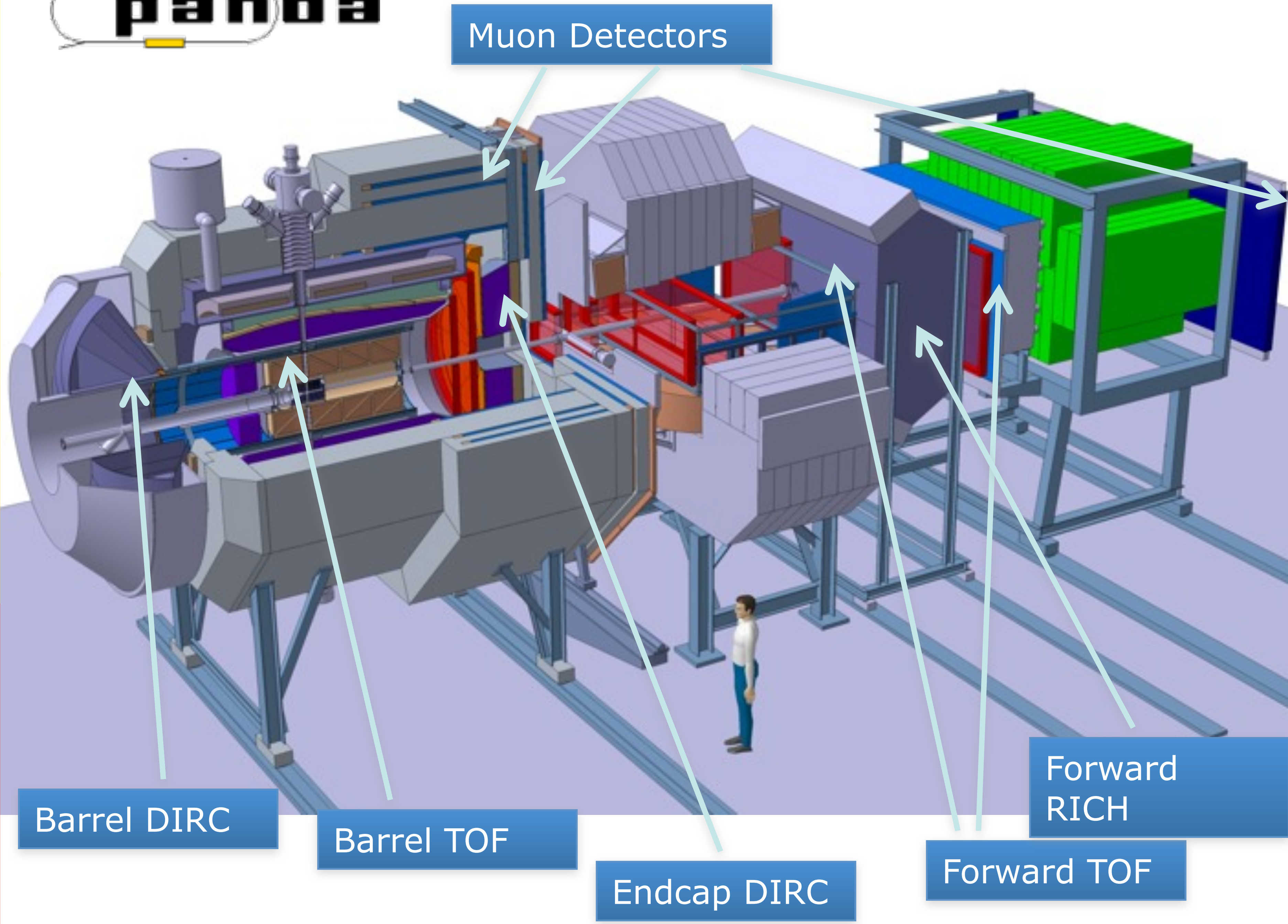
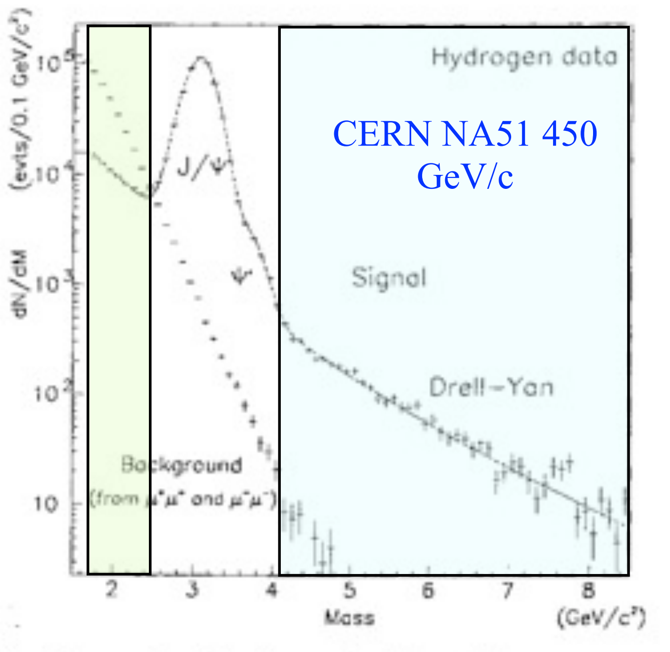

Muon Detectors
Barrel DIRC
Barrel TOF
Endcap DIRC
Forward TOF
Forward RICH

spin structure using Drell-Yan process: Muons
(Thanks to M.Maggiora and M.P. Bussa)

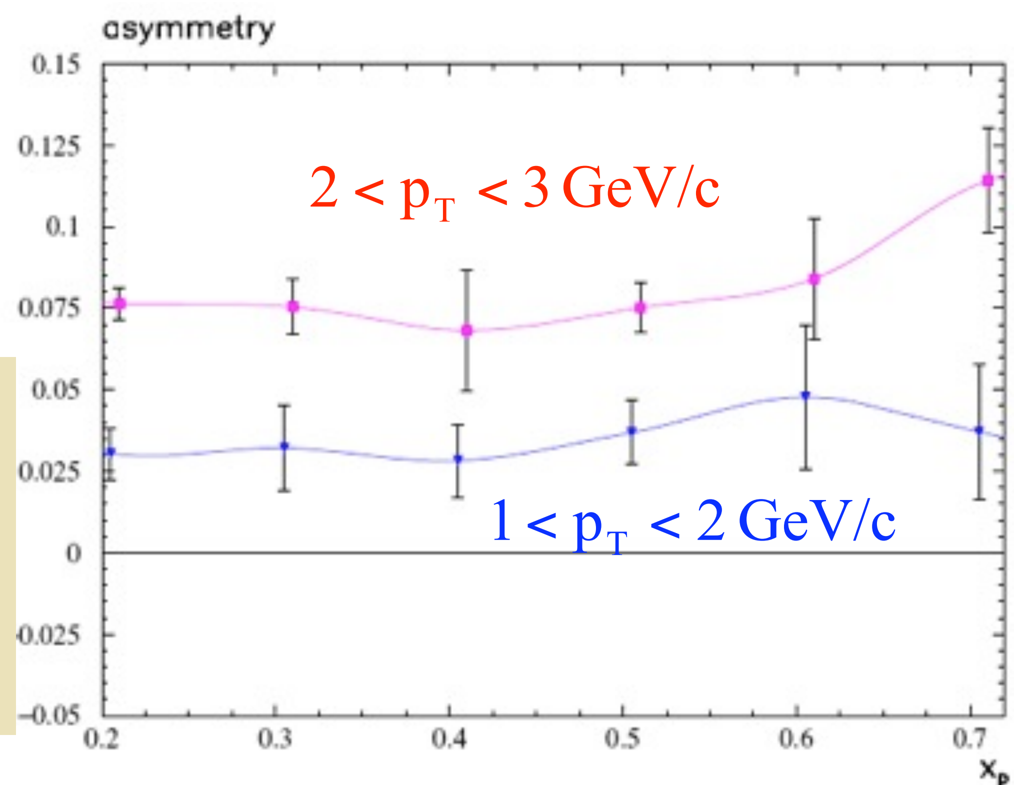
Unpolarised Drell-Yan Asymmetries —

40K ev[1] with $E_{\bar{p}} = 15$ GeV on fixed target, $1.5 < M < 2.5$ GeV/c^2



$s \sim 30$ GeV^2

azimuthal asymmetry
cos(2φ) contribution



$0.2 < x_{1,2} < 0.8$

error bars allow investigation of:

- small asymmetries
- their dependence on p_T

[1]A. Bianconi and M. Radici, Phys. Rev. D71 (2005) 074014

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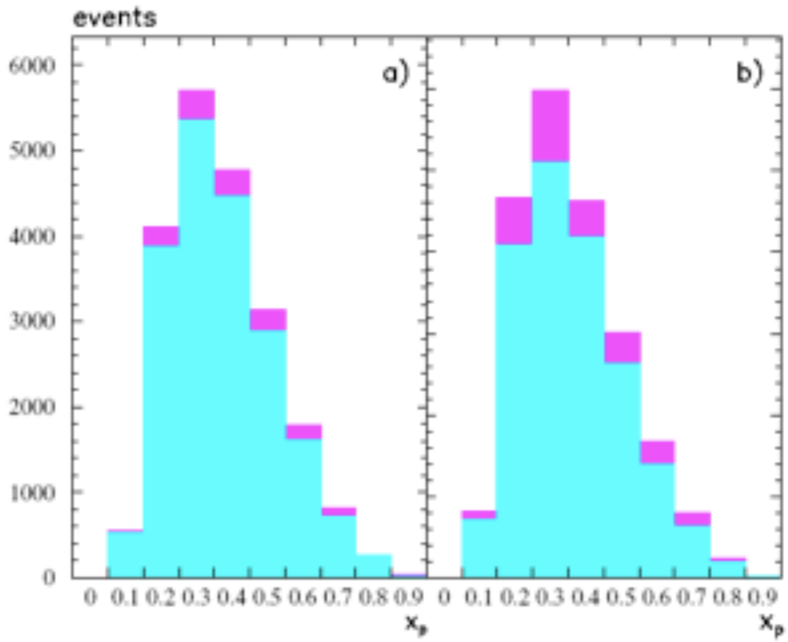

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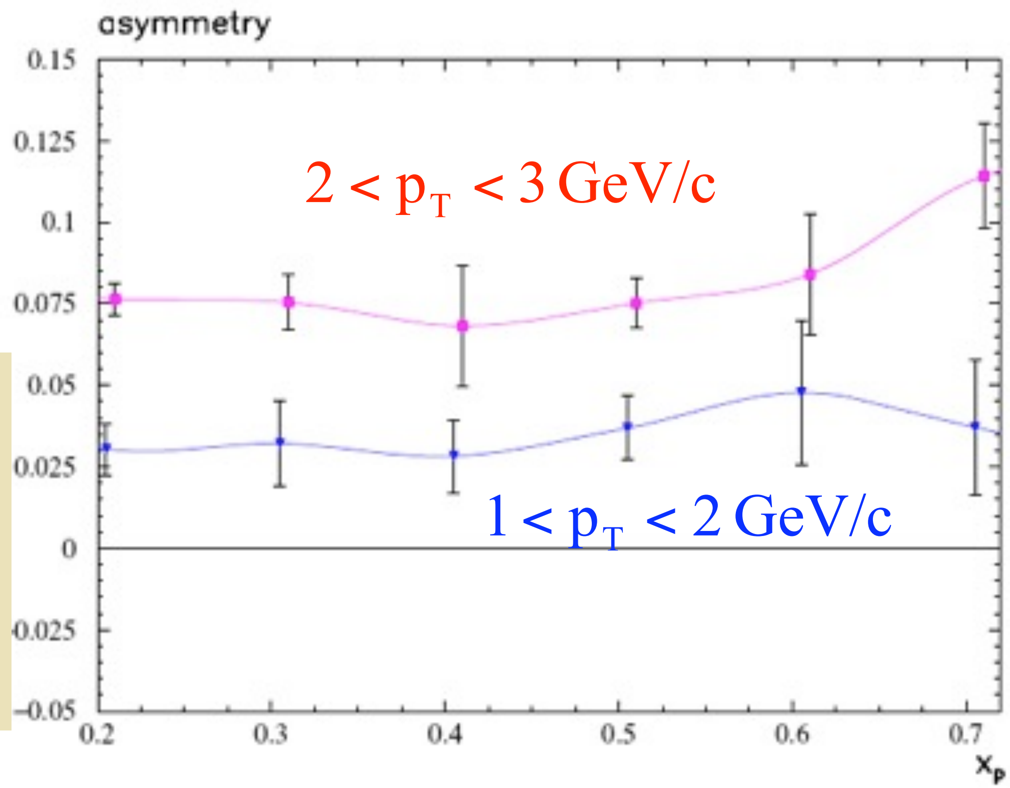

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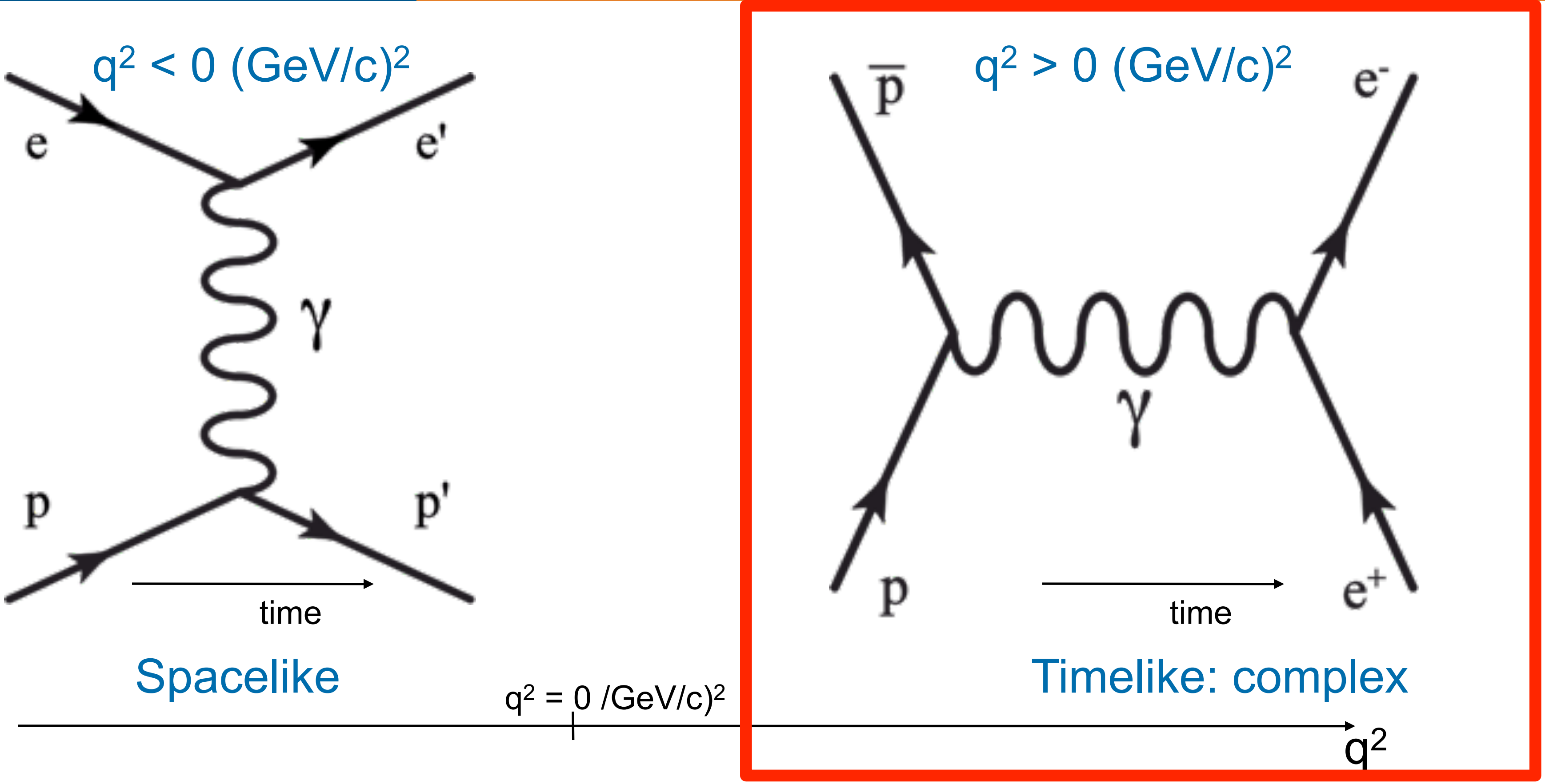
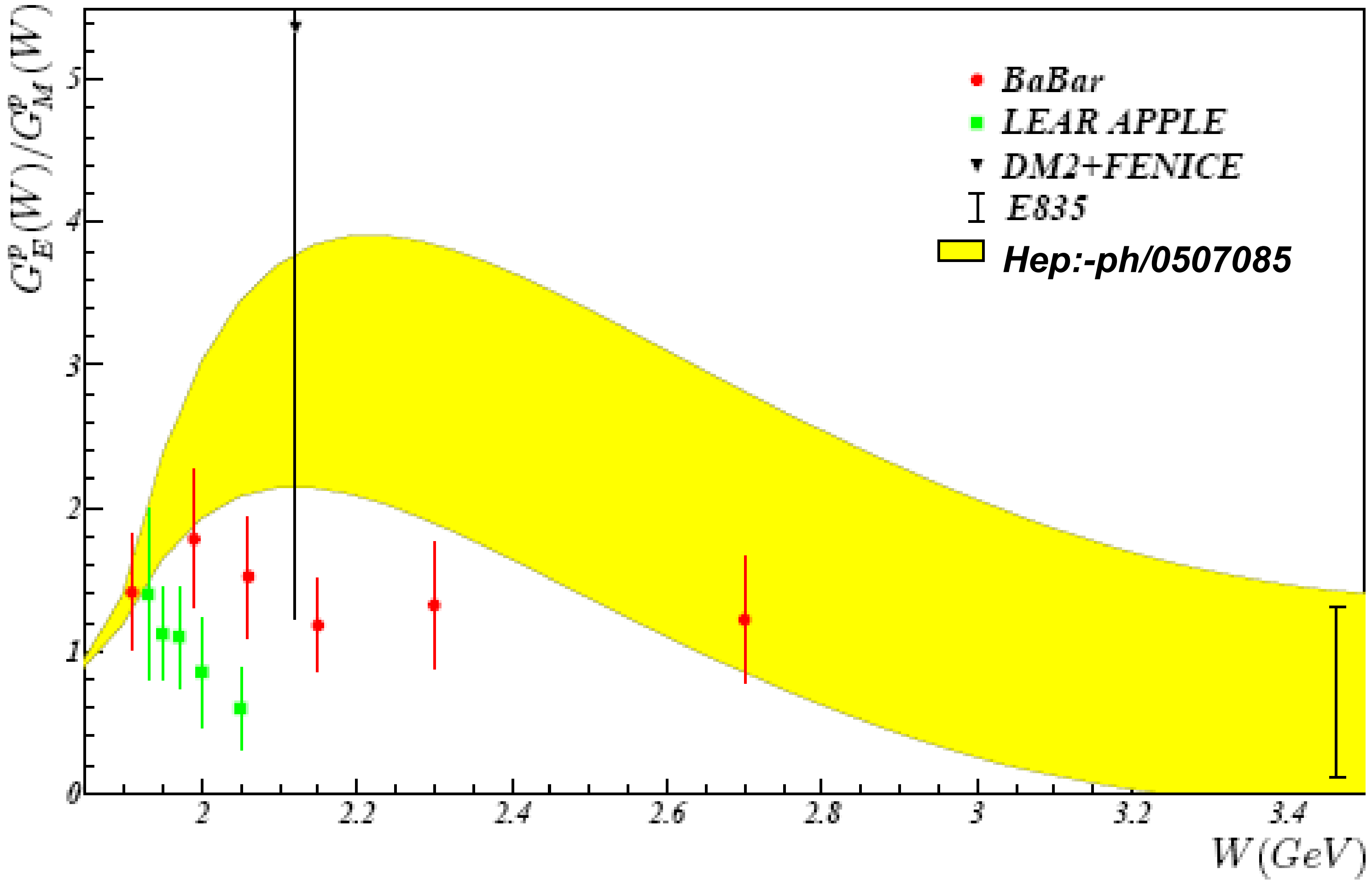
spin structure using Drell-Yan process: Eletrons

Timelike Electromagnetic Form Factors G_E G_M



Sapcelike and timelike region intimately connected
PANDA unprecedented luminosity
Antiproton annihilation opens a new window to
Precision electromagnetic (EM) probe hadron structure observables

Timelike Electromagnetic Form Factor: PANDA Simulations



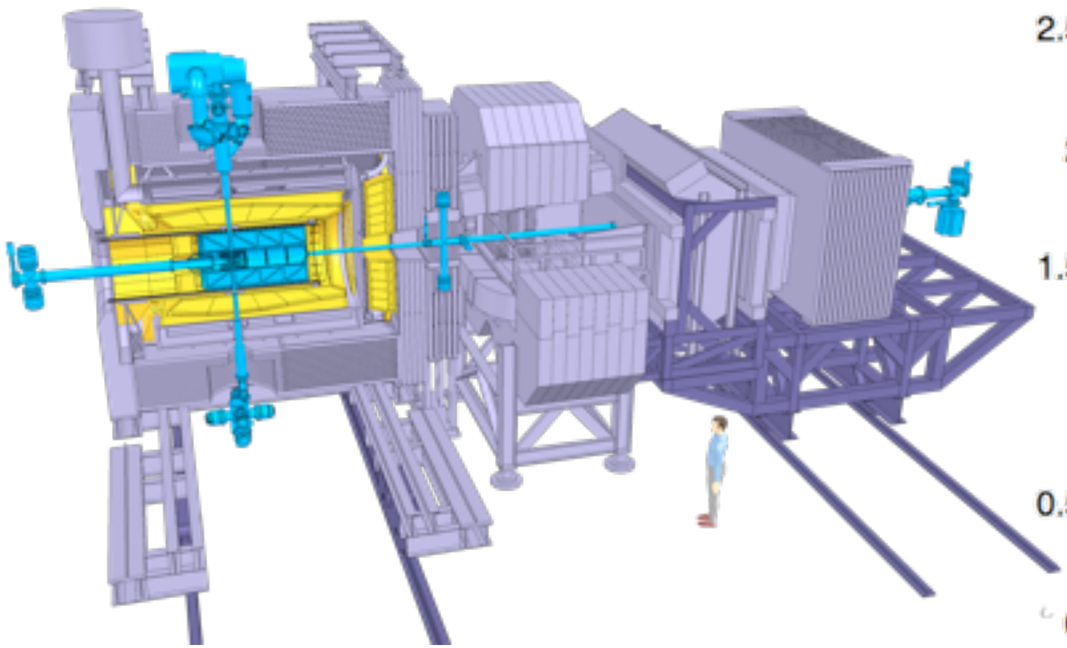
Hadronic Background

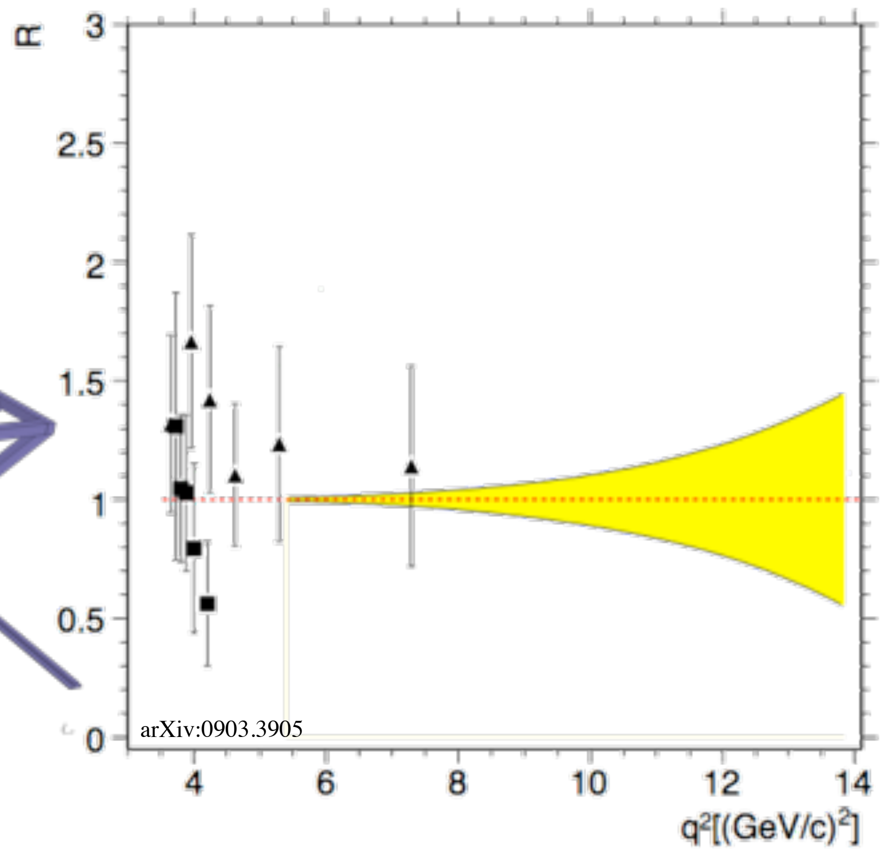
- Reactions with at least 3 particles, (e^+e^-X, $\pi^+\pi^-X$,…)
- Particle identification and kinematics constraints
  → no problem

- Reactions with 2 charged particles ($\pi^+\pi^-$)
- $\sigma(\pi^+\pi^-)/\sigma(e^+e^-) \approx 10^6$ (2μb/8pb at q^2=9.(GeV/c)^2)
- need rejection of $pp \rightarrow \pi^+ \pi^-$ by 10^{-8}
- binary event, mean reject. of 10-4 per π^+ and per π^-

- very close kinematics

Timelike Electromagnetic Form Factor: Panda Precision





Suppression of 10^6 times higher hadronic background

Improved precision by a factor 10 with PANDA

Published in PANDA physics book and in Phys. Rev.

Transition Distribution Amplitude (TDA)

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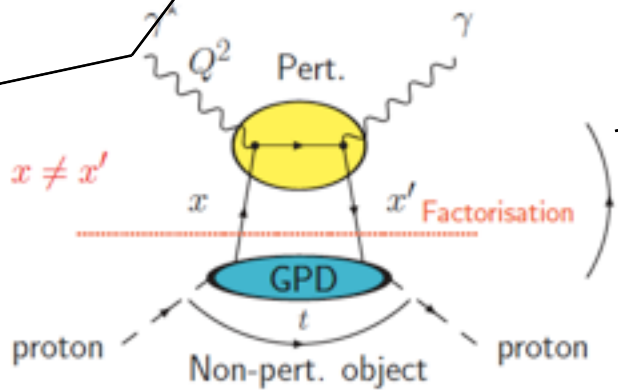
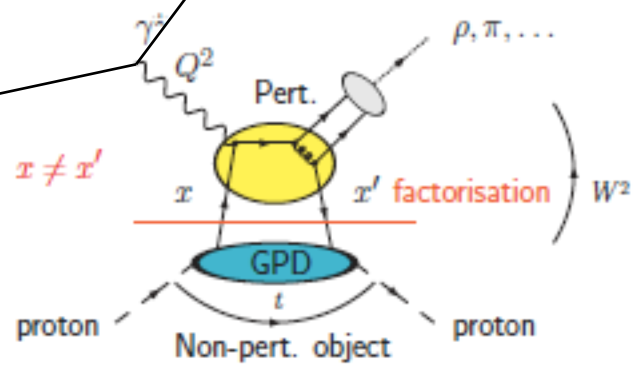
GPDs: Factorization: Hard limit for forward exclusive processes

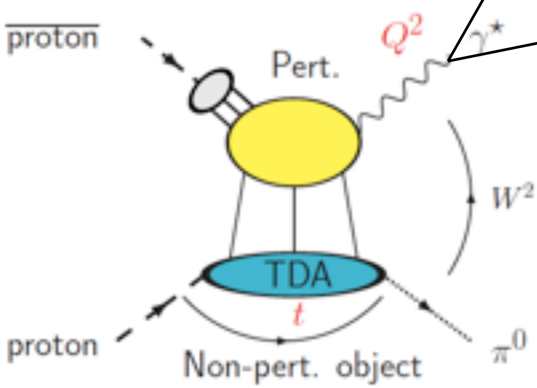
GPDs

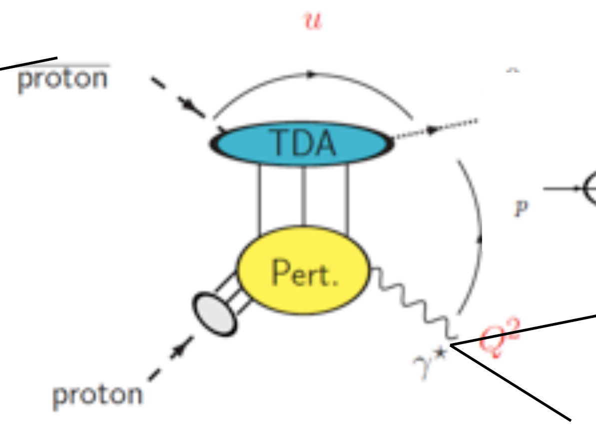


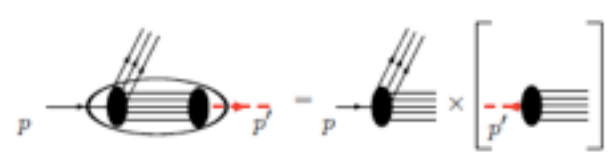


TDAs: Factorization: Hard limit for backward exclusive processes

TDAs







<u>Pbar P -> $e^+ e^- \pi^0$ can be studied by PANDA</u>

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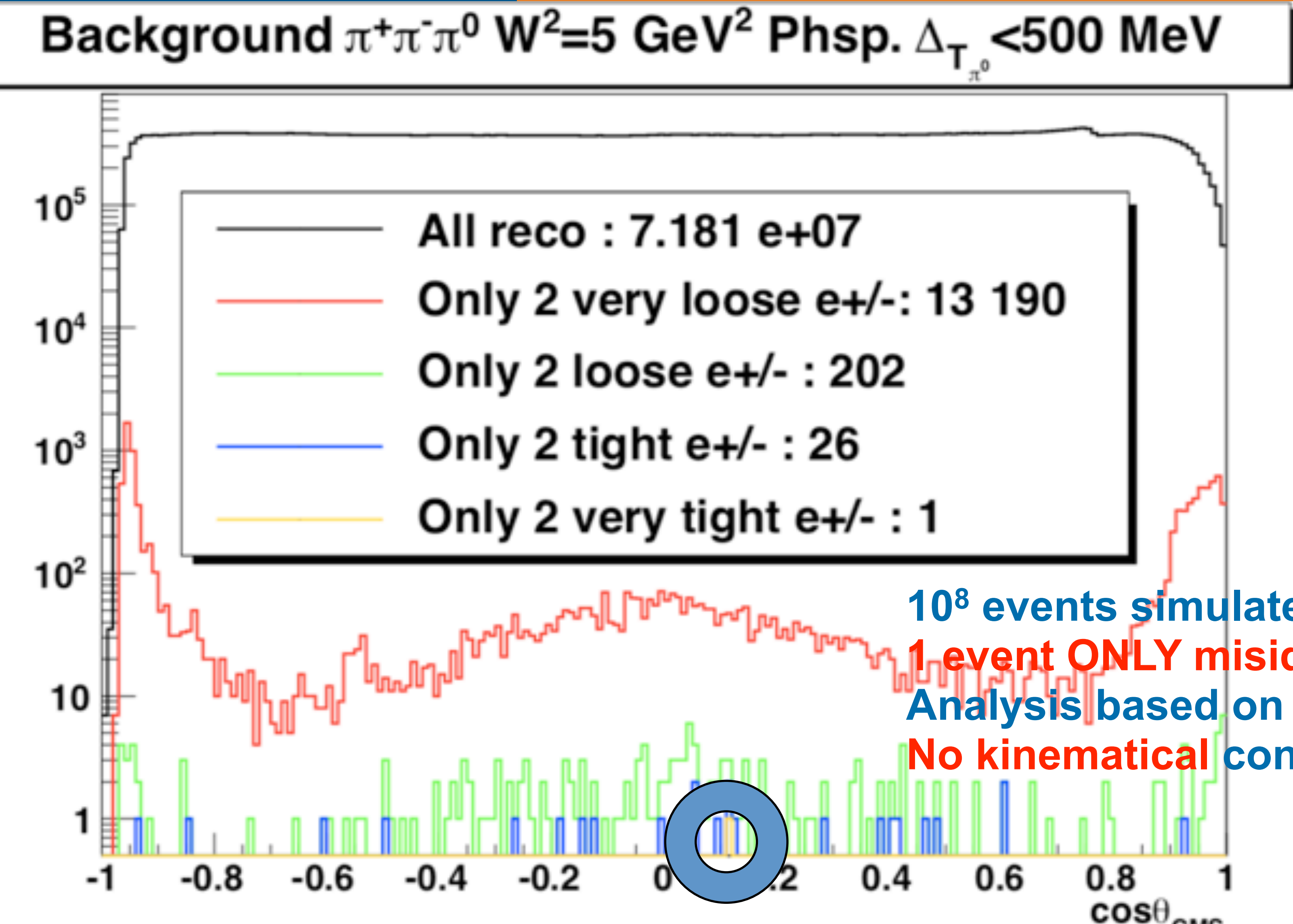
Background: Pbar P -> $\pi^+ \pi^- \pi^0$



10^8 events simulated

1 event ONLY misidentified

Analysis based on PID only

No kinematical constraints yet

Manuel Zambrana, Maria Carmen Mora Espi

Signal: Pbar P -> $e^+ e^- \pi^0$ (access to TDAs)

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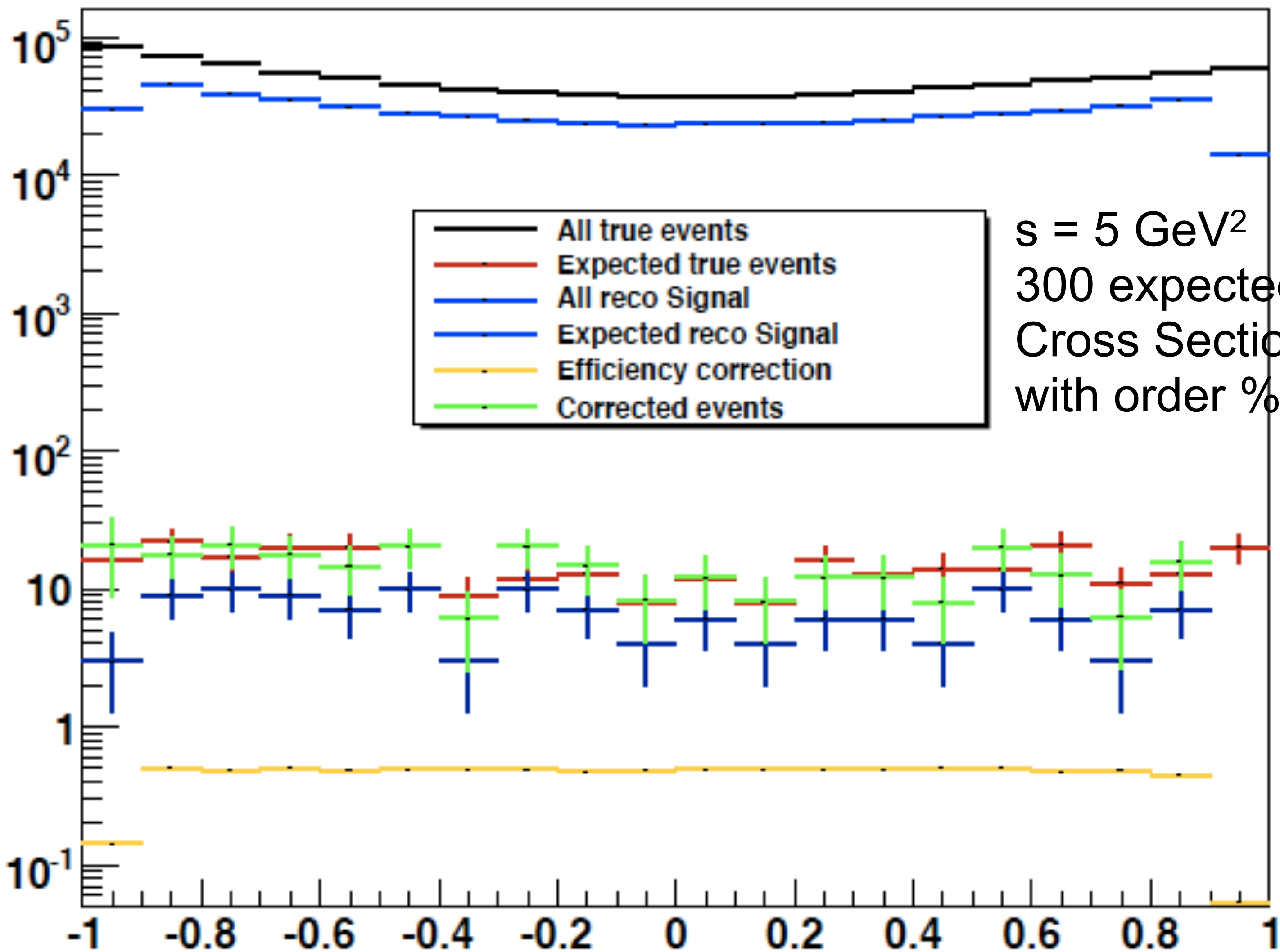
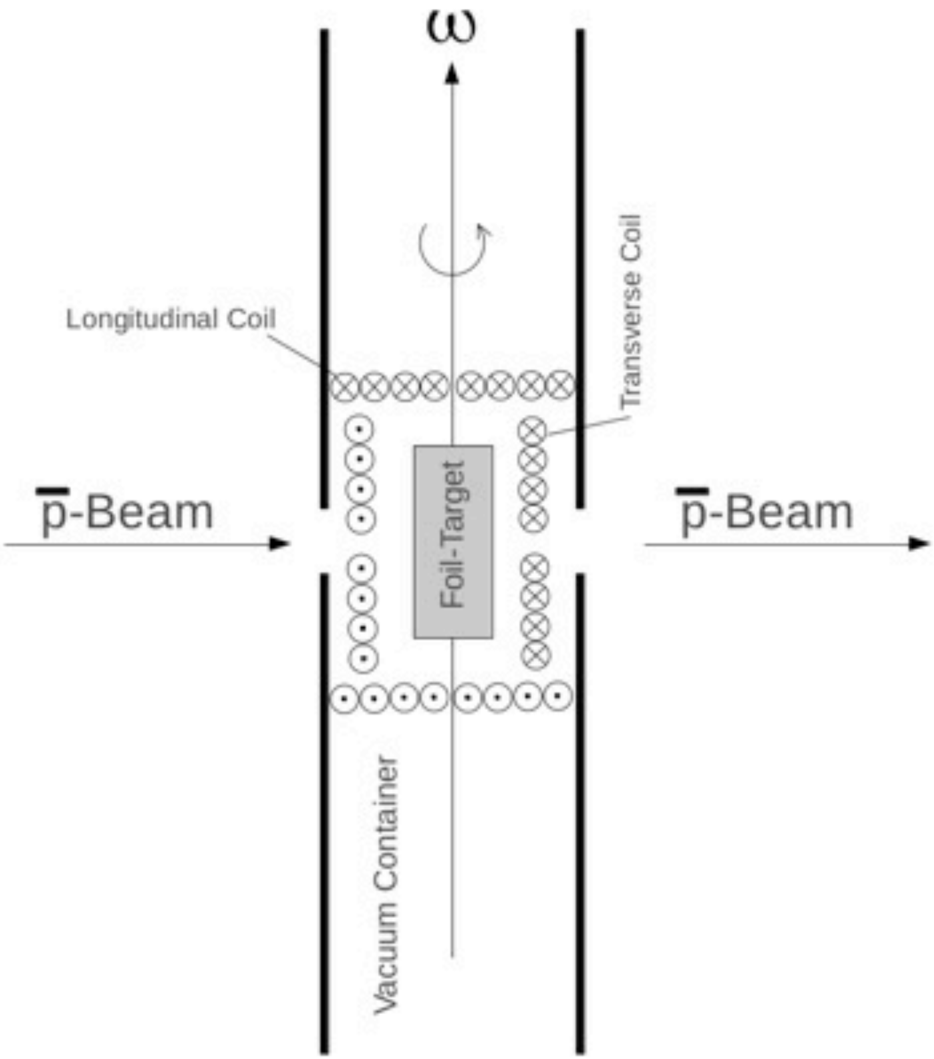


s = 5 GeV^2
300 expected events
Cross Section Measurement with order % accuracy

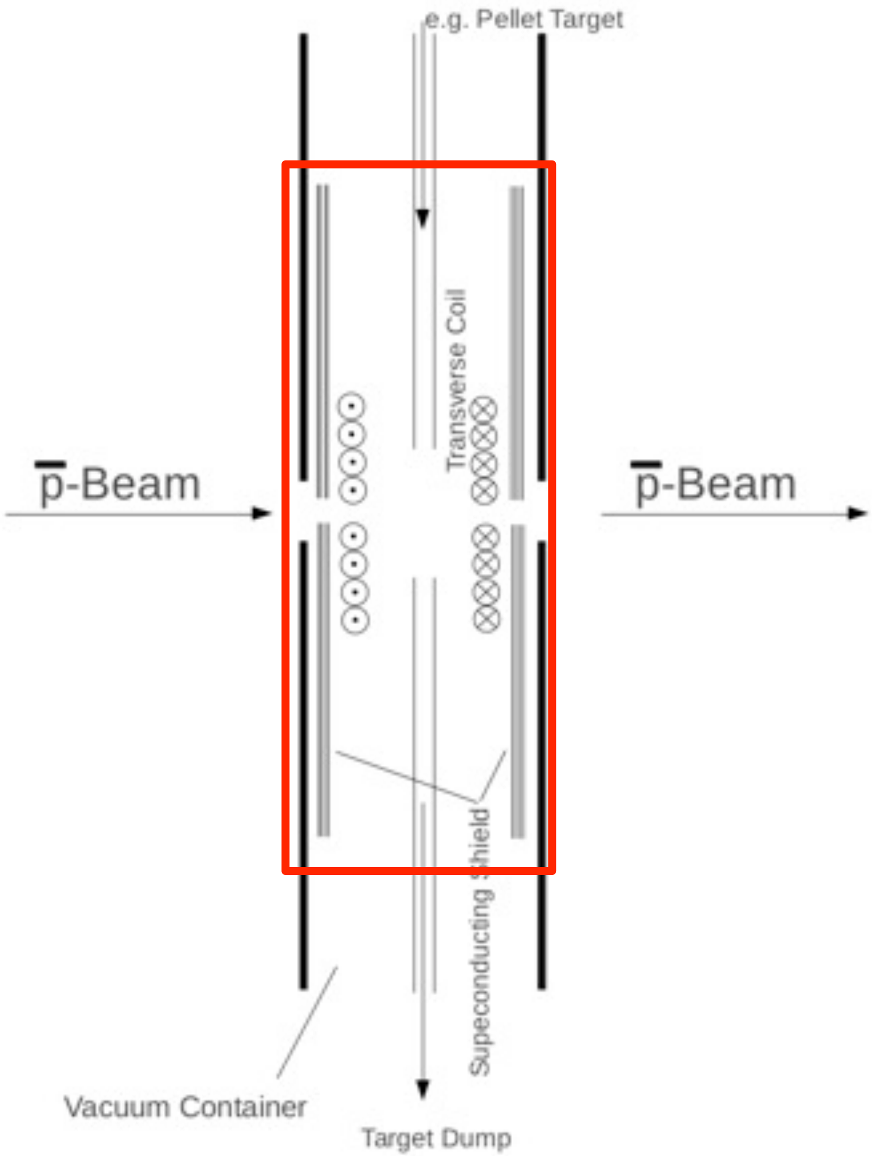
Manuel Zambrana, Maria Carmen Mora Espi

transversely polarised Target in PANDA



- 2T PANDA Solenoid
- a second thin superconducting solenoid in reversed direction
- additional transverse coil polarizes the target foil
- study the field inhomogeneity
- study torque acting on them

transversely polarised Target in PANDA



- Meissner Effect: superconducting foil for the shielding of the 2T field
- Transverse coil polarizes the target
- One cryogenic system for superconductor and target
- No torque on coil and low inhomogeniety in the magnetic field
- Study field penetration (Simulation with Opera and Mathematica)

Drell-Yan in PANDA: Pbar P -> $e^+ e^-$ X

- PANDA can be used as a di-electron Spectrometer
  large (10^6 - 10^7) hadronc background
  can be suppressed

- Shown in simulations for
  pbar p -> $e^+ e^-$
  pbar p -> $e^+ e^- \pi^0$
  using particle identification and kinematical constraints

- next step: apply to Drell-Yan process

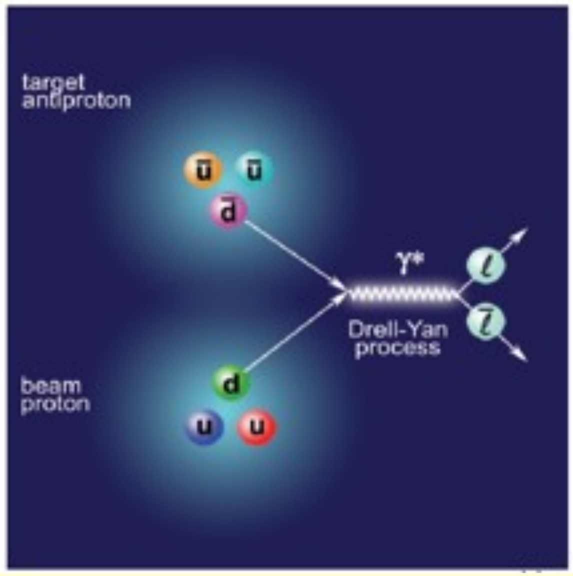
- polarised target: FEM simulations of magneic field and
  effect on detector performance (tracking): long way to go

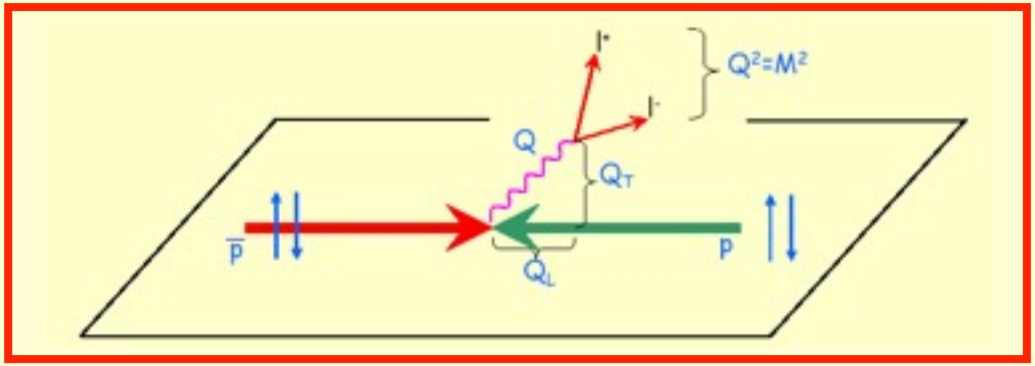
PAX-Experiment

doubly polarised Drell-Yan

(polarised Antiproton beam)

Accesso to transversity through Drell-Yan



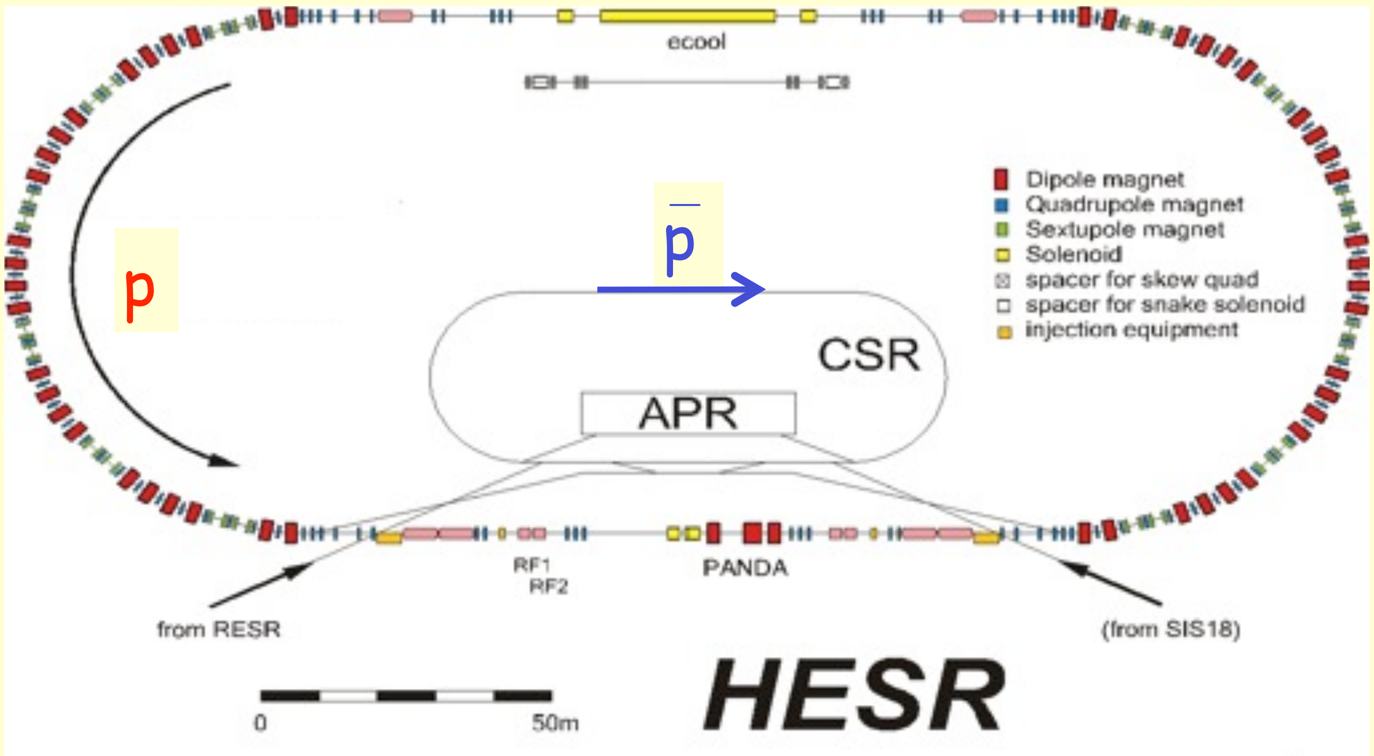


$$A_{TT} = \frac{d\sigma^{\uparrow\uparrow} - d\sigma^{\uparrow\downarrow}}{d\sigma^{\uparrow\uparrow} + d\sigma^{\uparrow\downarrow}} = \hat{a}_{TT} \frac{\sum_q e_q^2 \left[h_{1q}(x_1)h_{1q}(x_2) + h_{1\bar{q}}(x_1)h_{1\bar{q}}(x_2)\right]}{\sum_q e_q^2 \left[q(x_1)q(x_2) + \bar{q}(x_1)\bar{q}(x_2)\right]}$$

A double polarized pbar-p collider for FAIR

Asymmetric (double-polarized)

proton (15 GeV/c) – antiproton (3.5 GeV/c) collider



h_{1u} from $\bar{p}\uparrow$-$p\uparrow$ Drell-Yan at PAX

$$A_{TT} = \frac{d\sigma^{\uparrow\uparrow} - d\sigma^{\uparrow\downarrow}}{d\sigma^{\uparrow\uparrow} + d\sigma^{\uparrow\downarrow}} = \hat{a}_{TT} \frac{\sum_q e_q^2 \left[h_{1q}(x_1)h_{1q}(x_2) + h_{1\bar{q}}(x_1)h_{1\bar{q}}(x_2)\right]}{\sum_q e_q^2 \left[q(x_1)q(x_2) + \bar{q}(x_1)\bar{q}(x_2)\right]}$$

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- u-dominance
- $|h_{1u}| > |h_{1d}|$

$$A_{TT} \approx \hat{a}_{TT} \frac{h_{1u}(x_1)h_{1u}(x_2)}{u(x_1)u(x_2)}$$

h_{1u} from $\bar{p}\uparrow$-$p\uparrow$ Drell-Yan at PAX

$$A_{TT} = \frac{d\sigma^{\uparrow\uparrow} - d\sigma^{\uparrow\downarrow}}{d\sigma^{\uparrow\uparrow} + d\sigma^{\uparrow\downarrow}} = \hat{a}_{TT} \frac{\sum_q e_q^2 \left[h_{1q}(x_1)h_{1q}(x_2) + h_{1\bar{q}}(x_1)h_{1\bar{q}}(x_2)\right]}{\sum_q e_q^2 \left[q(x_1)q(x_2) + \bar{q}(x_1)\bar{q}(x_2)\right]}$$

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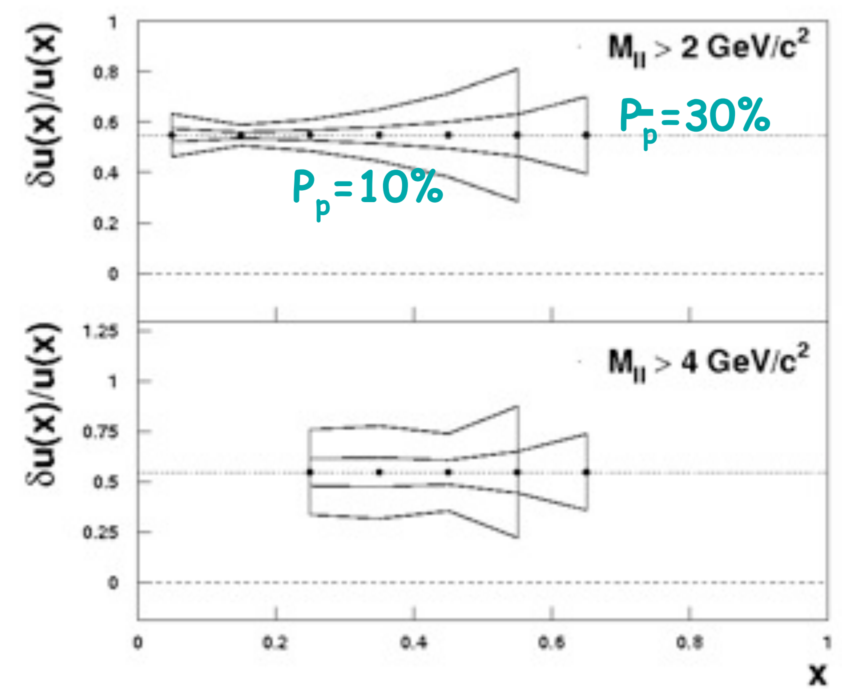


1 year run -> 10 % precision on the h_1^u (x) in the valence region

Polarized antiprotons

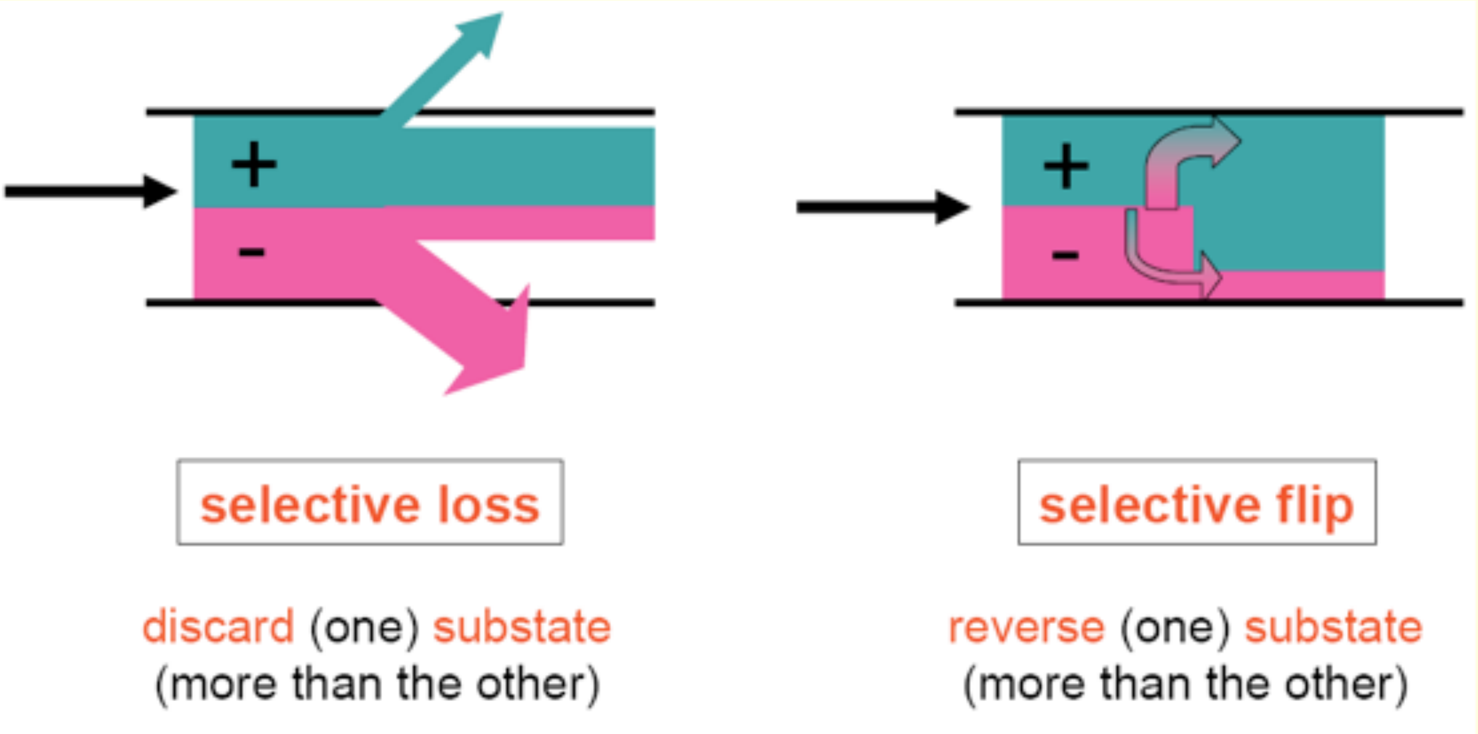
Intense beam of polarized pbar never produced:

- Synchr. radiation ~ $\mu(\gamma^4/R)$ -> τ_{pol} ~10^7 y in 20 TeV pbar ring
- Conventional methods (ABS) not applicable
- Polarized pbar from antilambda decay
  - $I < 1.5 \cdot 10^5\ s^{-1}$ ($P \approx 0.35$)
- Pbar scattering off liquid H_2 target
  - $I < 2 \cdot 10^3\ s^{-1}$ ($P \approx 0.2$)

Production of polarization in a stored beam

Two Methods: Loss versus spin flip

For an ensemble of spin ½ particles with projections + (↑) and – (↓)



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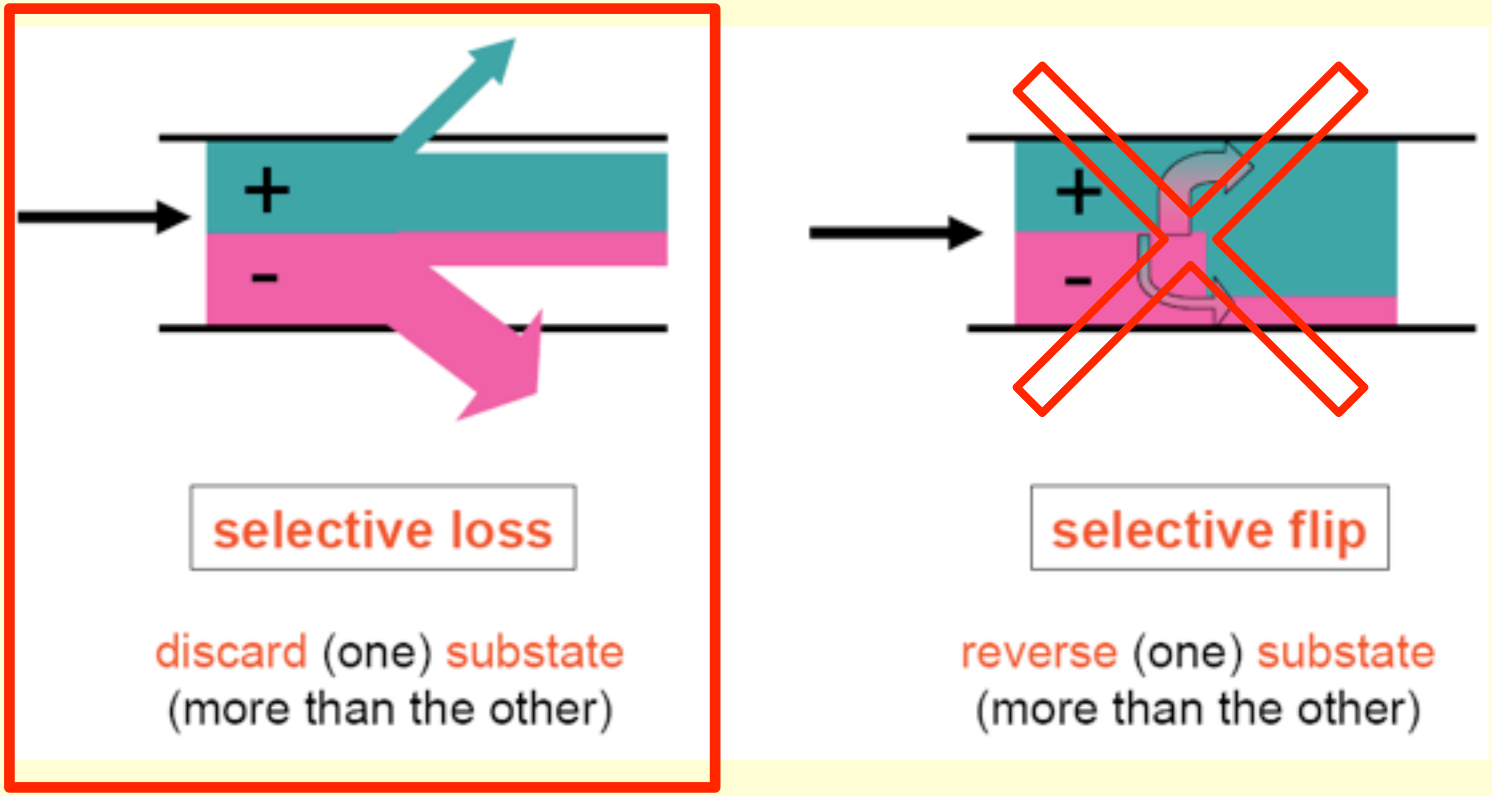
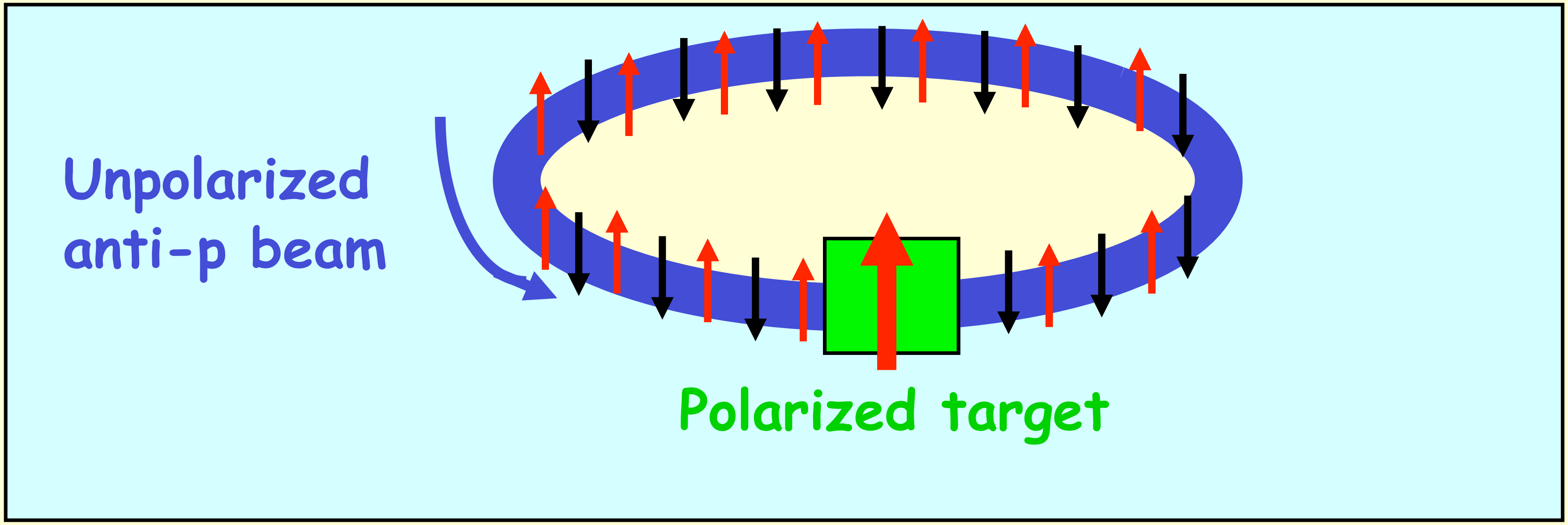


Polarization Buildup

$$P(t) = \frac{N_{\uparrow} - N_{\downarrow}}{N_{\uparrow} + N_{\downarrow}} = \tanh(t/\tau_1)$$



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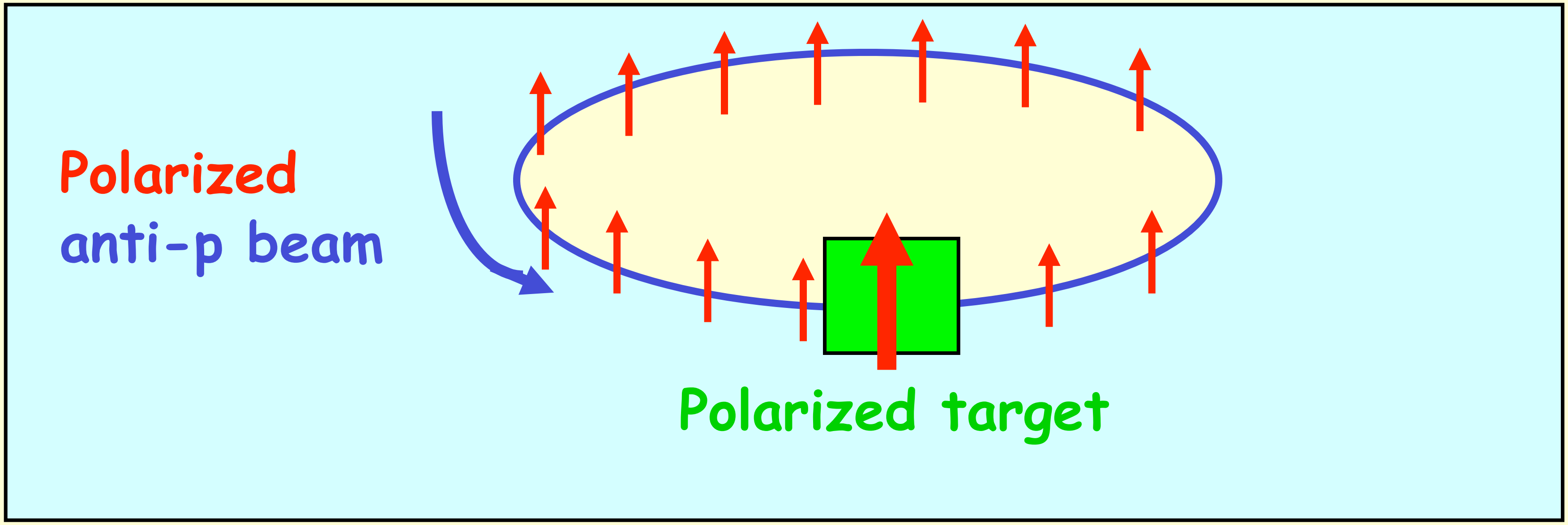
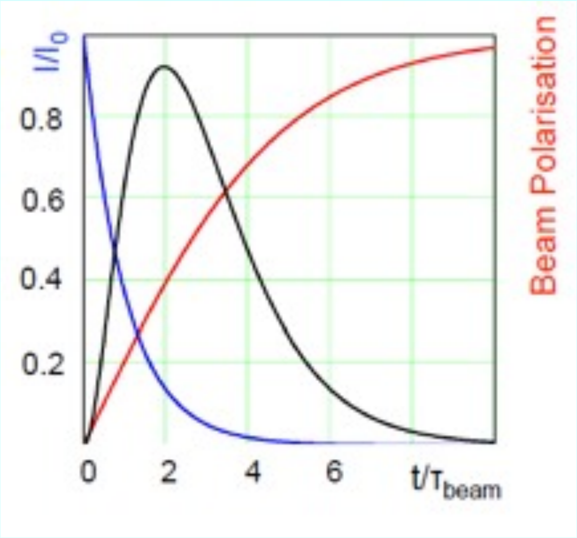


Polarization Buildup

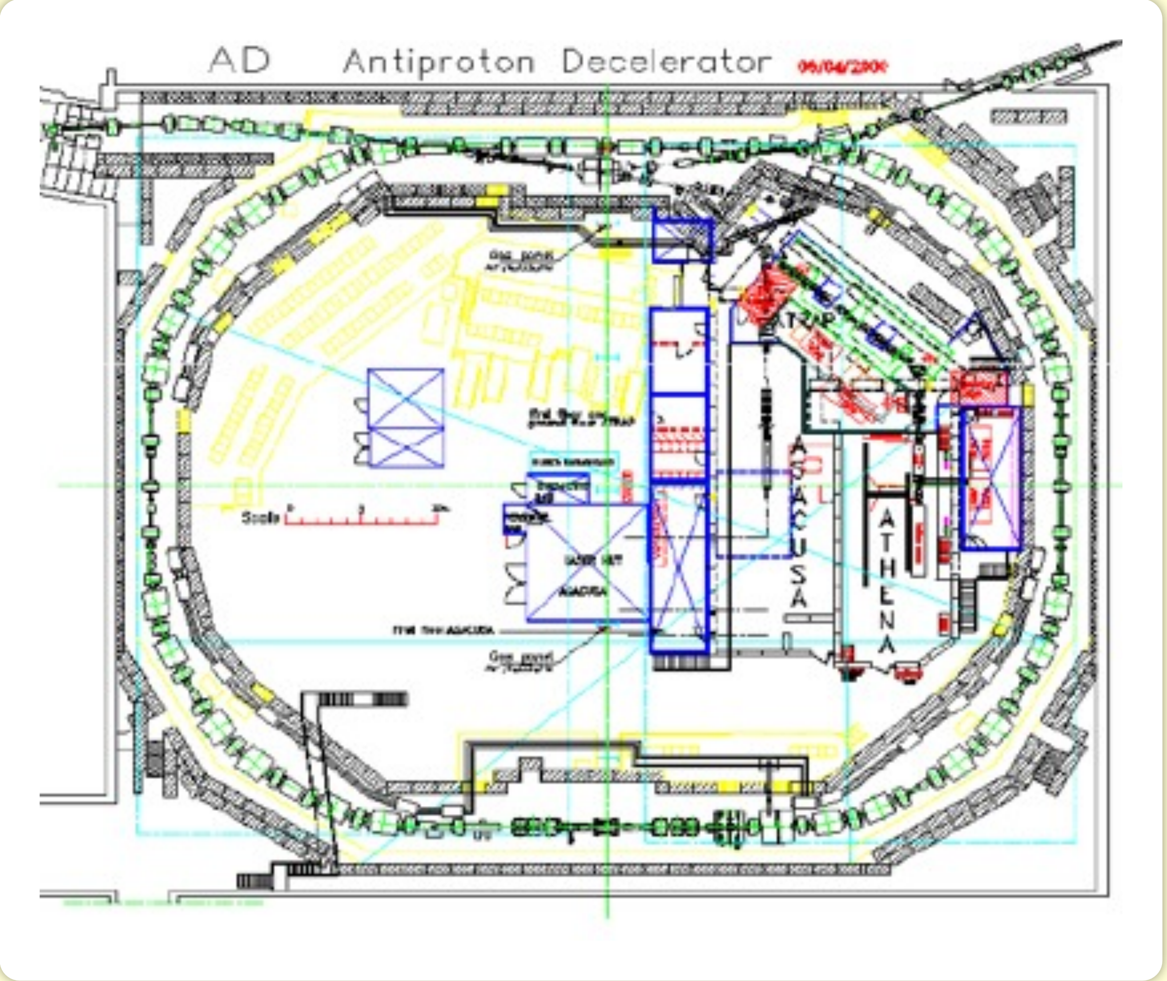
$$P(t) = \frac{N_{\uparrow} - N_{\downarrow}}{N_{\uparrow} + N_{\downarrow}} = \tanh(t/\tau_1)$$

Optimum (black curve)
after 2 lifetimes filtering



Measurements at AD (CERN)

- Aim: 1st measurement of the spin-dependence of the pbar-p cross section
- Method: measurement of polarization build-up by spin-filtering



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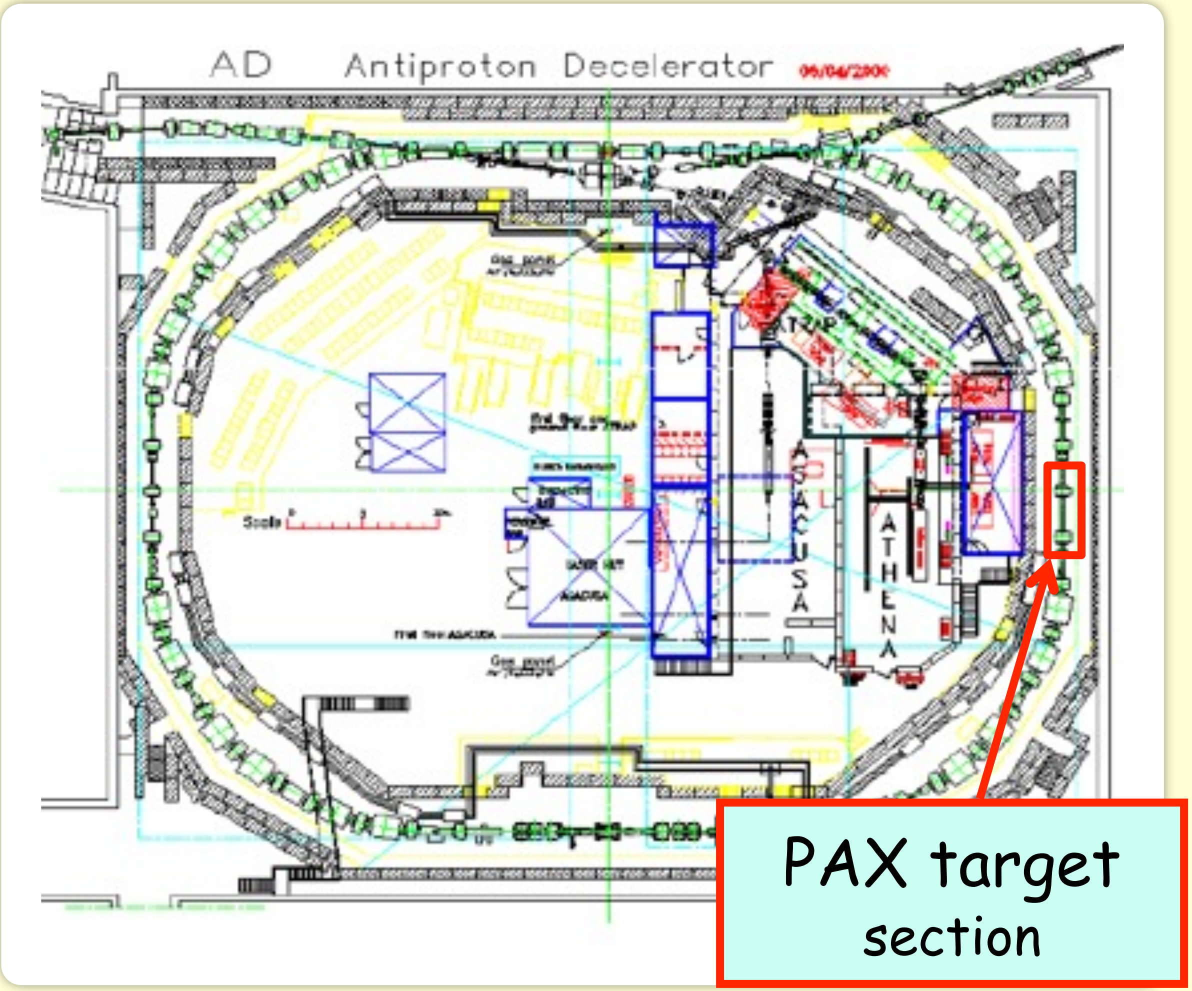
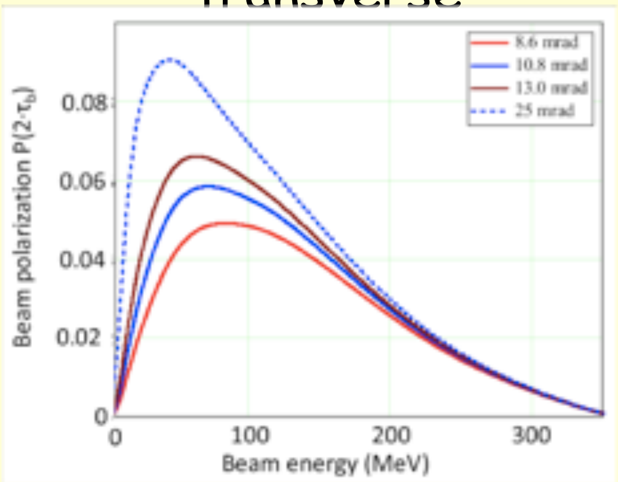


Expected polarizations after filtering for two lifetimes

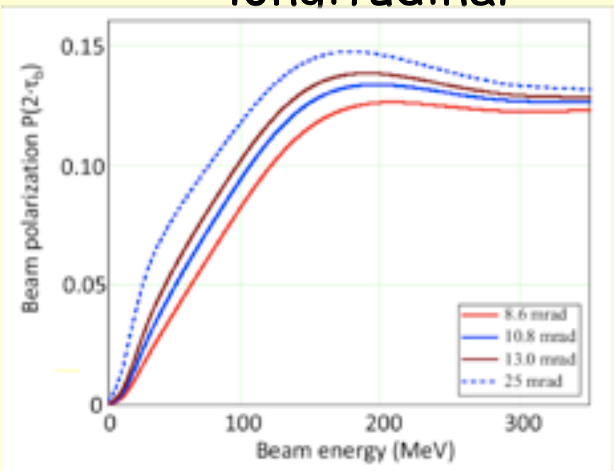
- Measurement of the polarization buildup allows determination of σ_1 and σ_2
- Once pbar polarization available, spin-correlation coefficients accessible

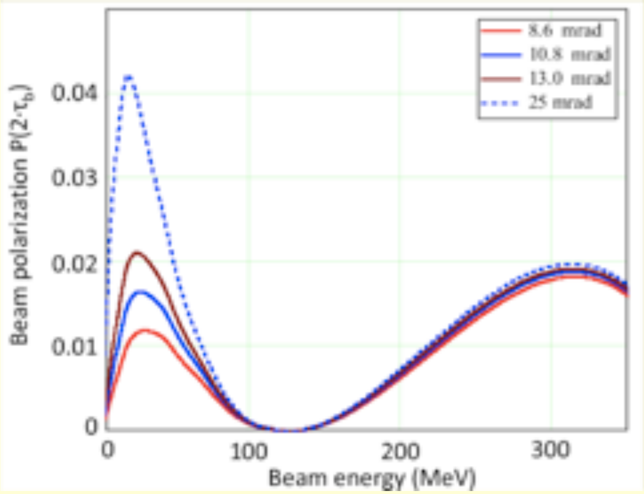
transverse

longitudinal

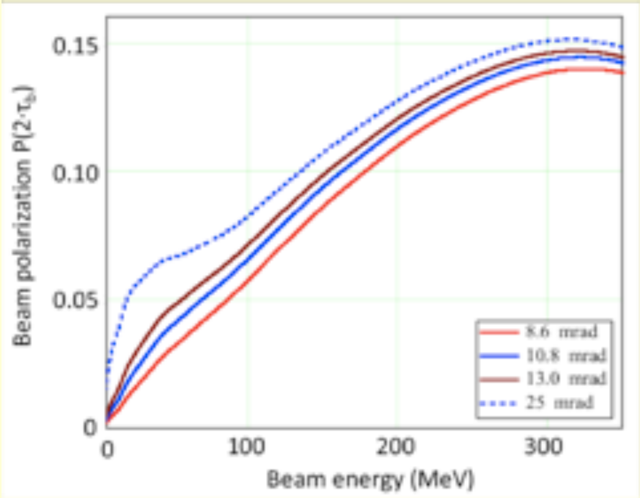


A





D



Installation of low-β section at COSY

- Beam has to fit through storage cell target ($d_t = 5 \times 10^{13}$ atoms/cm^2)
- Increase acceptance angle at target position

Now: 4 weeks run for spin filtering at COSY

Electron-Nucleon Collider (ENC)

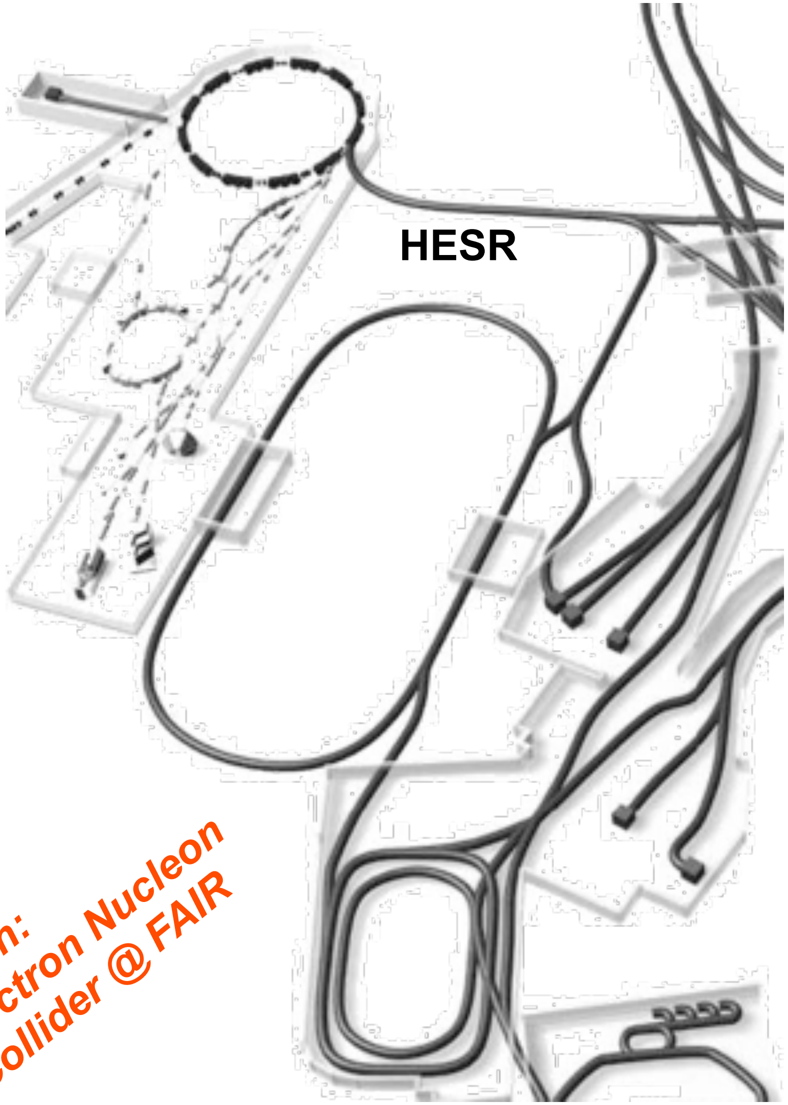
polarised electron-nucleon collider

at PANDA@HESR@FAIR

High luminosity lepton-nucleon collider

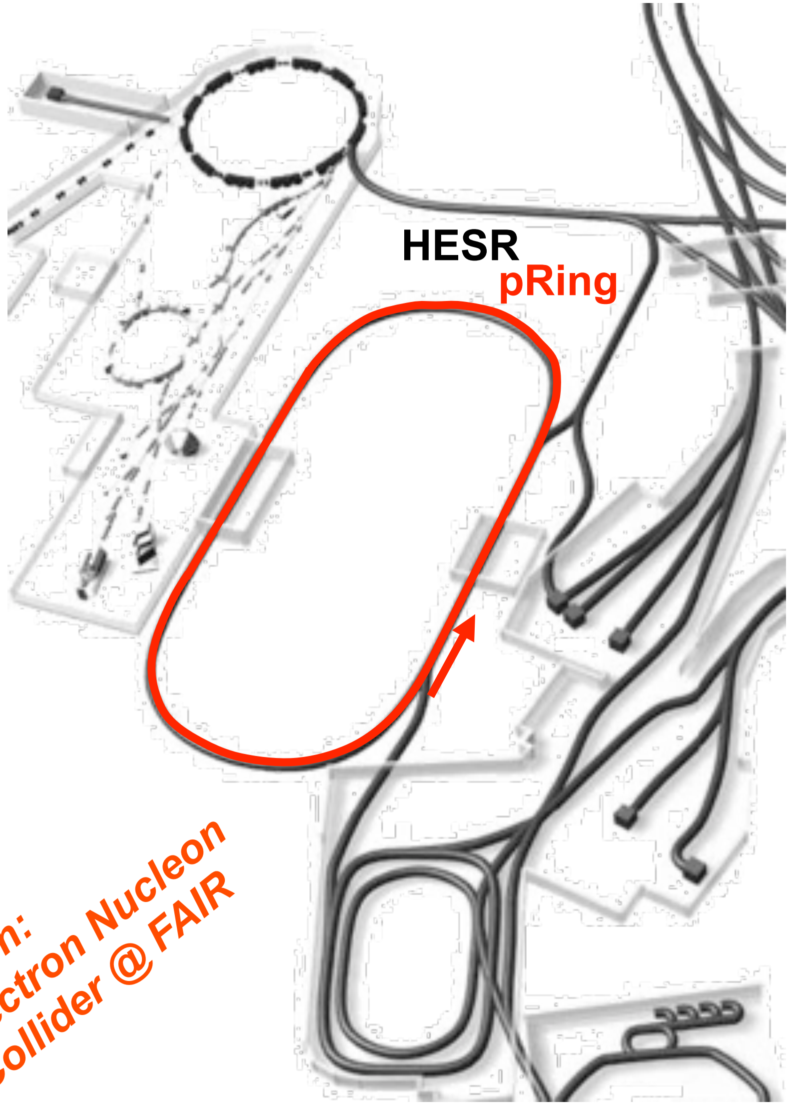
- High E_{cm} yields a large range of x, Q^2
  - x range: valence, sea quarks, glue
  - Q^2 range: evolution equations of QCD
- High polarization of lepton, nucleon achievable
  - dilution in fixed target experiments
- Collider geometry allows complete reconstruction of final state

ENC Accelerator issues



Vision:
Electron Nucleon
Collider @ FAIR

ENC Accelerator issues



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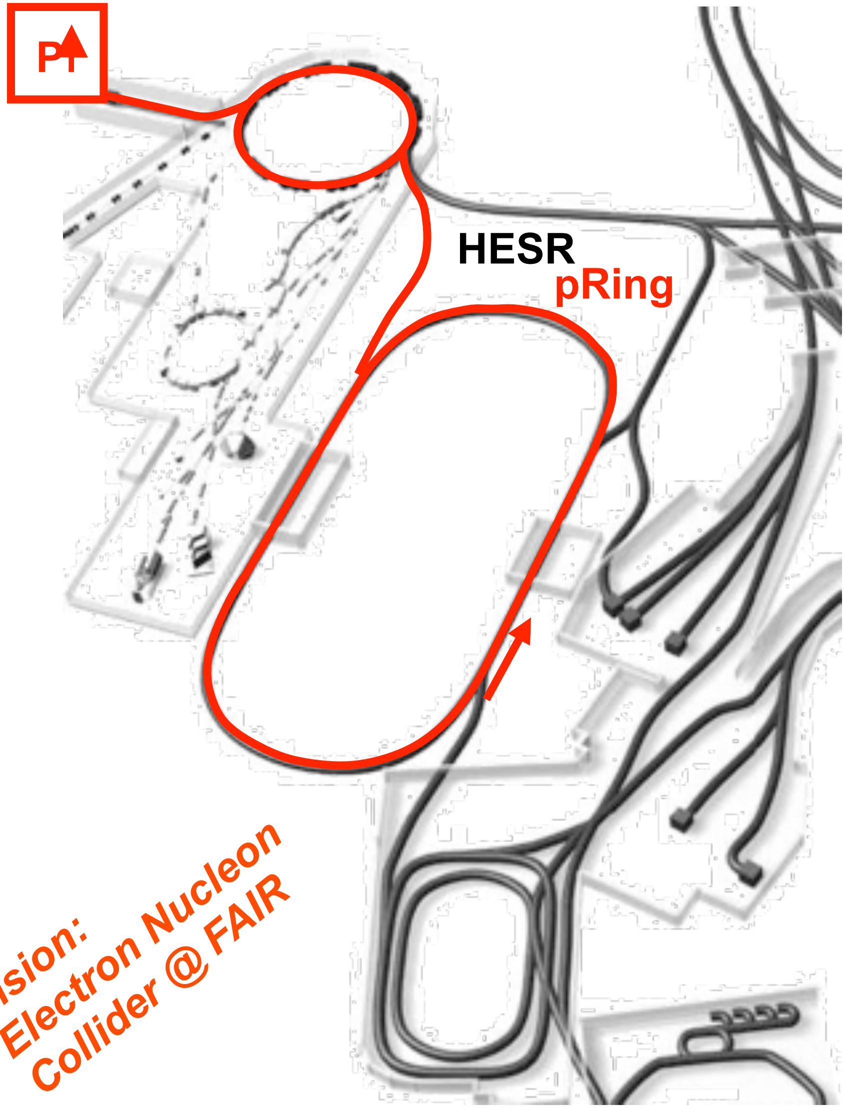

Vision:
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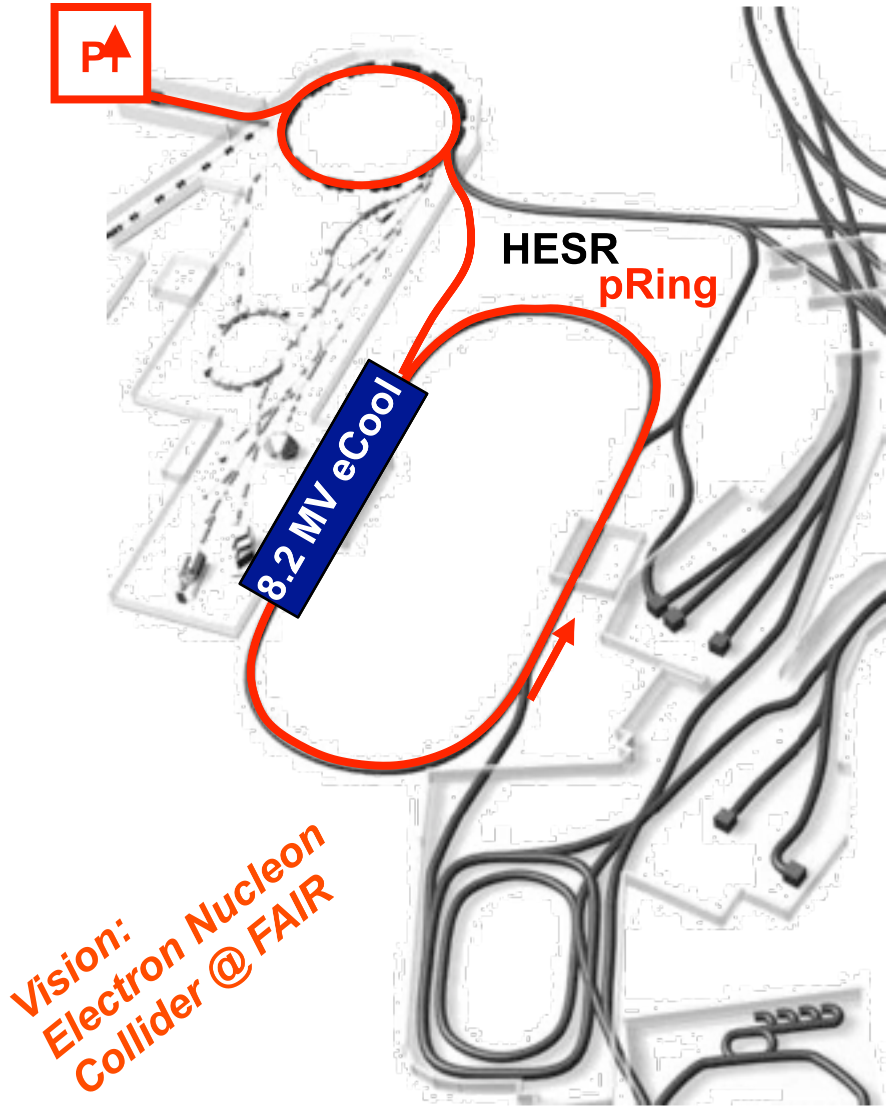

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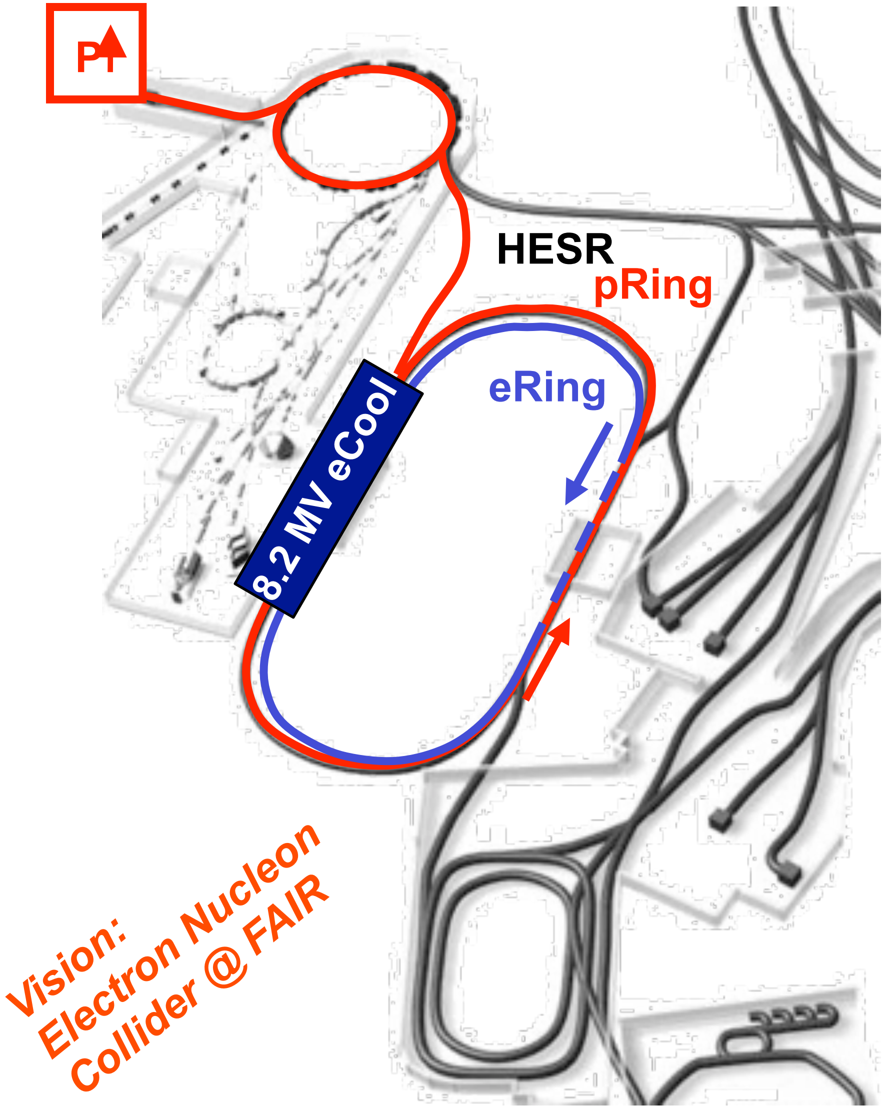

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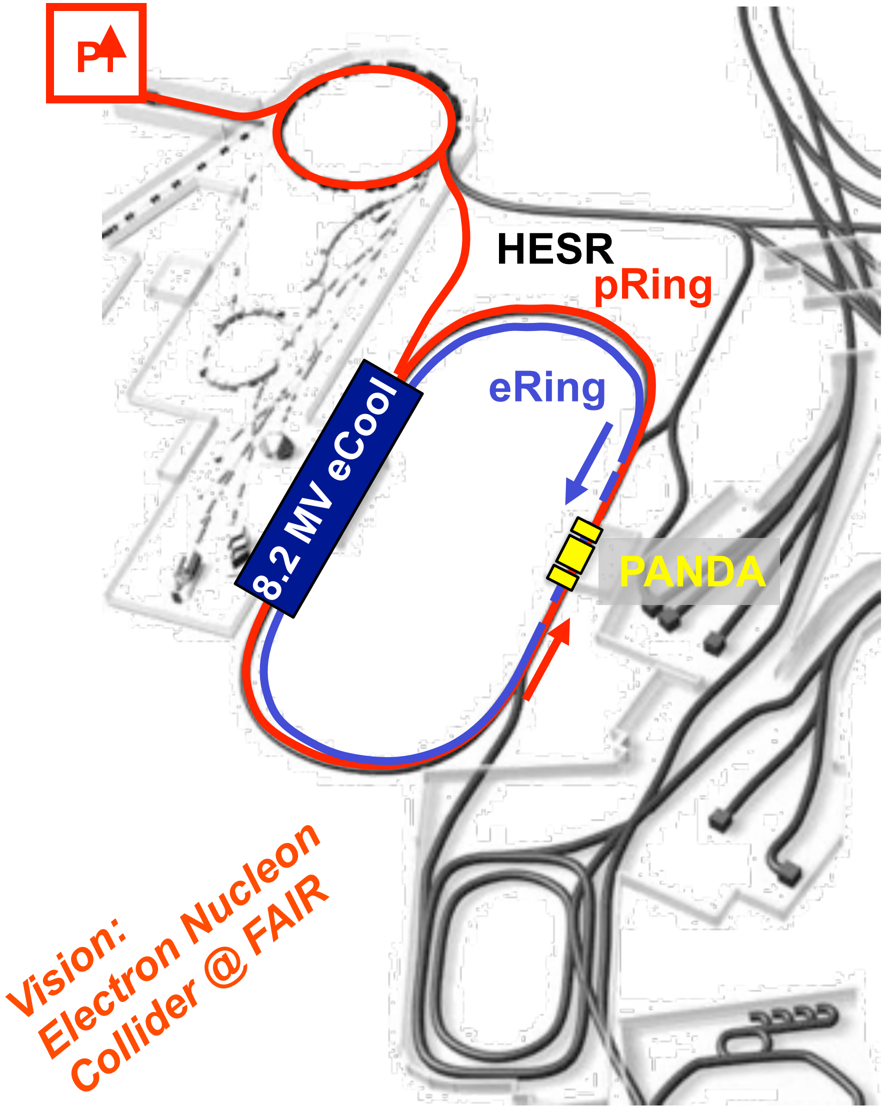
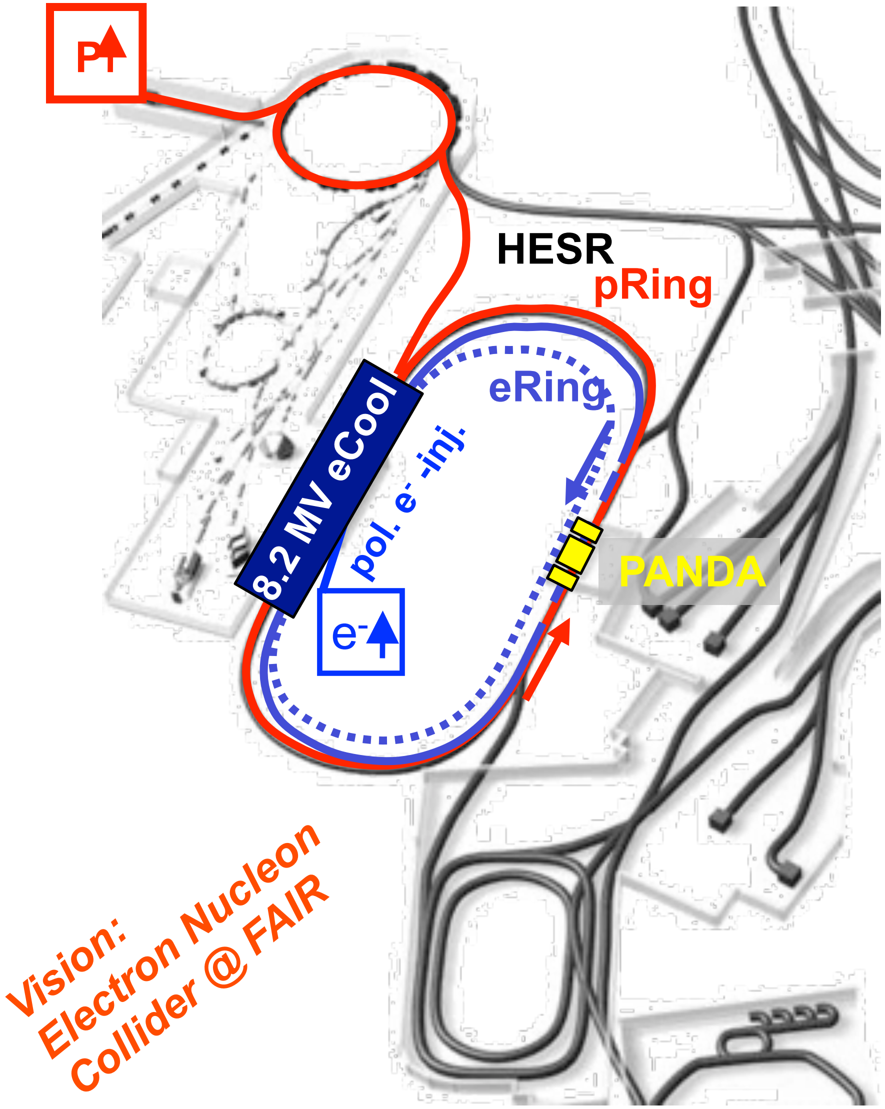
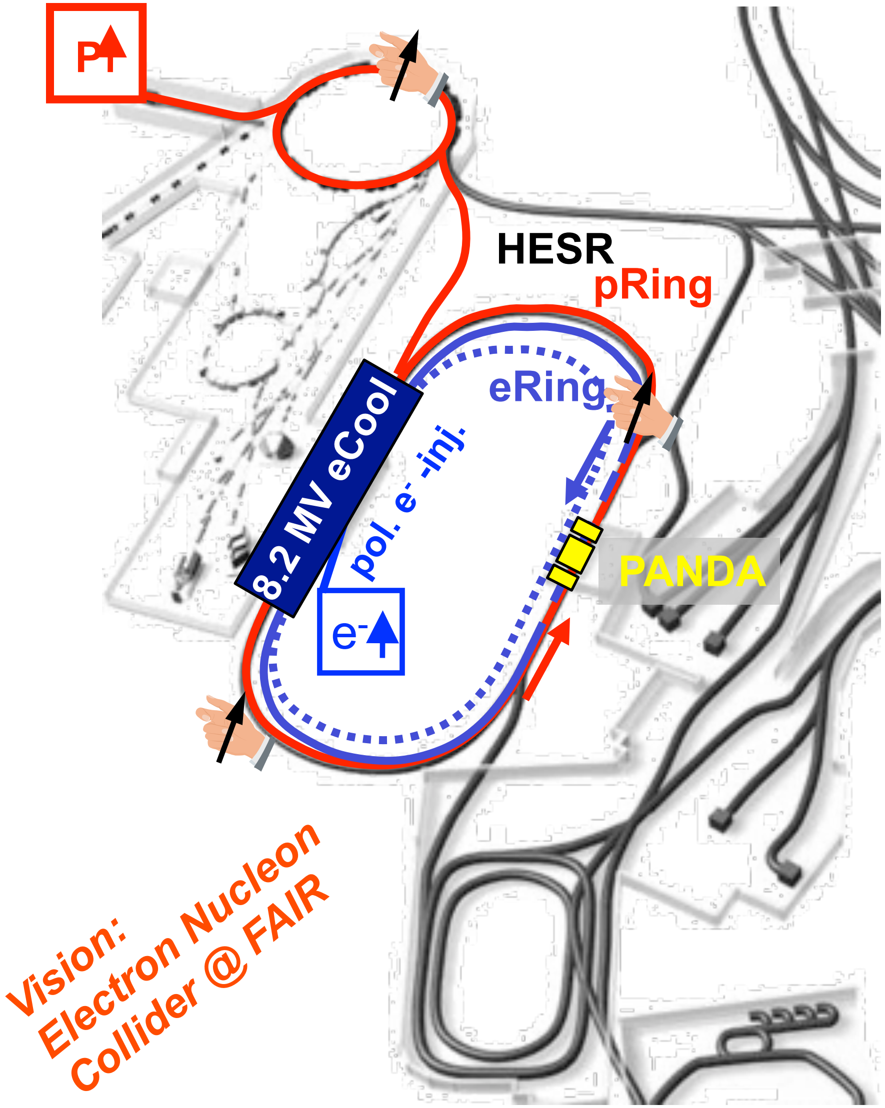


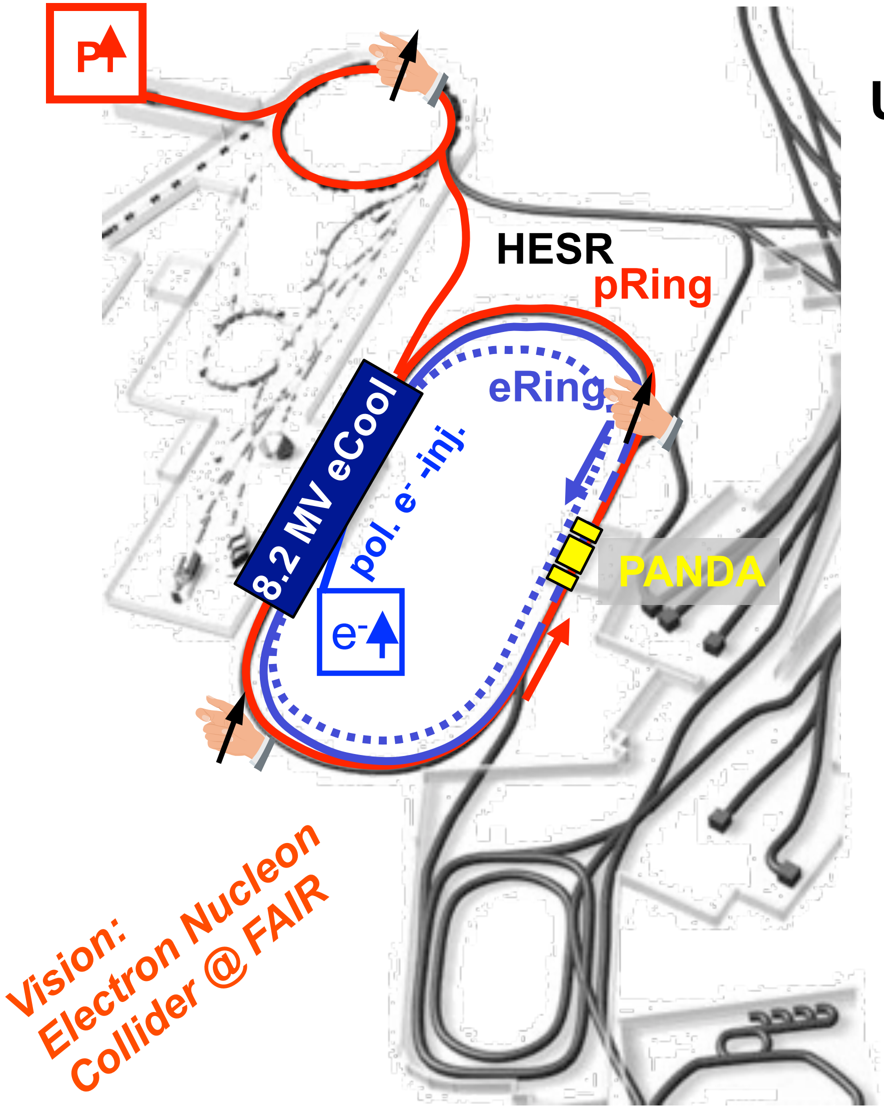
ENC Accelerator issues



ENC Accelerator issues



ENC Accelerator issues



Accelerator collaboration:
Universities Bonn/Dortmund/Mainz and Forschungszentrum Jülich

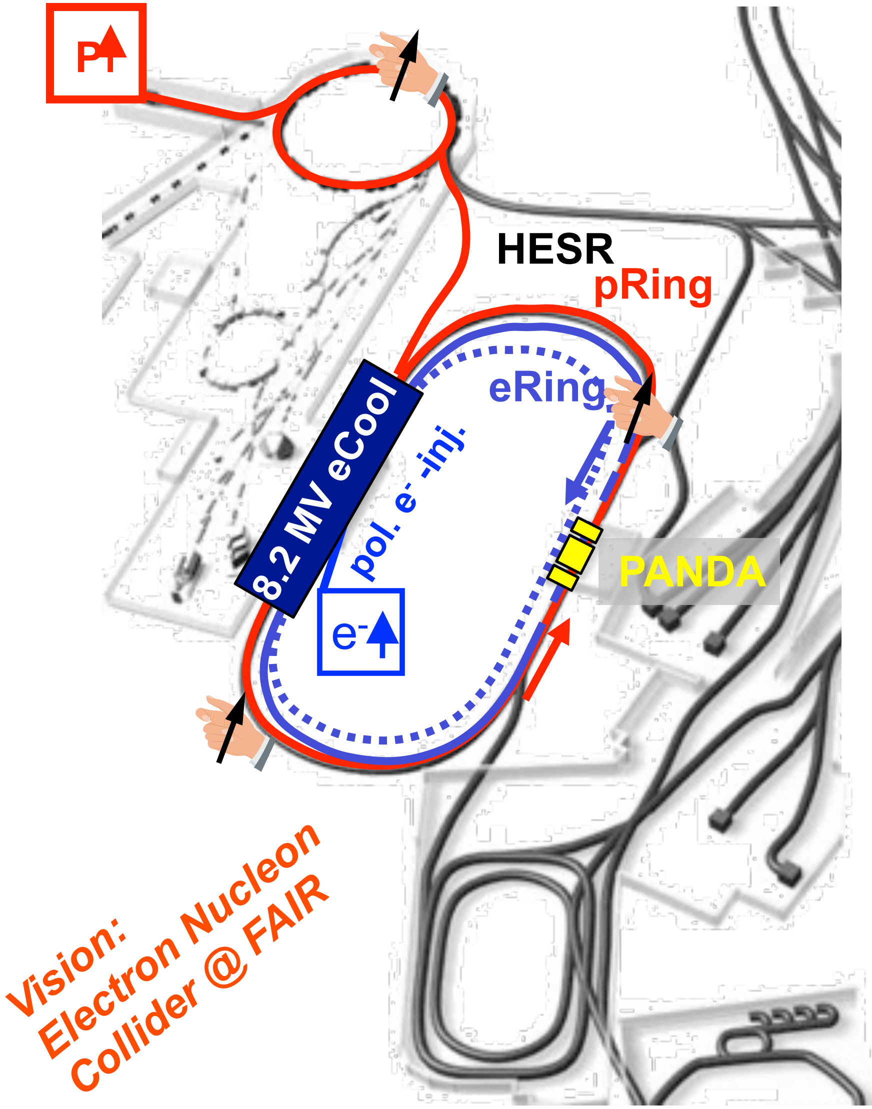
Goal:

L > 4 - 6·10^{32} 1/cm^2s

$s^{1/2}$ > 14 GeV
(3.3 GeV e^- ↔ 15 GeV p)

polarised e^- (80%)
↔
polarised p / d (80%)
(transversal + longitudinal)

ENC Accelerator issues



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$s^{1/2} > 14$ GeV
(3.3 GeV e^- ↔ 15 GeV p)

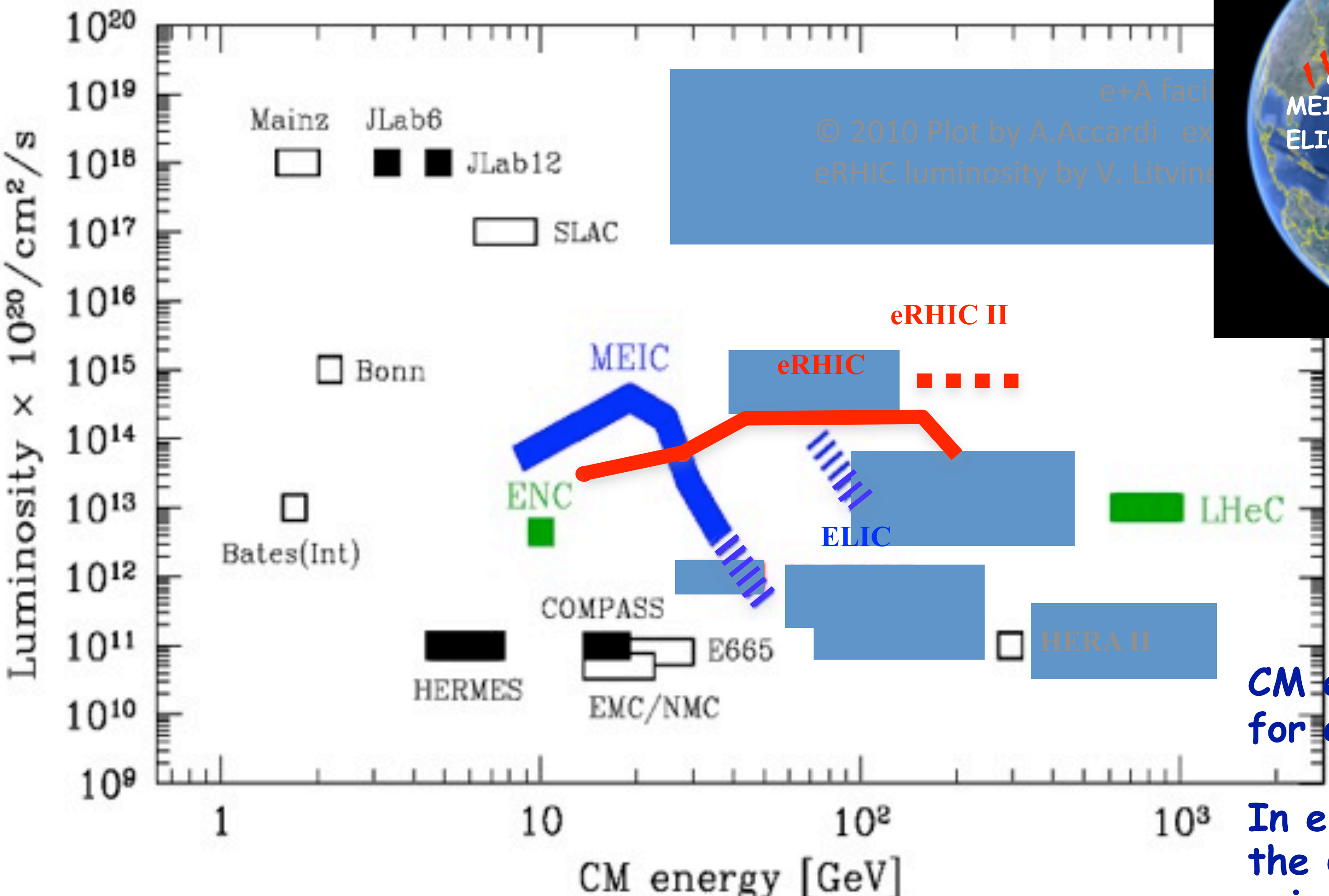
polarised e^- (80%)
↔
polarised p / d (80%)
(transversal + longitudinal)

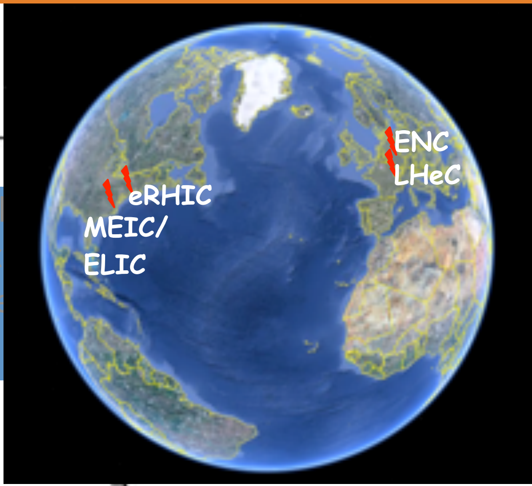
First double polarised Electron Nucleon Collider

Luminosity: 8 x HERA (unpol.)

HELMHOLTZ ASSOCIATION
Helmholtz Institute Mainz

ENCstudy: Energy/Luminosity Landscape

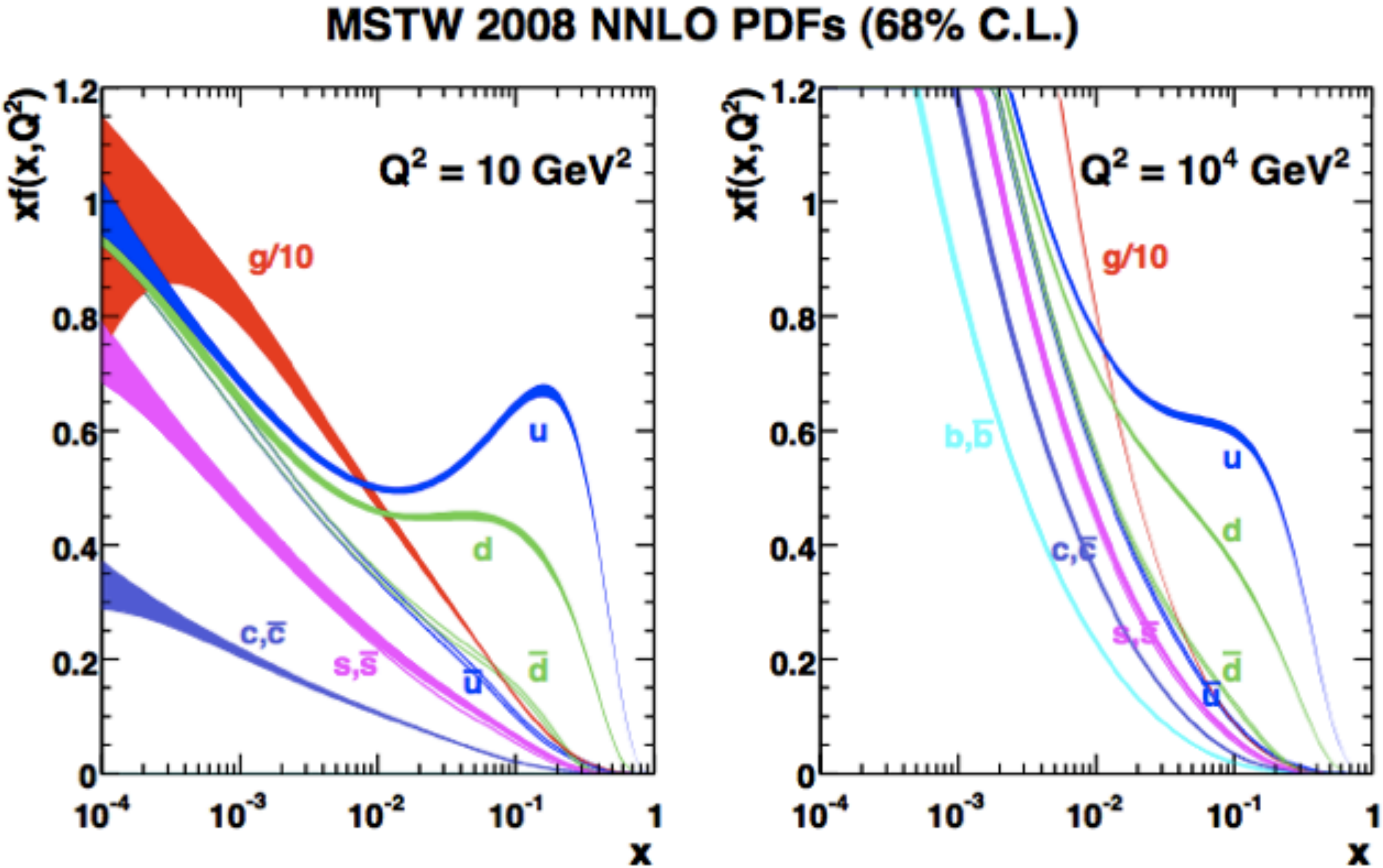




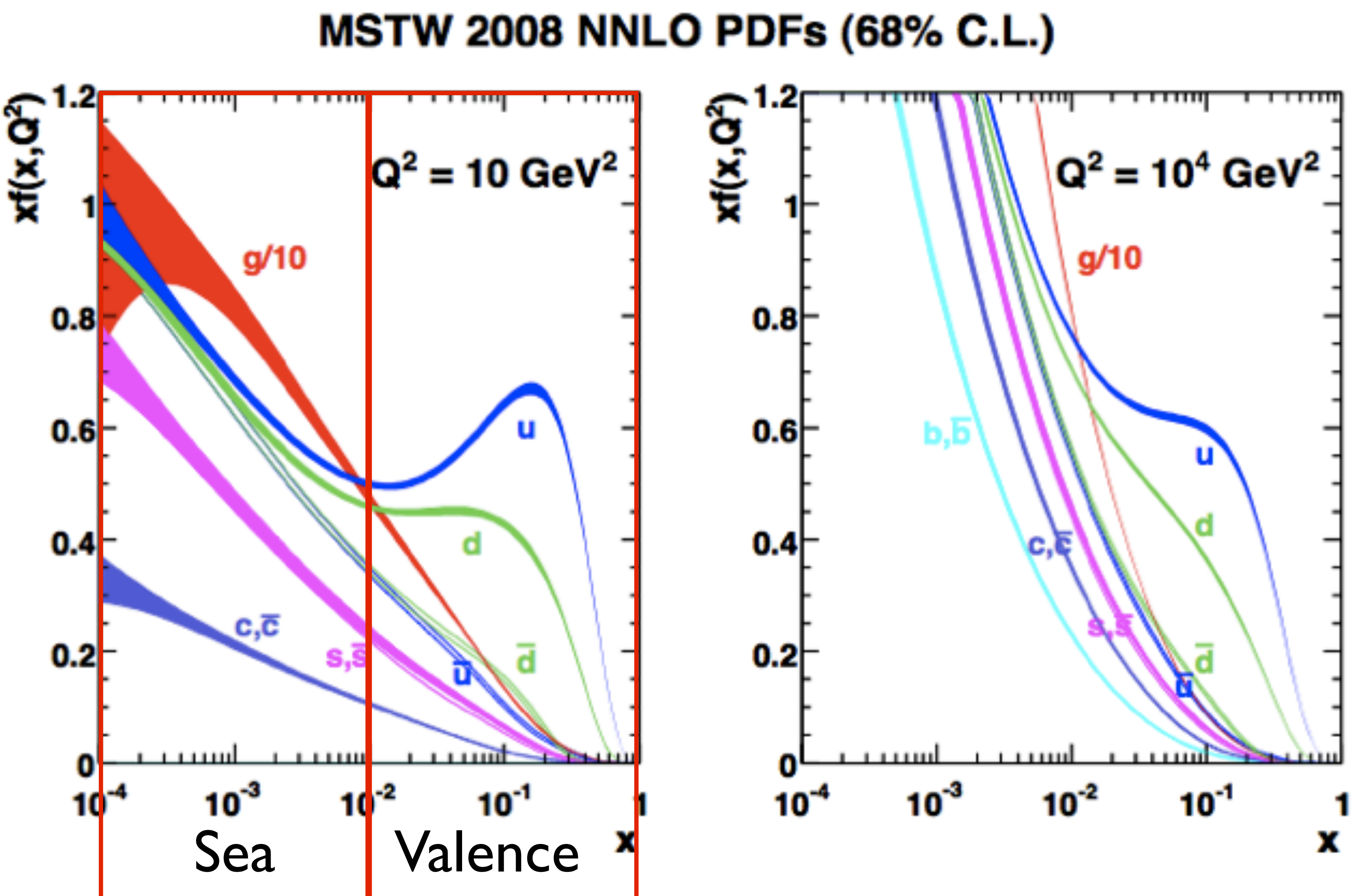
CM energy is shown for e-p collisions

In e-A collisions the CM energy of a pair e-nucleon is ~1.58-fold lower

Unpolarised Parton Distributions



Unpolarised Parton Distributions



Gluon Polarisation

D^0 reconstruction

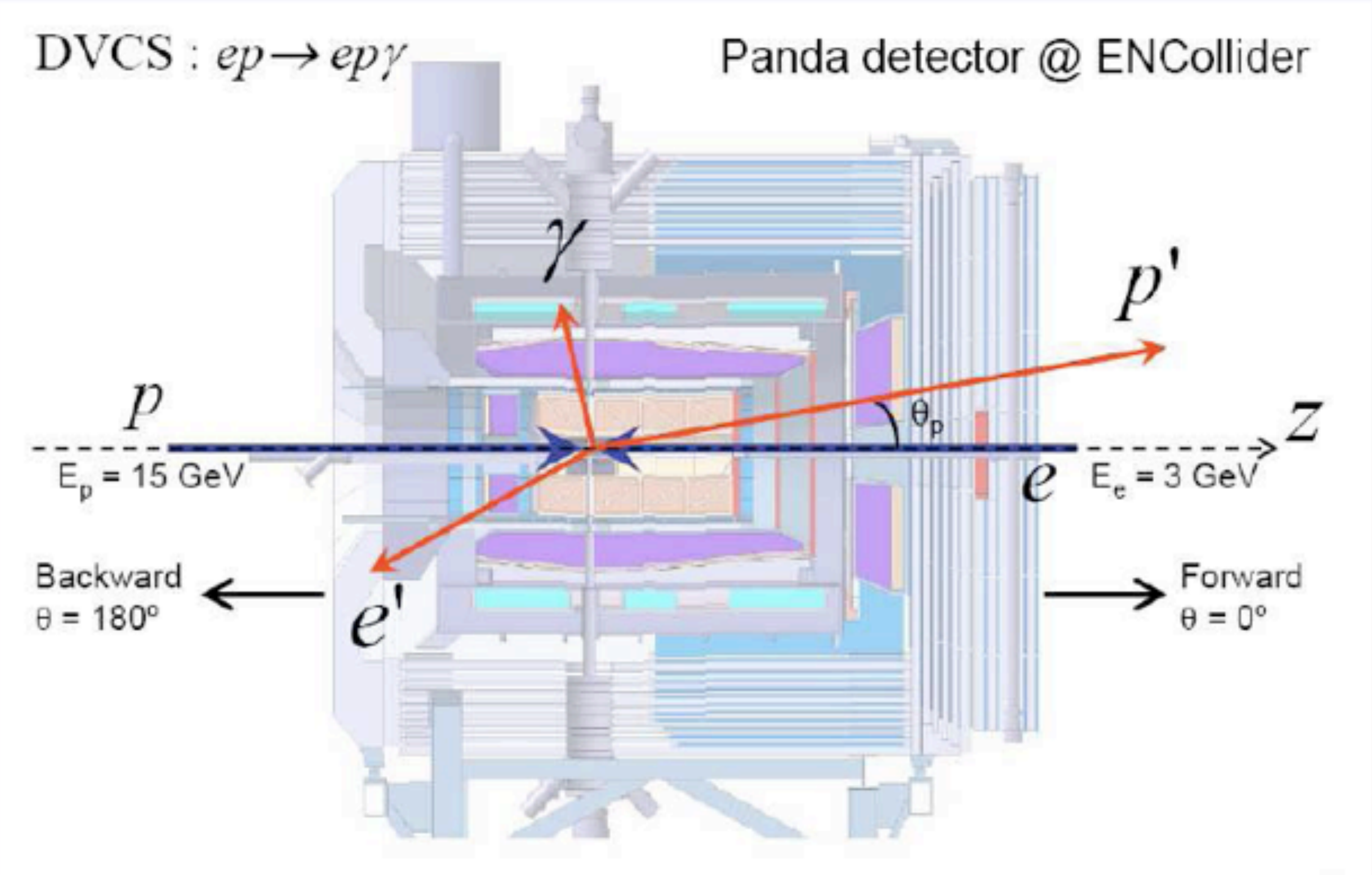
	COMPASS S:B	collider S:B	Gain in FOM*
D^0	1:10	4:1	11
D^*	1:1	1:0	2.6

In COMPASS D^0 and D^* have approximately the same FOM:

$\Rightarrow$ total gain $\approx \frac{11+2.6}{2} =$ **7**

	diluting factor		ratio
	COMPASS	ENC	
double spin asymmetries $(P_T f P_B)^2$	0.026	0.41	16
reconstruction of hadronic final state			≈ 10
mass resolution	☹	☺	
displaced vertices	☹	☺	
more D^0 deacy ch.	☹	☺	
determination of x_g due to reconstruction of D and $\bar{D}$	☹	☺	

Deep Virtual Compton Scattering



Studies done by D. Kang, W. Gradl & M. Fritsch

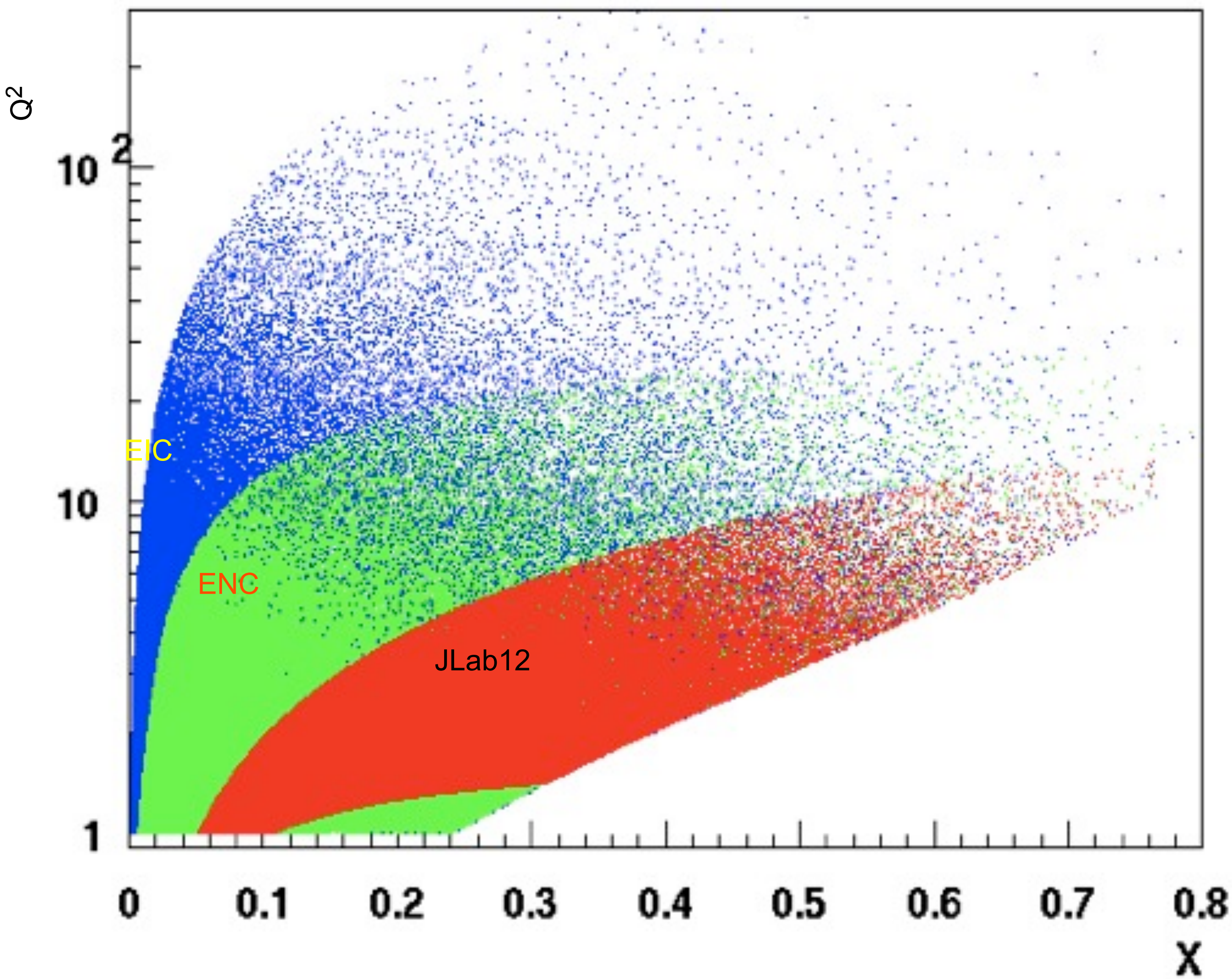
Reconstruction efficiency

using PANDA setup

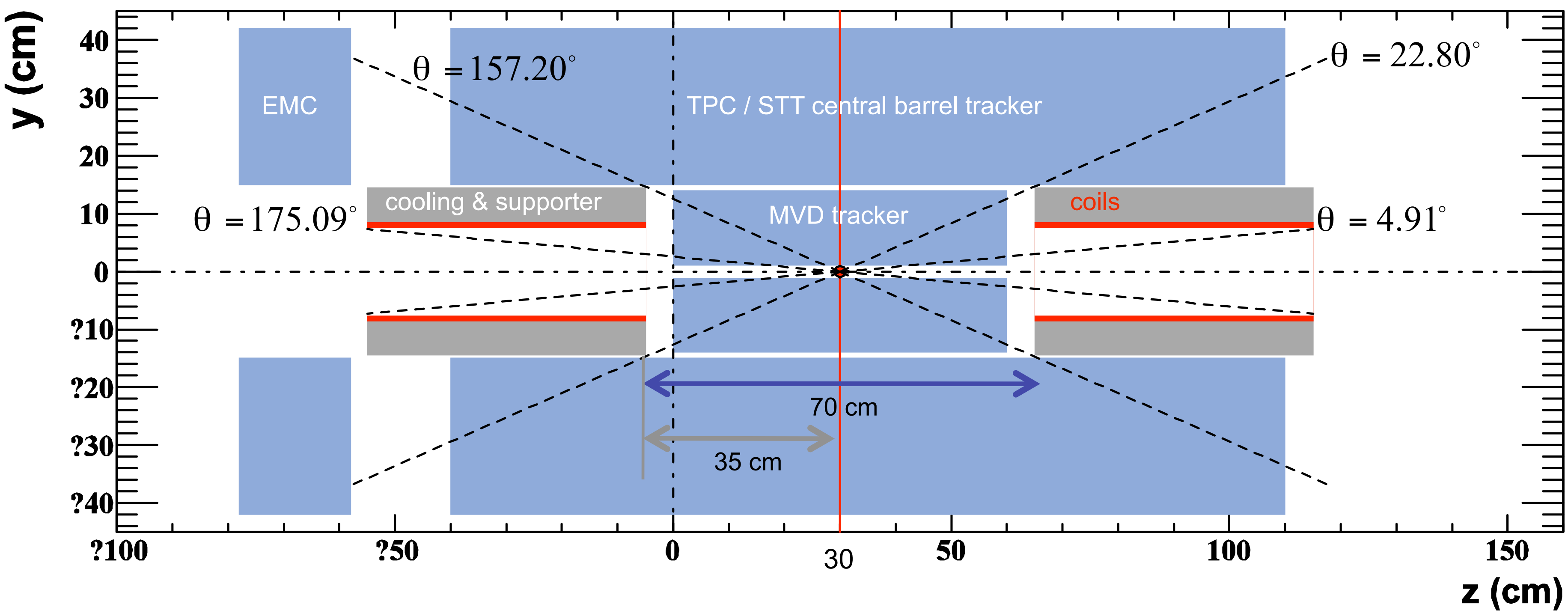
particle	efficiency	resolution $\delta p/p$	resolution $\delta\theta/\theta$
e	83%	$< 2\%$	$< 2\%$
γ	93%	$< 2\%$	$< 5\%$
p	64%	$< 1\%$	$< 10\%$

combined efficiency 43%

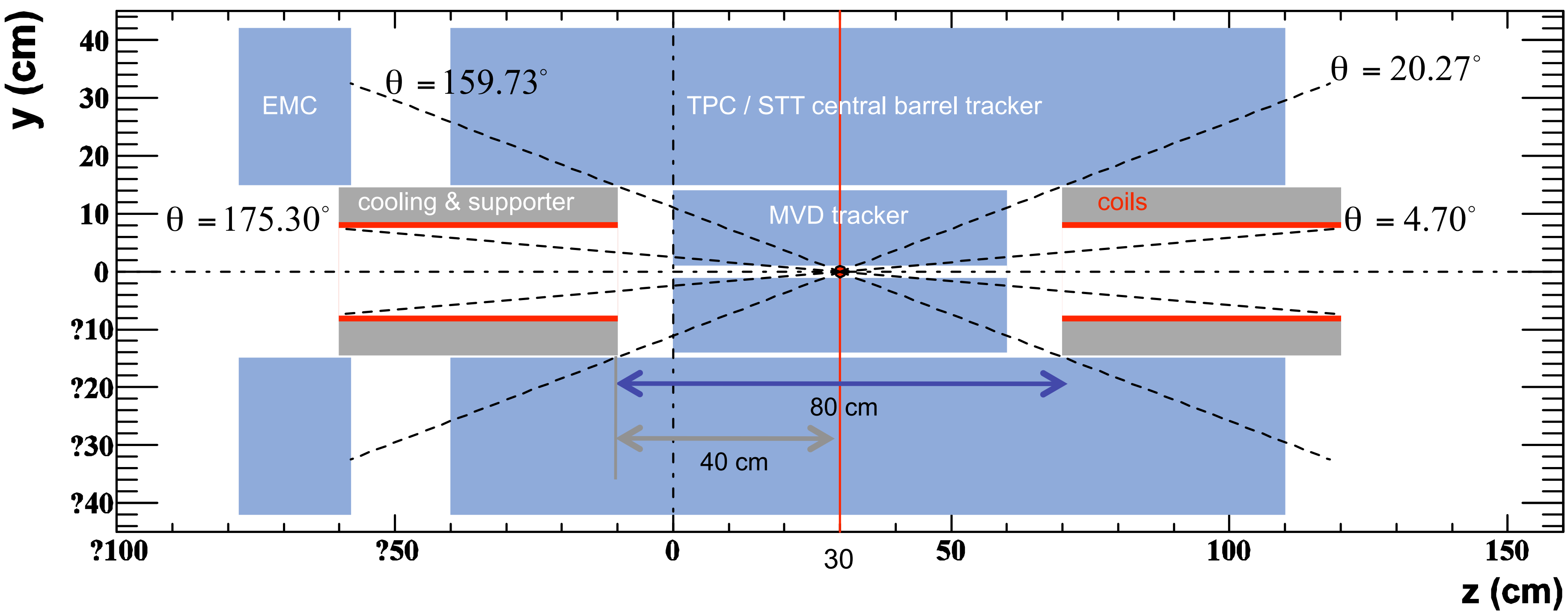
ENC: Kinematical Range

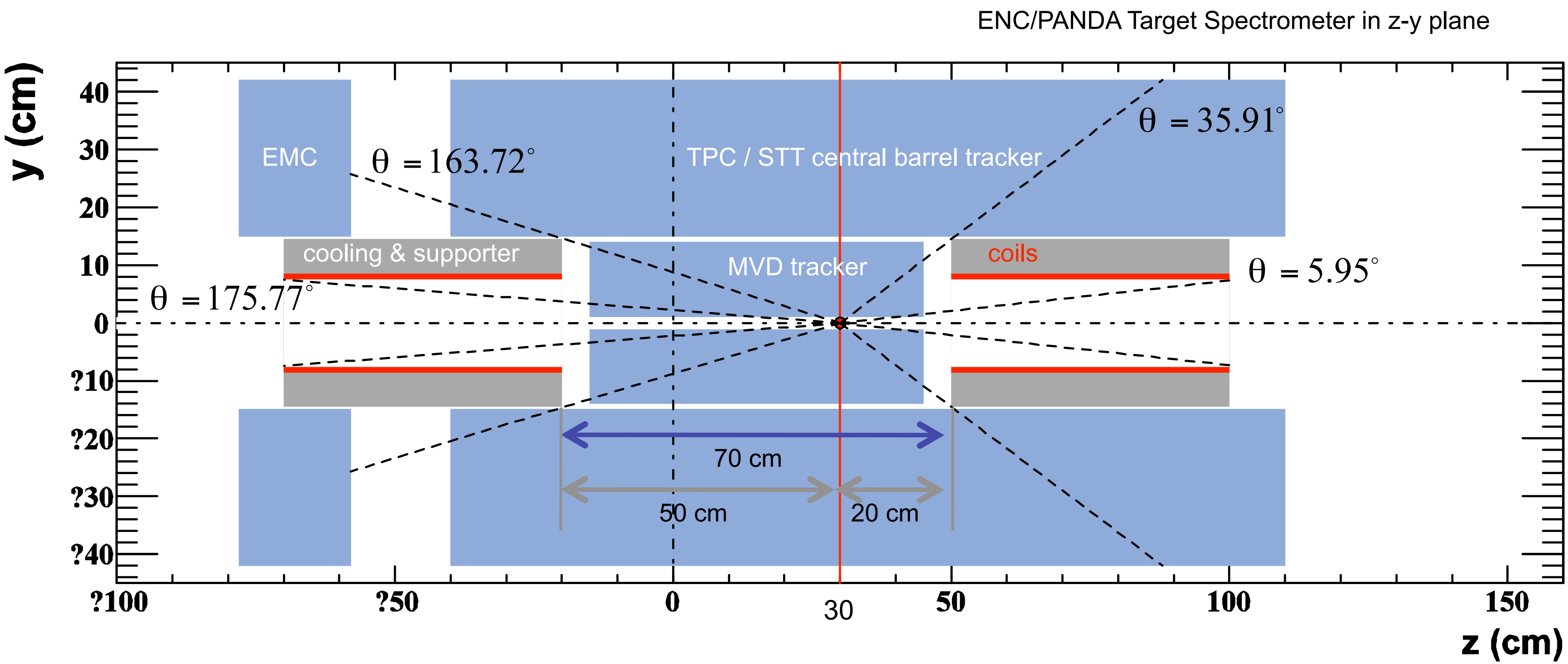


ENC/PANDA Target Spectrometer in z-y plane

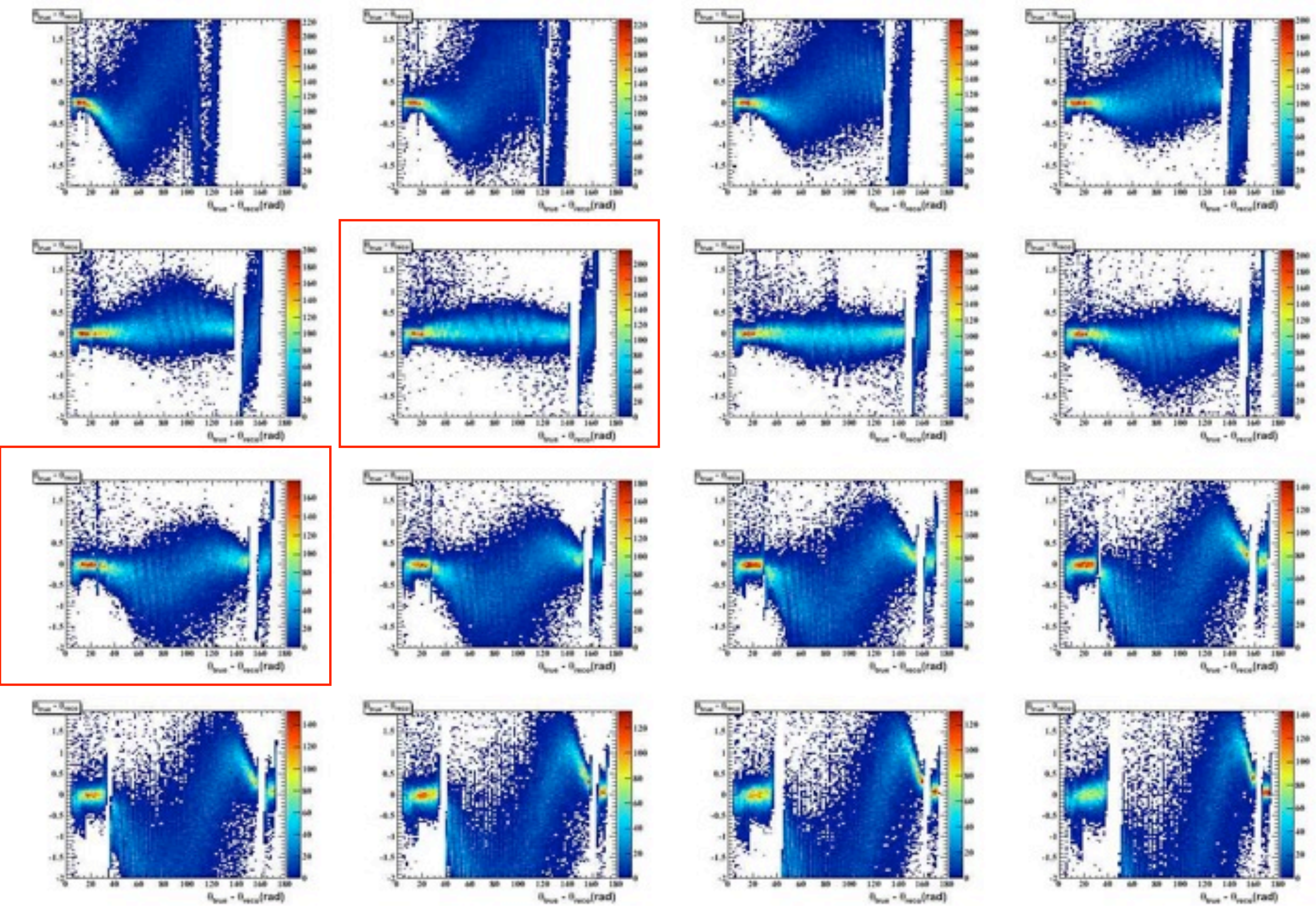


ENC/PANDA Target Spectrometer in z-y plane

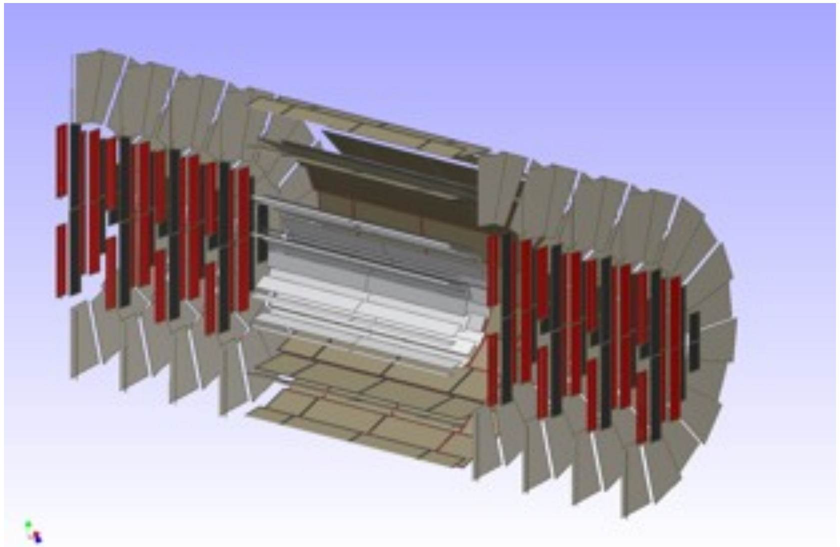


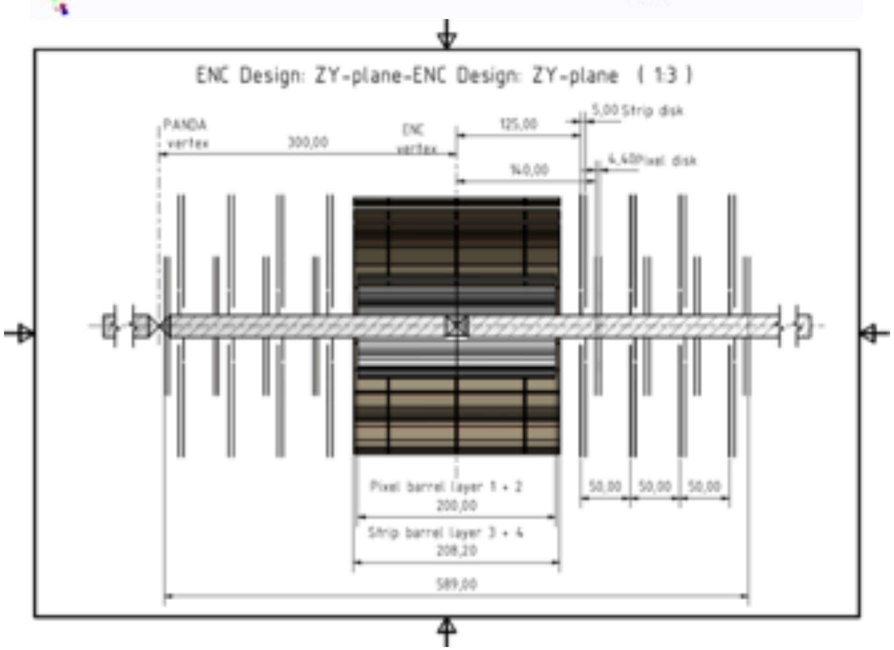

ENC/PANDA Target Spectrometer in z-y plane
y (cm)
z (cm)
EMC
TPC / STT central barrel tracker
MVD tracker
cooling & supporter
coils
θ = 163.72°
θ = 35.91°
θ = 175.77°
θ = 5.95°
70 cm
50 cm
20 cm
30

Electron-Nucleon Collider



Very preliminary 1st version of modified ENC-MVD





- design with AutoCAD program
- converting from CAD to Root Geo.
- Pixel and Strip sandwitch layers
- 60cm length & 2.4 beam diameter
- readout cables and supporting frame will be combined with Inner Dipoles

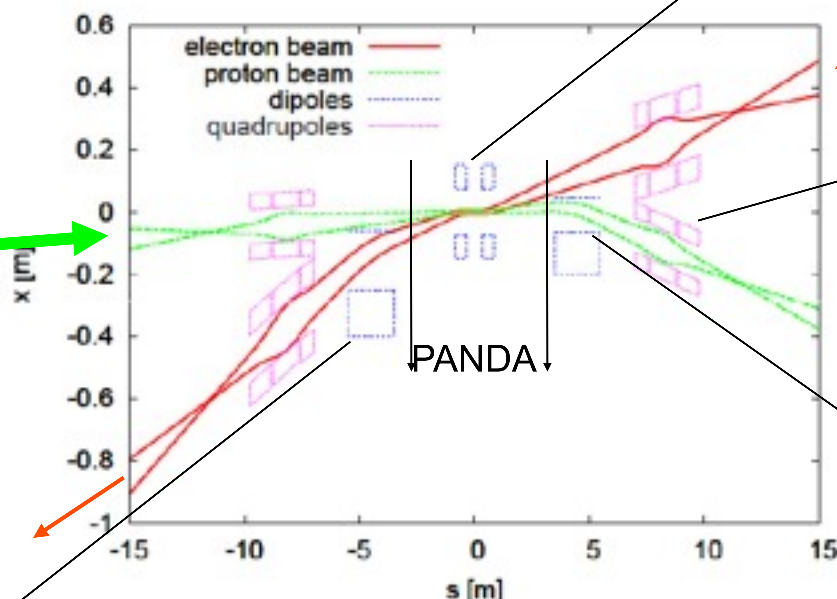
ENC@FAIR:Interaction region

IP Layout

Top view

Dipoles around IP)

Proton tripletts



Panda forward dipole (1T)
as separator
(Electrons shielded):
Protons as in Antiproton operation

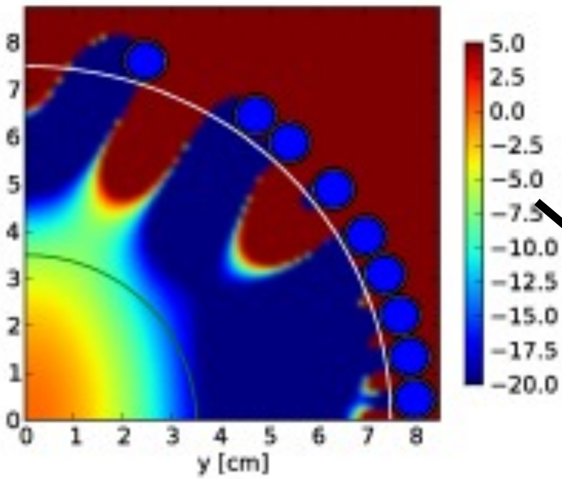
new spectrometer dipole
Protons shielded

Sufficient separation at $s = 1.44$m for 200 bunches
$\beta_{x,y}^* = 0.3$m

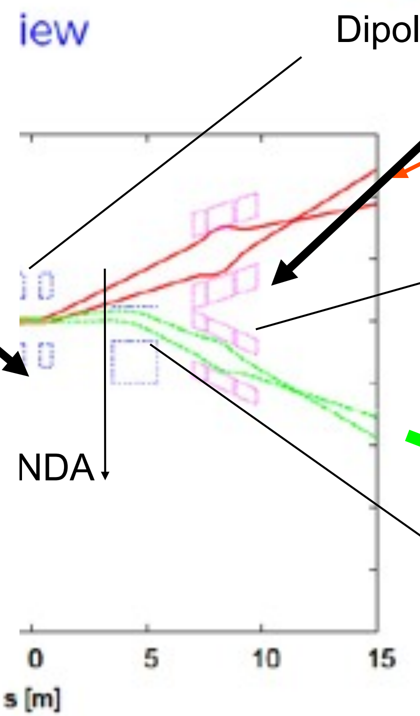
Chr. Montag, BNL

- Input for the simulation of polarization
- Dipoles around PANDA

ENC@FAIR:Interaction region



gure 3: The cross section of the IR dipole. The blue cles denote the positions of the coil windings. The field ality b_y (in units) is depicted in the magnet aperture.



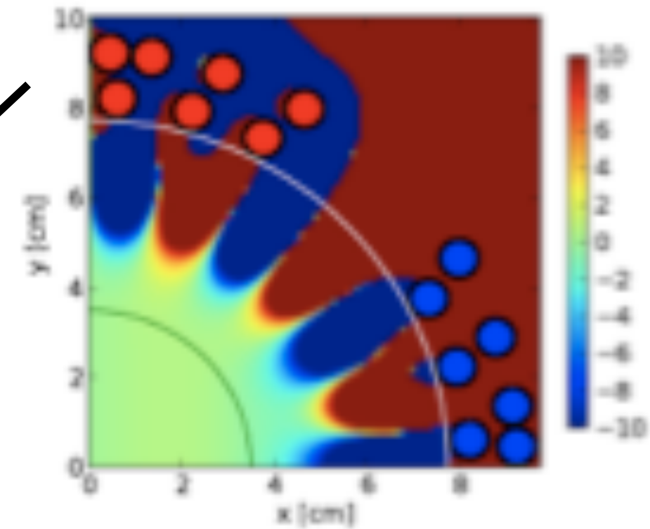


Figure 4: The 2D cross section of the IR quadrupole as well as the field homogeneity.

Protons as in Antiproton operation

Sufficient separation at s = 1.44m for 200 bunches

new spectrometer dipole
Protons shielded

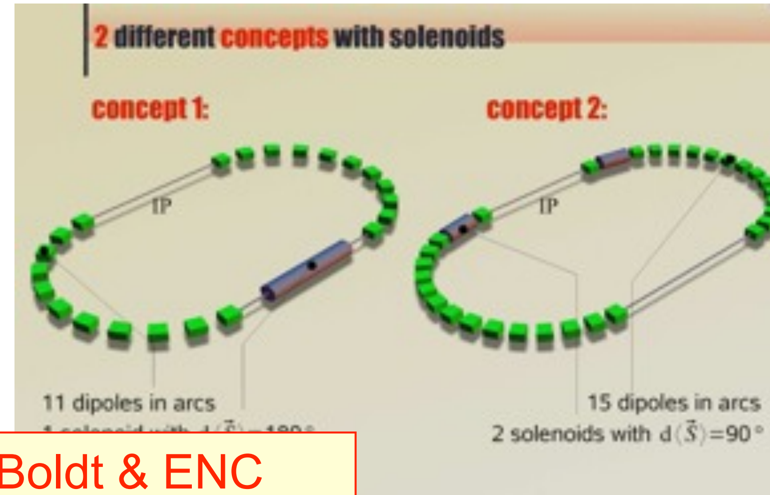
P. Schnizer & ENC working group
• refined Magnet design → in IPAC 2011
• offers for HTSC-tubes , procurement in 2011
• first HTSC tests end 2011/2012

- Input for the simulation of polarization
- Dipoles around PANDA

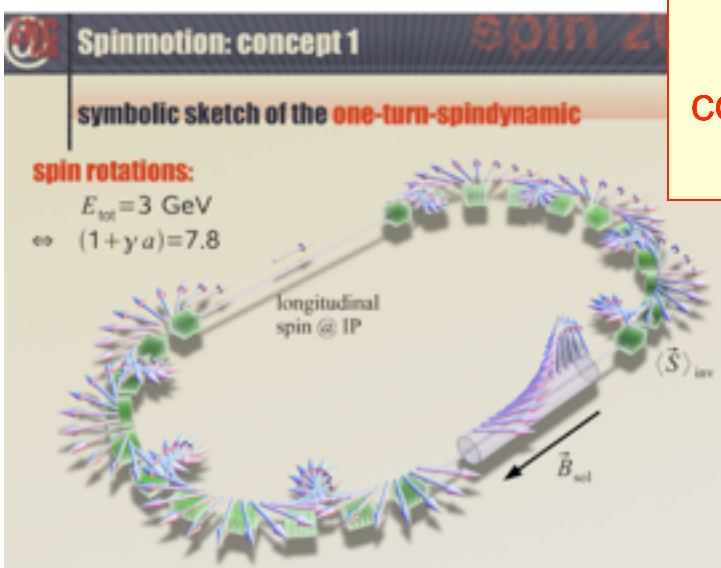
HELMHOLTZ ASSOCIATION
Helmholtz Institute Mainz

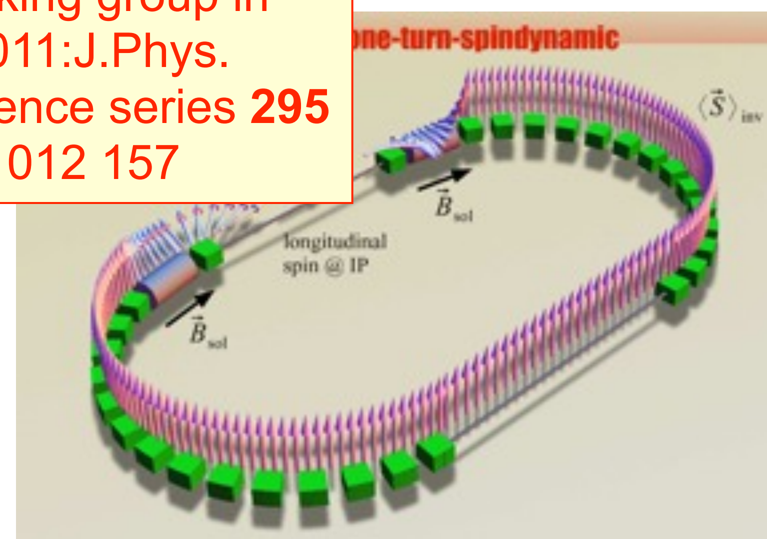
Investigation of various electron-ring concepts for the ENC

- Depolarizing effects (stochastic emission of synchrotron radiation, dispersion, depolarizing resonances)
- „spin-stabilization“ by a siberian snake, 30 Tm-solenoidal field provides for long. Polarization IP → tb >> tp (version 1)
- Continous refill of highly polarized electrons by compensating the losses driven by Intra-beamscattering → tp >> tb (version 2)
- Different problems: Vertical spin orientation in the arcs → spinrotation by solenoid providing long. Spin@IP: enough space, complex optical layout…

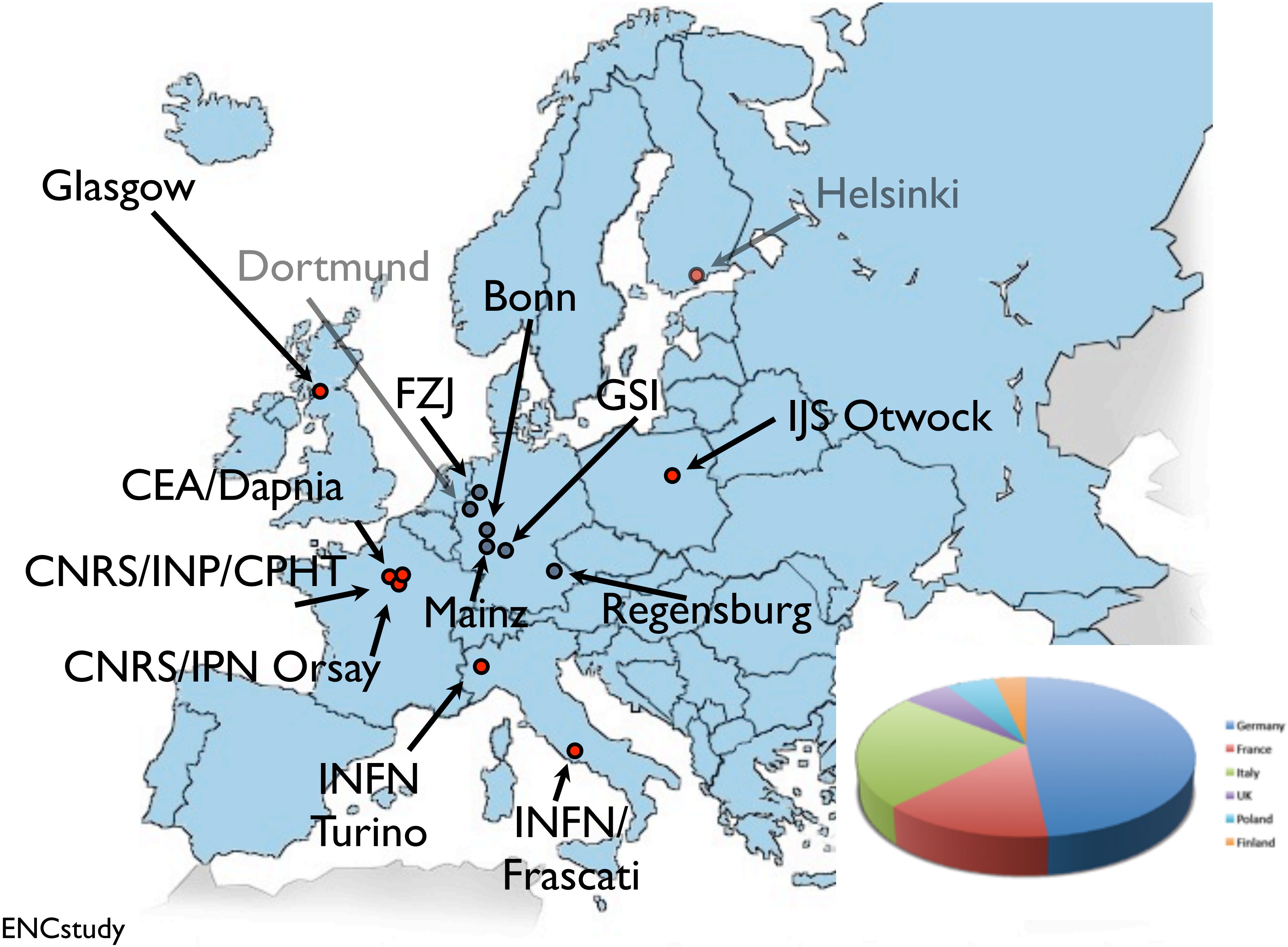


O. Boldt & ENC working group in 2011:J.Phys. conference series **295** 012 157





HP3: ENCstudy
(now approved)


Glasgow
Dortmund
Bonn
Helsinki
FZJ
GSI
IJS Otwock
CEA/Dapnia
CNRS/INP/CPHT
Mainz
Regensburg
CNRS/IPN Orsay
INFN
Turino
INFN/
Frascati
Germany
France
Italy
UK
Poland
Finland

Expertise

Experimental/ Simulation	Theory	Accelerator
Mainz	Mainz	Mainz
GSI	IPN Orsay	FZJ
Bonn	CPhT Palaiseau	Bonn
IPN Orsay	INFN Torino	Dortmund
CEA Saclay	Helsinki	
INFN Frascati		
INFN Torino		
Glasgow		

Summary

PANDA@FAIR

unpolarised Drell-Yan: Muons

Electrons seem feasible

SSA: polarised Hydrogen Target in PANDA,

Study of field magnetic configuration and tracking

PAX-Experiment

doubly polarised Drell-Yan

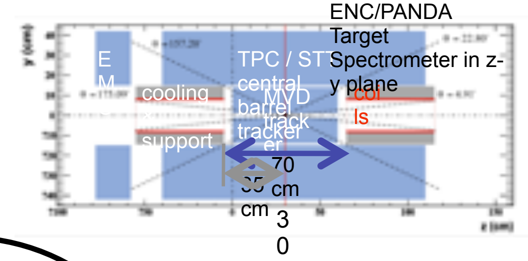
polarised Antiproton beam: demonstration of understanding of ring and apparatus underway at COSY, next step: antiproton ring (AD) at CERN

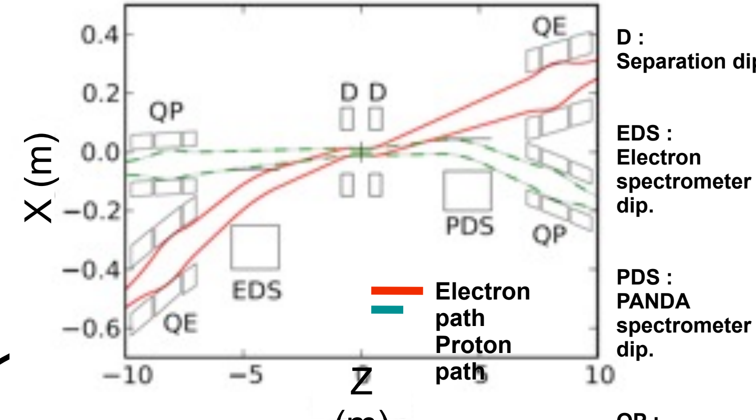
Electron-Nucleon Collider (ENC)

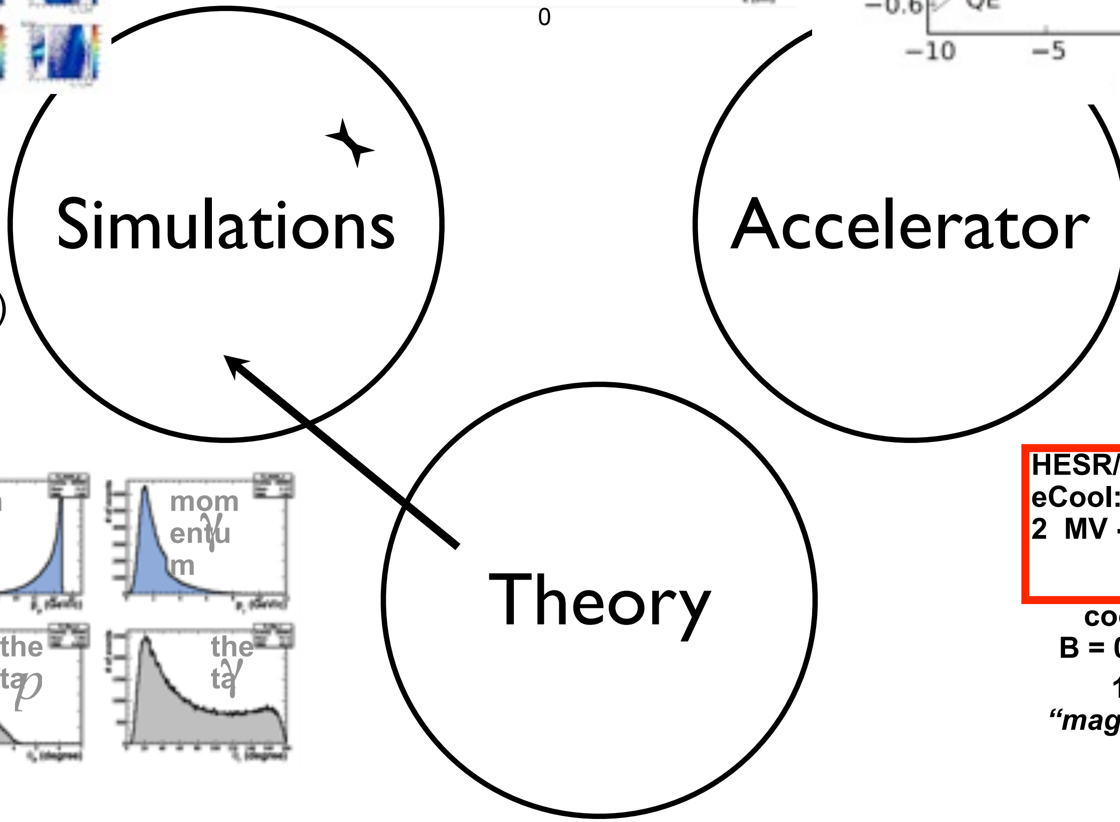
polarised electron-nucleon collider at PANDA@HESR@FAIR: feasibility study under way

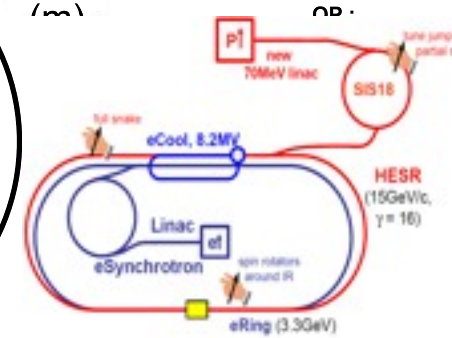
WP29 IA HP3

Expertise

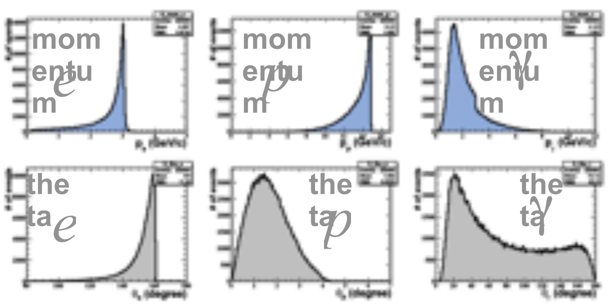




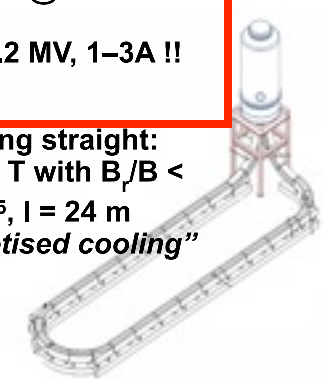




$Q^2 > 1.0$ (GeV/c²)
DVCS event :
generated by
GenDVCS1.0



HESR/ENC@FAIR
eCool:
2 MV - 8.2 MV, 1–3A !!

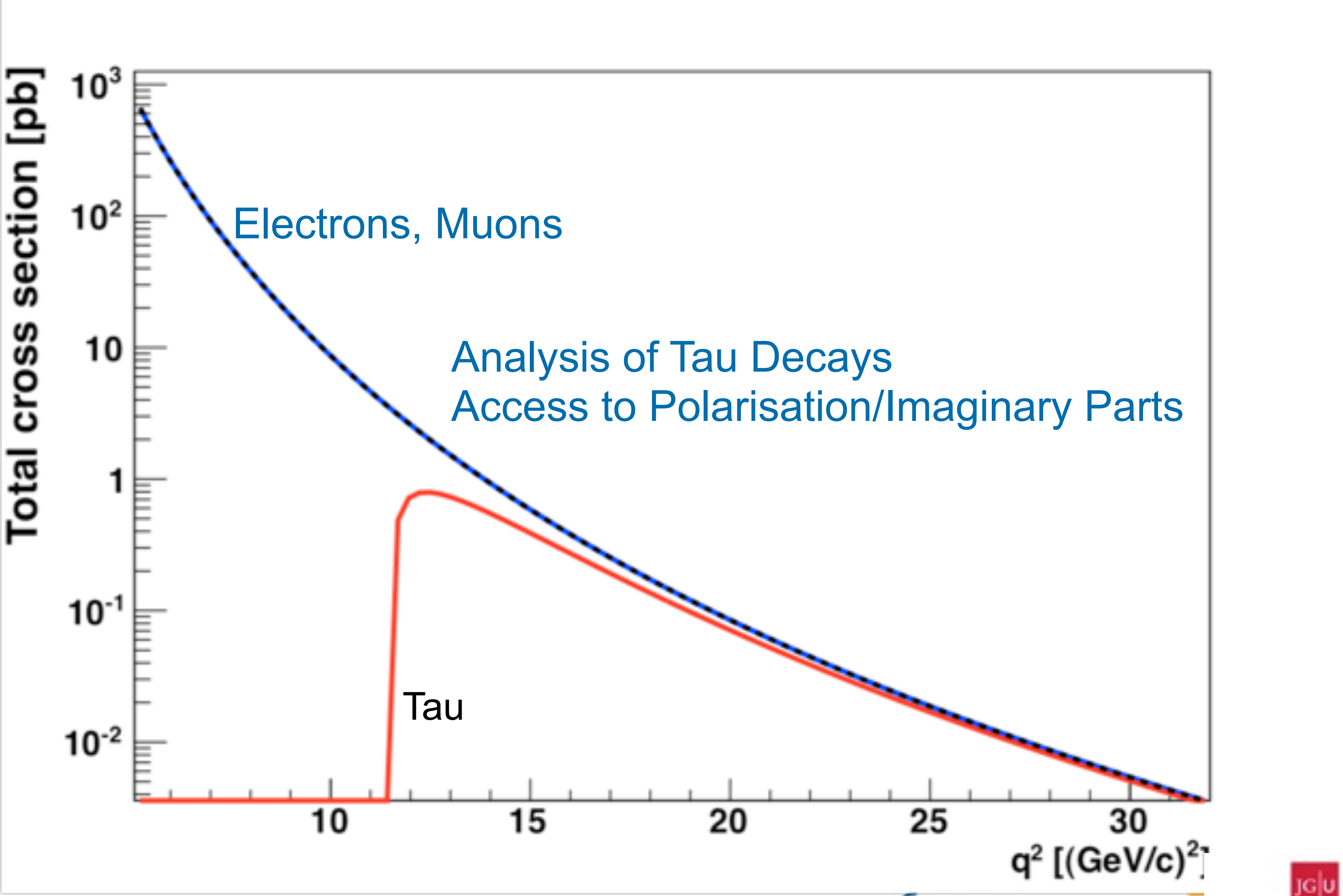


cooling straight:
B = 0.2 T with $B_r/B <$ 10^{-5}, l = 24 m
"magnetised cooling"

Two Tasks:

1) Physics Simulations of Benchmark Channels
2) Electron Ring Design Study

Signal: Pbar P -> $(e\mu\tau)^+ (e\mu\tau)^-$

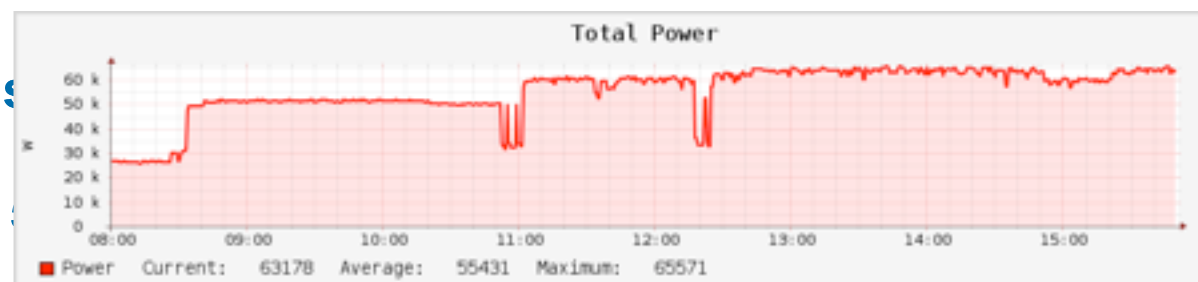


04.10.2010 Schloss Biebrich, Wiesbaden
Signing Ceremony of FAIR international Convention

Finland, France, Germany, India, Poland, Romania, Russia, Slovenia and Sweden

High Performancw Cluster in HIM: HIMSTER

HIMSTER
134 Nodes
AMD Magny Cours
  8 cores pro socket
ASUS Mainboard
2000 Cores
4.7 TByte RAM
136 TByte Disk Space
Infiniband QDR
19 TFLOPs
Experiment Simulation



Delivery in Mainz: May
Power-On: May 6
First Simultions: May 12 (EMP, 4 10^8 events)

Scientific Goals

Electromagnetic Processes:

- spin flavour structure f, g (longitudinal), h(transverse) of Quarks and Gluons
- Effects of finite transverse size, correlation of b and x, orbital angular momentum, GPDs
- Effects of transverse momentum $k_\perp$ of quarks, gauge links
- Factorisation breaking, Fragmentation
- Isospin dependences, light quark differences, SU3 breaking
- Spin sum rule contributions from small x

Electroweak processes:

- Prescott experiment, running of Weinberg angle
- W, Z exchange: tag flavours, quarks and antiquarks, more polarized structure functions
- Symmetry breaking P, CP, rare processes (e.g. lepton flavour), substructure

Spin-filtering at COSY

Main purpose:

1. Commissioning of the experimental setup for CERN/AD
2. Quantitative understanding of the machine parameters