The status of the PAX project at FAIR

Polarized **A**ntiproton E**X**periments

http://www.fz-juelich.de/ikp/pax

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Nucleon Structure at FAIR, Ferrara 15-16 October 2007

Polarized Antiproton eXperiments

Nucleon structure: polarized reactions

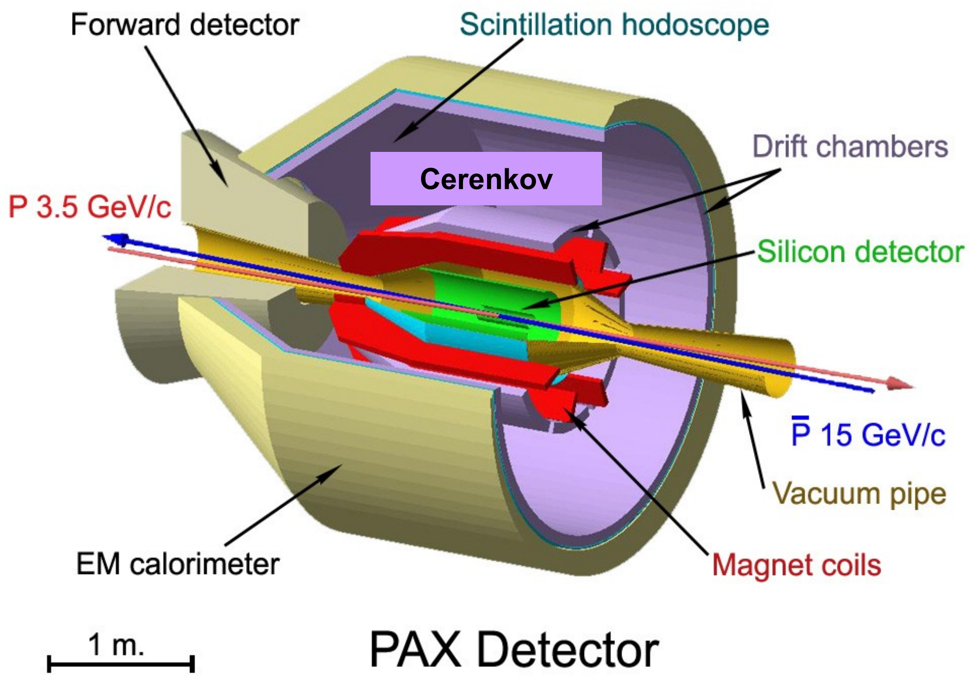
Parton distribution: transversity & Sivers

pbar-p elastic

$$p^{\uparrow}\bar{p}^{\uparrow} \rightarrow p\,\bar{p}$$

Proton EFFs

$$p^{(\uparrow)}\bar{p}^{\uparrow} \rightarrow e^{+}e^{-}$$



Drell-Yan

$$p^{\uparrow}\bar{p}^{\uparrow} \rightarrow e^{+}e^{-}X$$

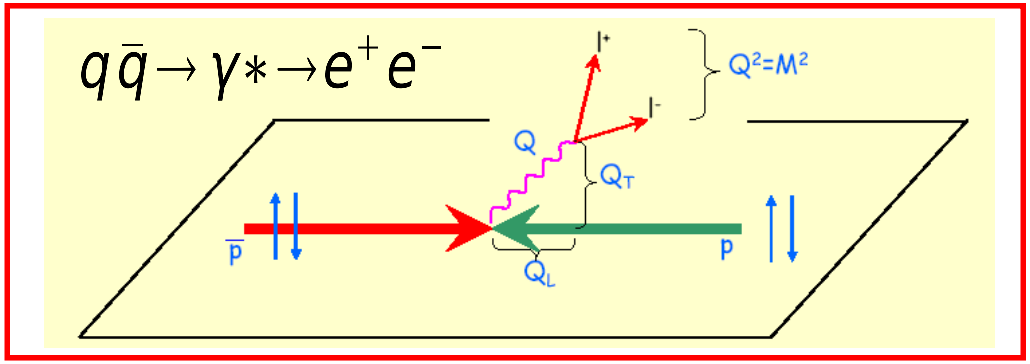
SSA

$$\bar{p}\,p^{\uparrow} \rightarrow e^{+}e^{-}X$$

Fixed target experiment ($\sqrt{s}<2$ GeV):
- pol./unpol. pbar beam (p<4 GeV/c)
- internal H polarized target

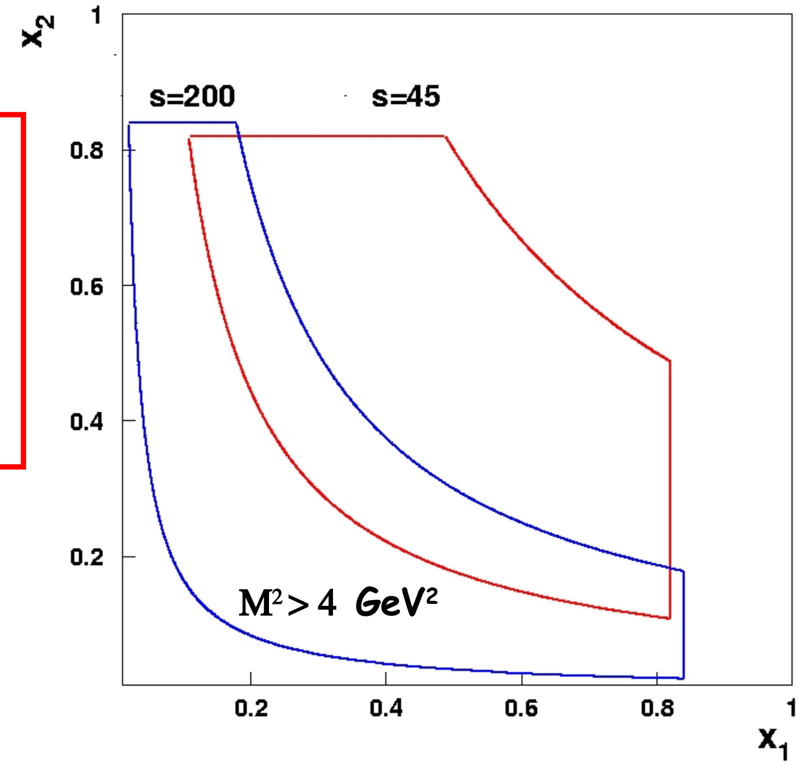
Asymmetric collider ($\sqrt{s}=15$ GeV):
- polarized antiprotons in HESR (p=15 GeV/c)
- polarized protons in CSR (p=3.5 GeV/c)

Drell-Yan



H. Shimizu et al., hep-ph/0503270

V. Barone et al., in preparation



$$\frac{d^2\sigma}{dM^2 dx_F} = \frac{4\pi\alpha^2}{9M^2 s} \frac{1}{x_1+x_2} \sum_q e_q^2 \left[q(x_1)\bar{q}(x_2) + \bar{q}(x_1) q(x_2) \right]$$

$$q = u, \bar{u}, d, \bar{d}, \ldots$$

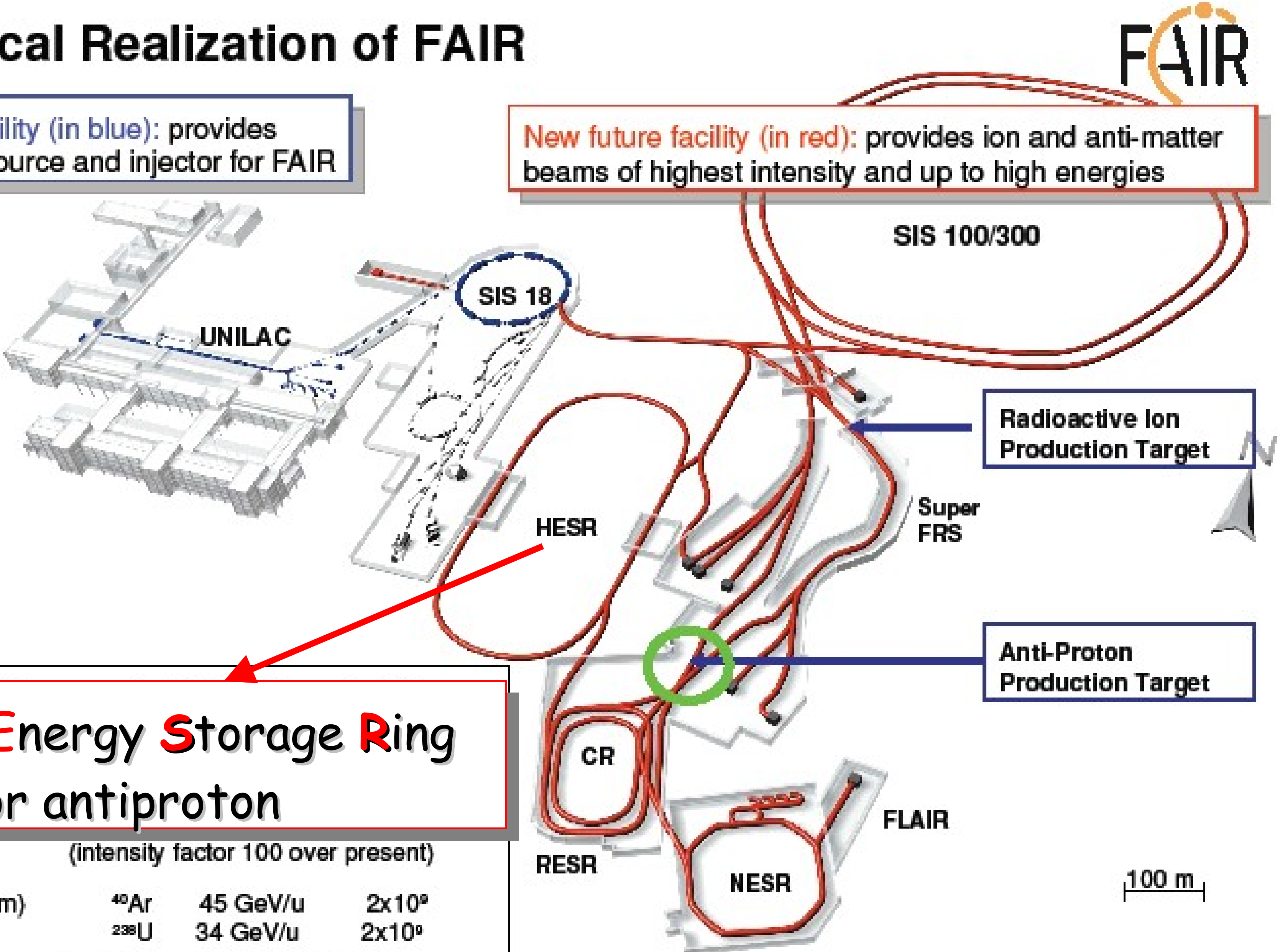
$$x_F = x_1 - x_2 \qquad x_1 x_2 = M^2/s \equiv \tau \qquad x_F = 2Q_L/\sqrt{s}$$

M invariant Mass of lepton pair

Technical Realization of FAIR

Existing facility (in blue): provides ion-beam source and injector for FAIR

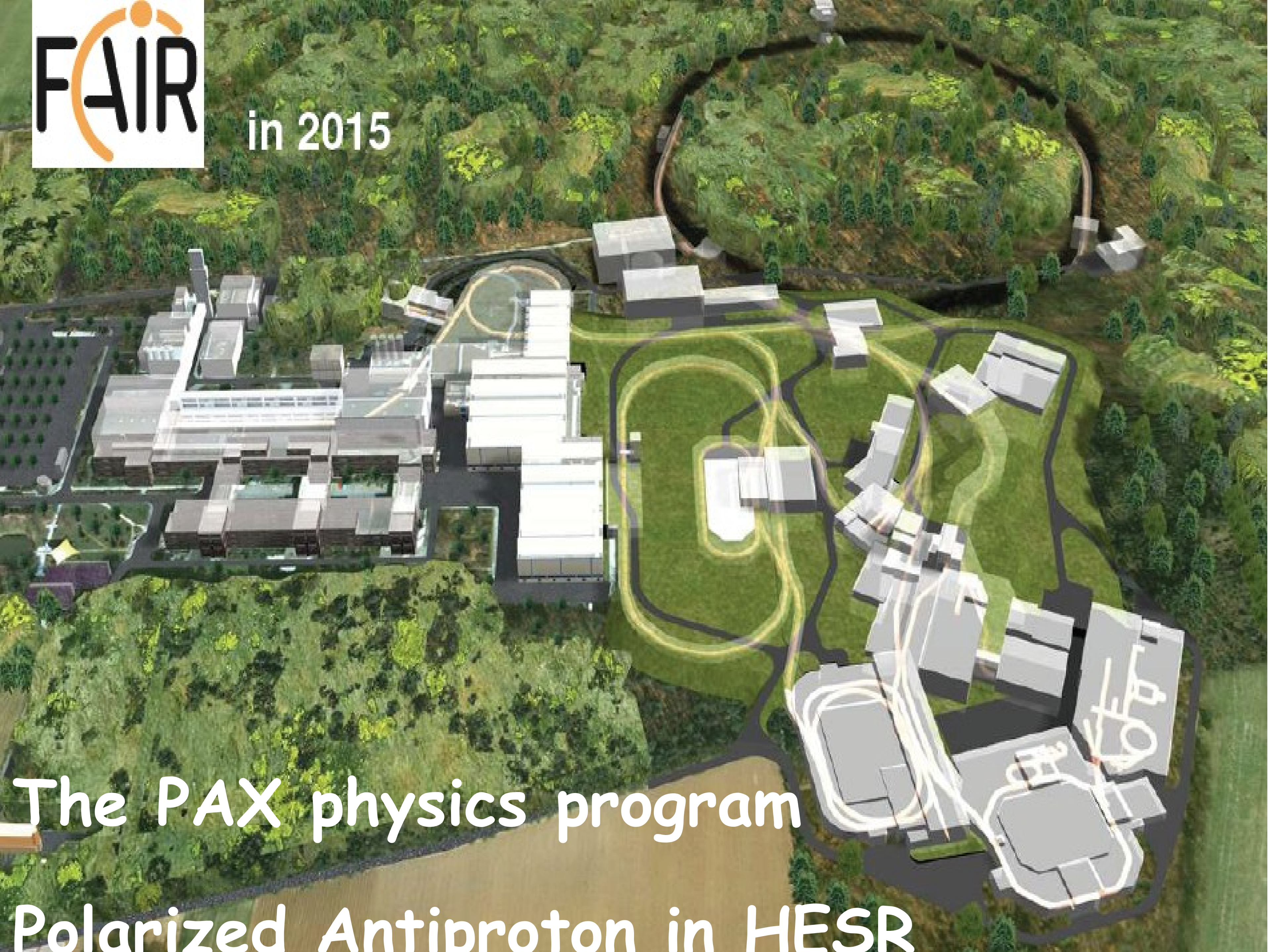
New future facility (in red): provides ion and anti-matter beams of highest intensity and up to high energies



High Energy Storage Ring for antiproton

(intensity factor 100 over present)

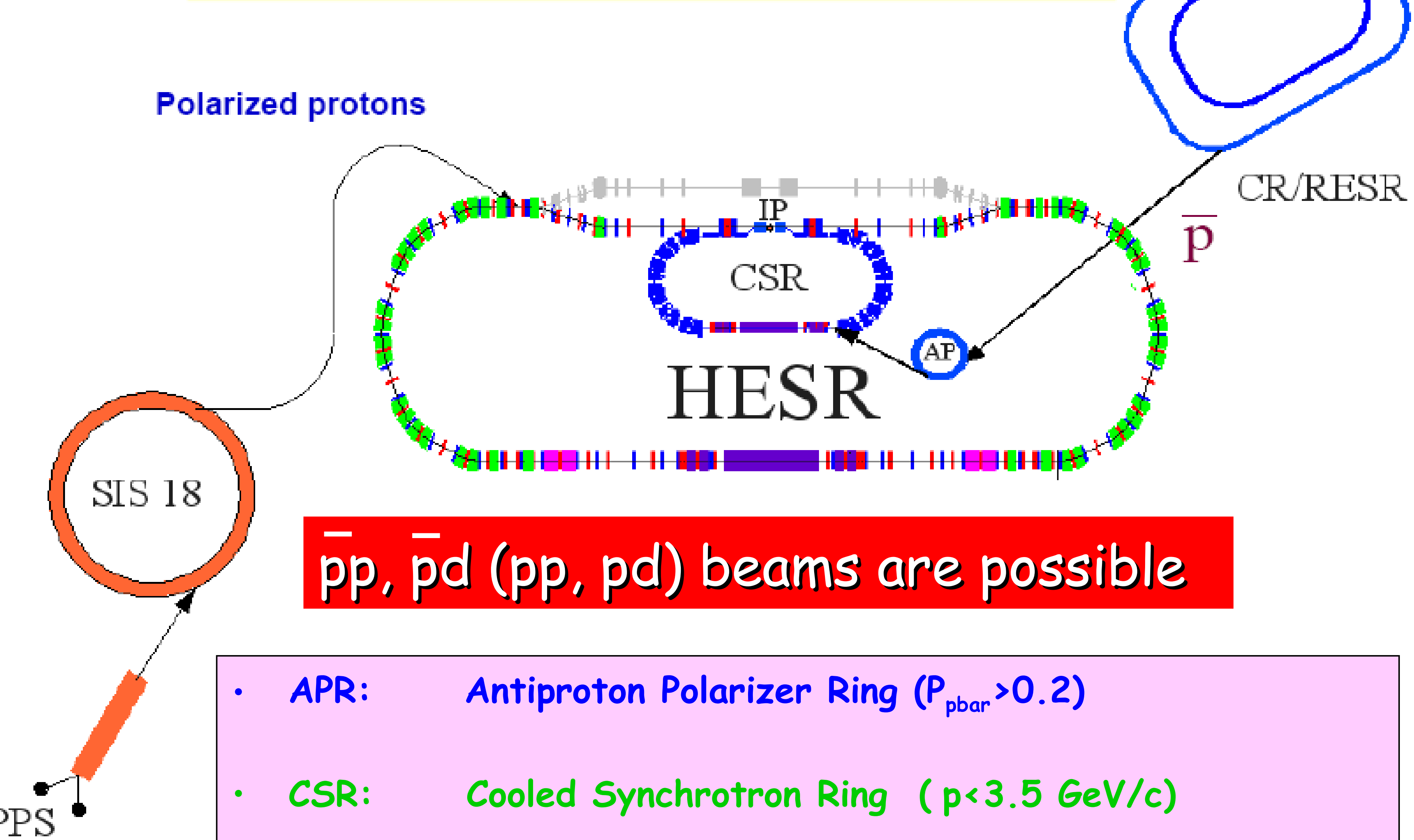
SIS300 (300Tm)	^{40}Ar	45 GeV/u	2×10^{9}
	^{238}U	34 GeV/u	2×10^{9}
CR/RESR/NESR	ion and antiproton storage and experiment rings		
HESR	antiprotons	14 GeV	$\sim 10^{11}$
SuperFRS	rare-isotope beams	1 GeV/u	$<10^{9}$



The PAX physics program

Polarized Antiproton in HESR

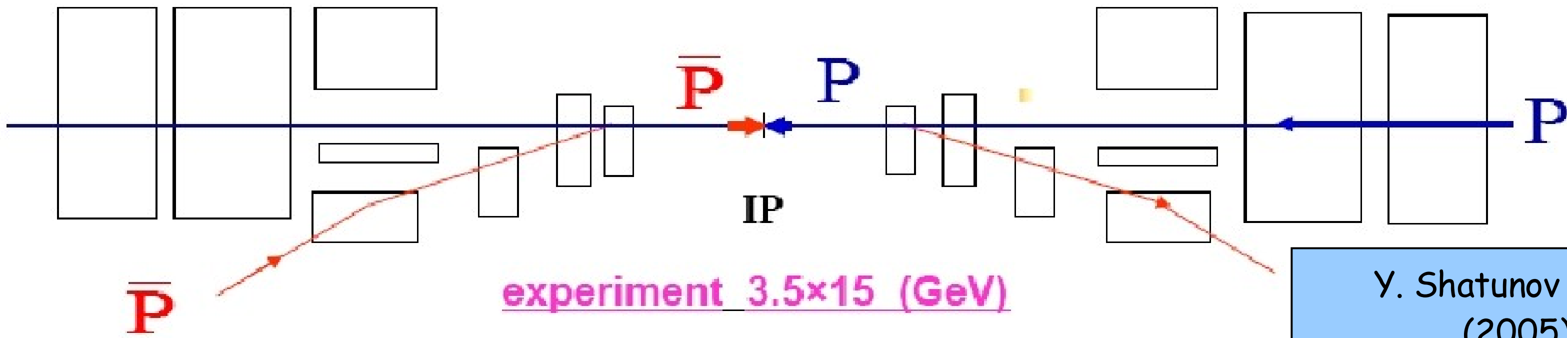
Asymmetric collider option



$\bar{p}p$, $\bar{p}d$ (pp, pd) beams are possible

- APR: Antiproton Polarizer Ring (P_{pbar}>0.2)
- CSR: Cooled Synchrotron Ring (p<3.5 GeV/c)
- HESR: High Energy Synchrotron Ring (p<15 GeV/c)

Sketch of the interaction area



Y. Shatunov et al., (2005)

Ring circumferences,	l_1 / l_2	536 /134	m
Beam energies	E_p / E_{p_bar}	15 / 3.5	GeV
Total number of antiprotons,	N_P	0.1 / 0.3 / 1	10^{12}
Total number of protons,	$N_{\bar{P}}$	7 / 7/ 7	10^{12}
Proton beam emittance,	ε_P	2.5 / 2.5 / 2.5	10^{-6} cm · rad.
Antiproton beam emittance,	$\varepsilon_{\bar{P}}$	0.25 / 0.75 / 2.5	10^{-6} cm · rad
Space charge tune shift,	$\Delta\nu_{\bar{P}}$	0.1 / 0.1 / 0.1	
Beam-beam parameter,	$\xi_{\bar{P}}$	?	
Luminosity	L_{max} (l=2m)	5 / 5 / 5	10^{31} $cm^{-2} \cdot s^{-1}$

Asymmetric collider **Luminosity up to $5 \cdot 10^{31}$ $cm^{-2}s^{-1}$**

PAX Detector Concept

Physics: h_1 distribution — $\cos(2\phi)\sin^2\theta$
EMFF — $\sin 2\theta$
pbar-p elastic — high |t|

→ Azimuthally Symmetric:
BARREL GEOMETRY
LARGE ANGLES

Experiment: Flexible Facility

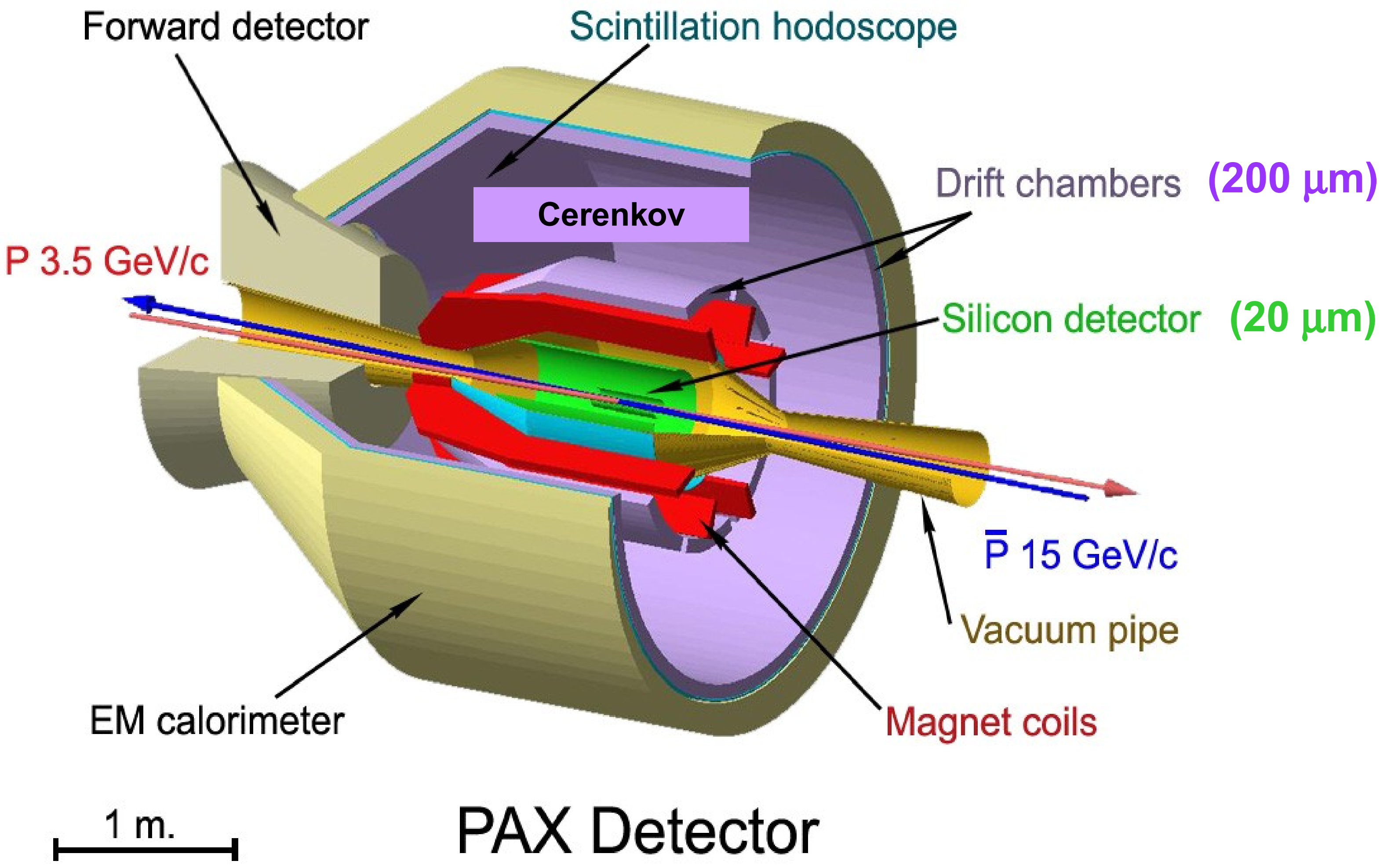
→ e^+e^-

Detector:
- Extremely rare DY signal (10^{-7} p-pbar)
- Excellent PID (hadron/e rejection ≥ 10^4)
- High mass resolution (≤2 %)
- Maximum Bjorken-x coverage (M interval)
- Moderate lepton energies (0.5-5 GeV)

Magnet:
- Minor influence on beam polarization
- Compatible with Cerenkov
- Compatible with polarized target

→ TOROID
NO FRINGE FIELD

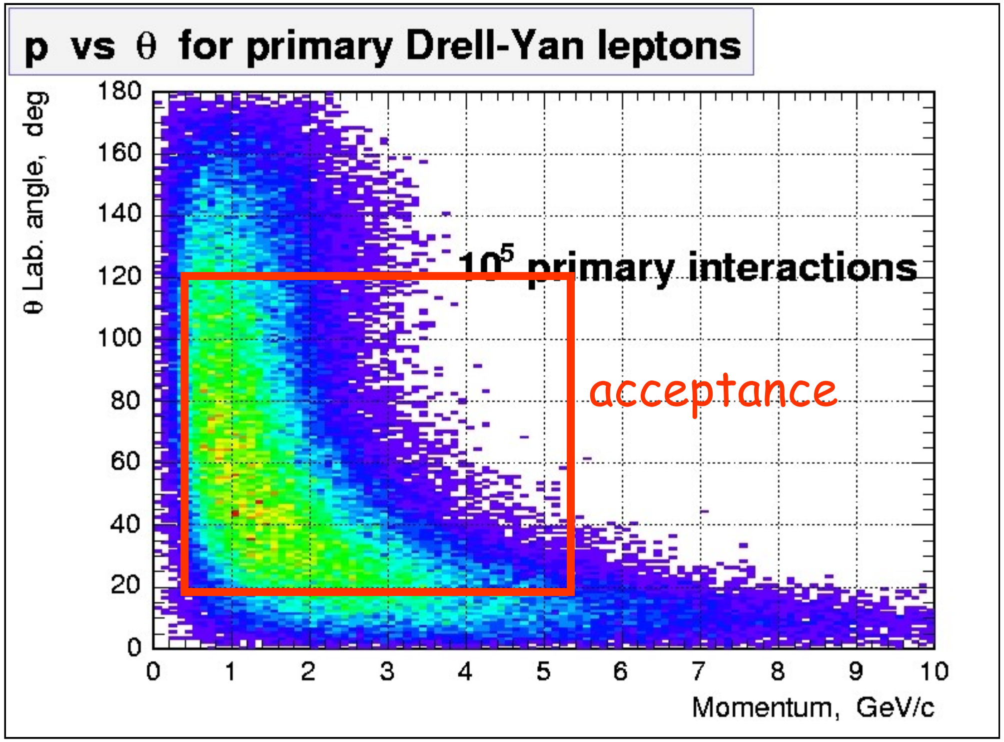
PAX Detector Concept

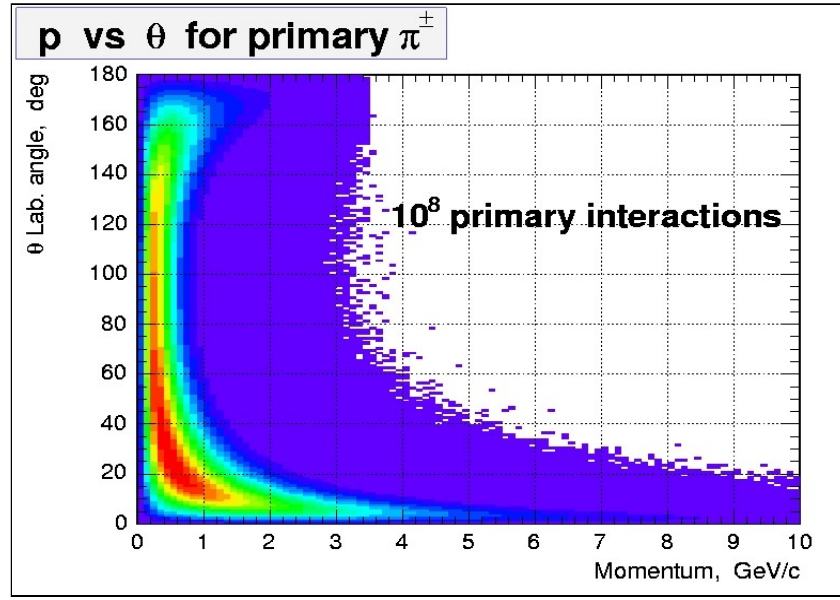


PAX Detector

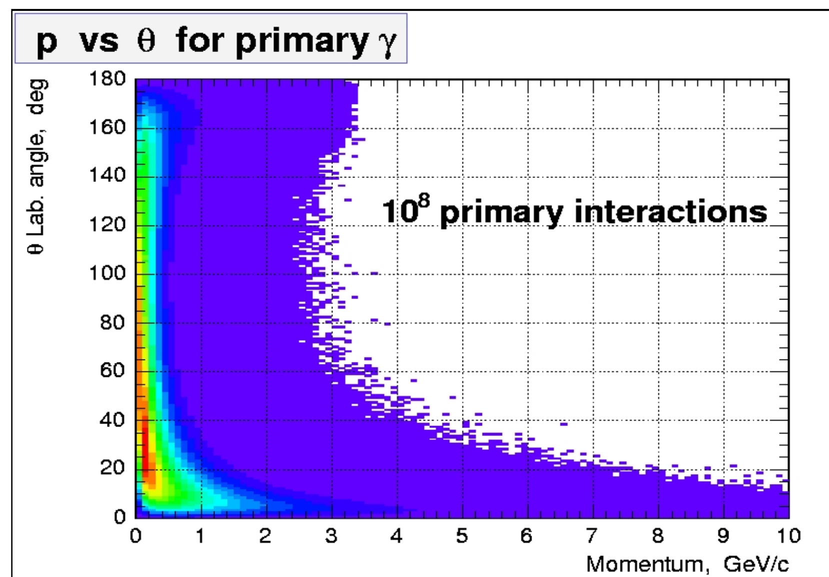
Designed for Collider but compatible with fixed target

θ-p Phase Space





GEANT simulations



Background peaks at

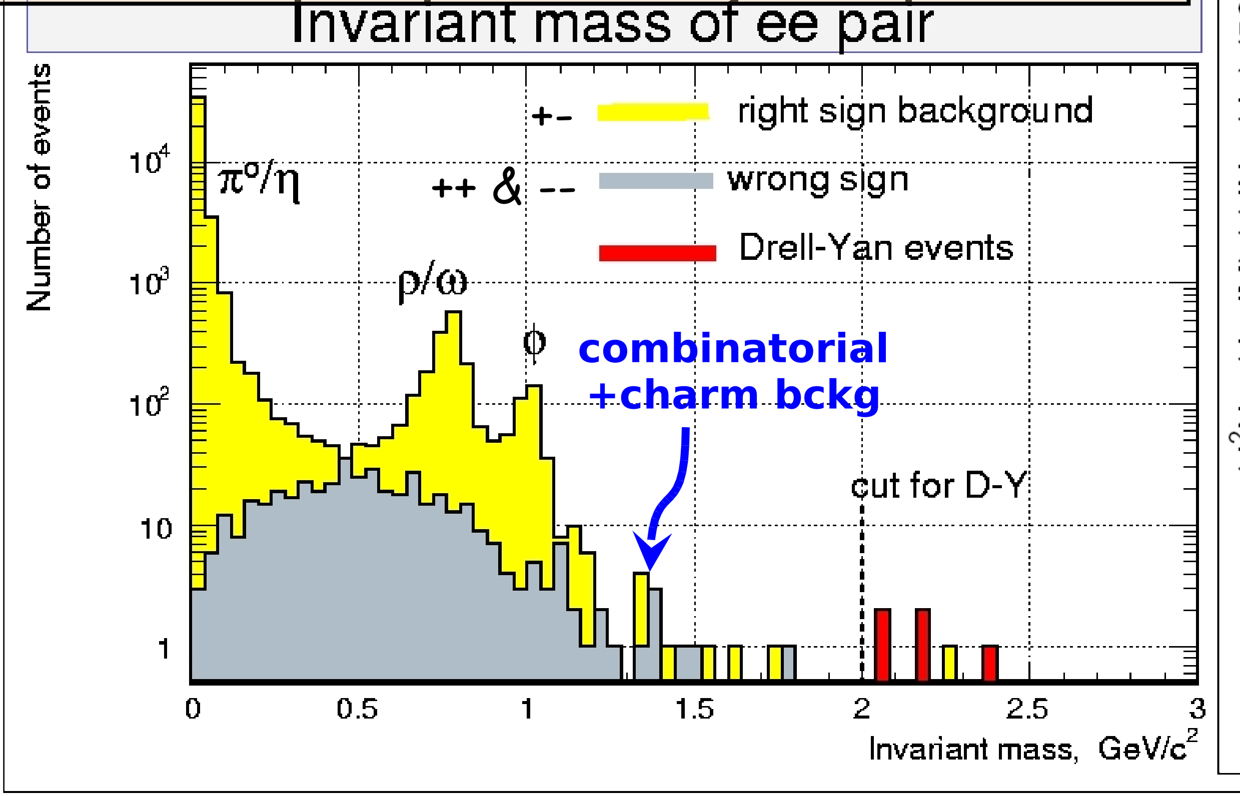
* low energy
* forward direction

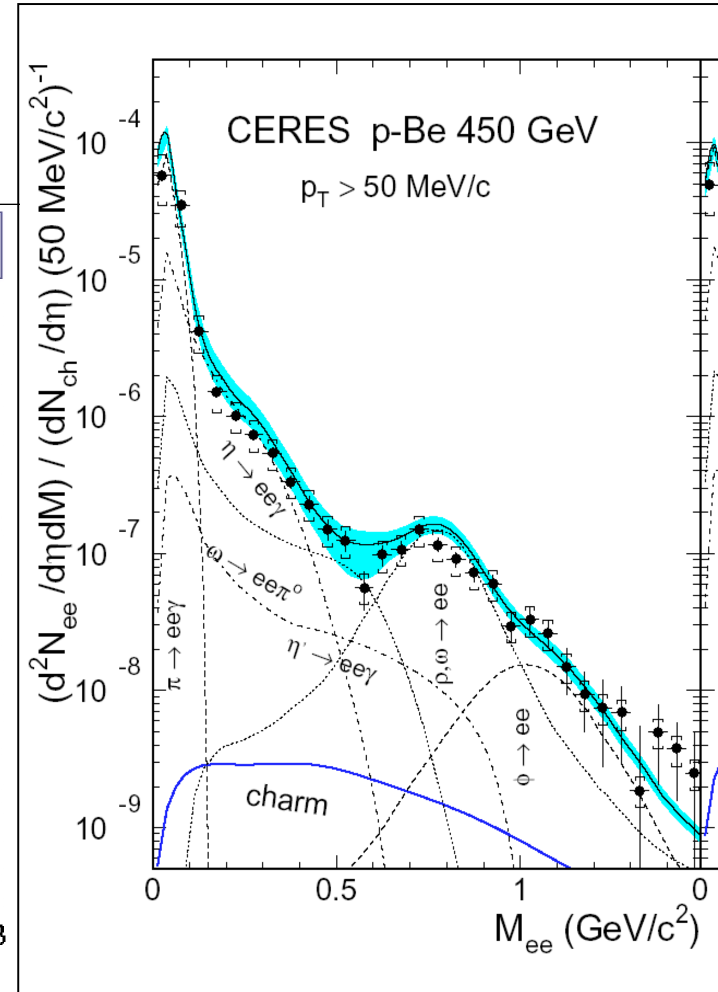
Background to Drell-Yan e^+e^-

Few min. experiment:

$2 \cdot 10^8$ p-pbar interactions

several DY events



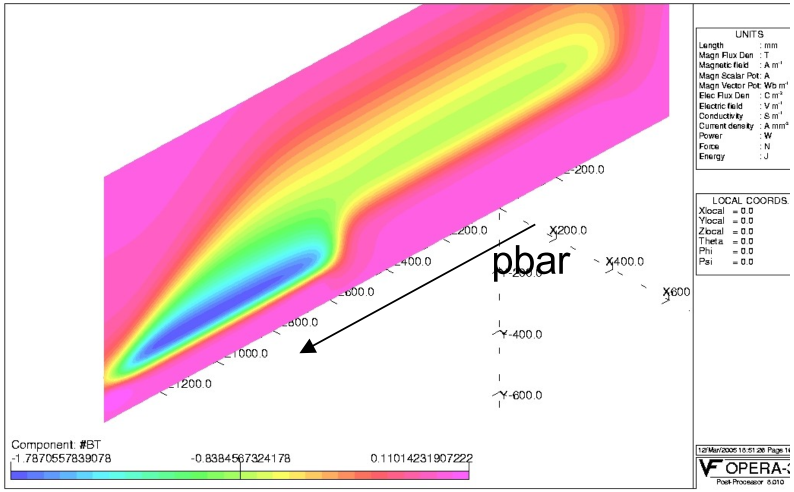


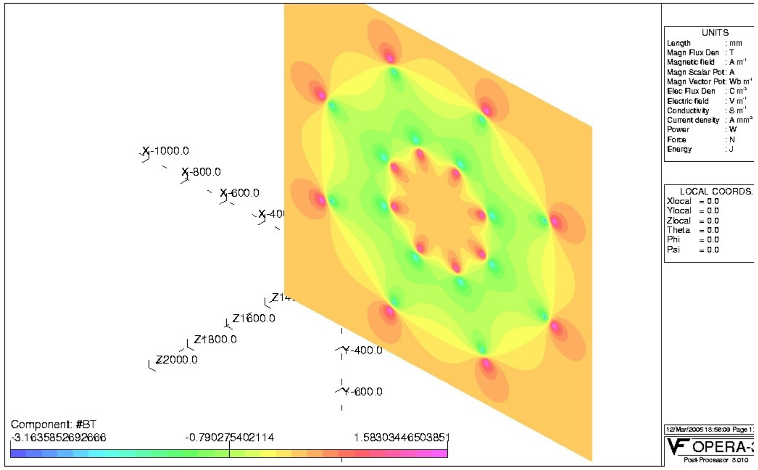
Background 1:1 to signal after PID, E>300 MeV, conversion veto, mass cut

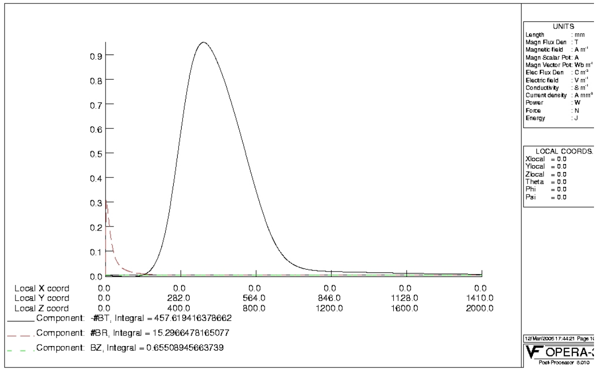
* the combinatorial component can be subtracted (wrong-sign control sample)
* the charm can be reduced (vertex decay)

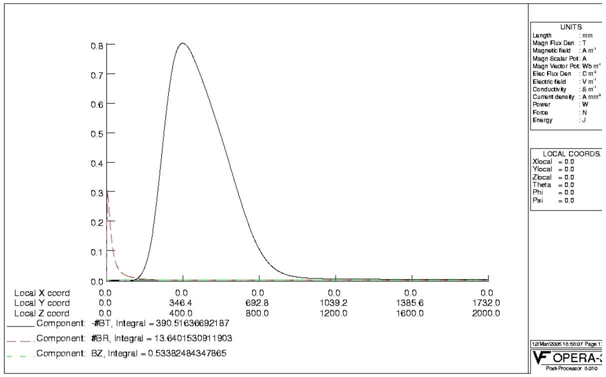
Toroid field

Transverse field matching the momentum, no fringe field





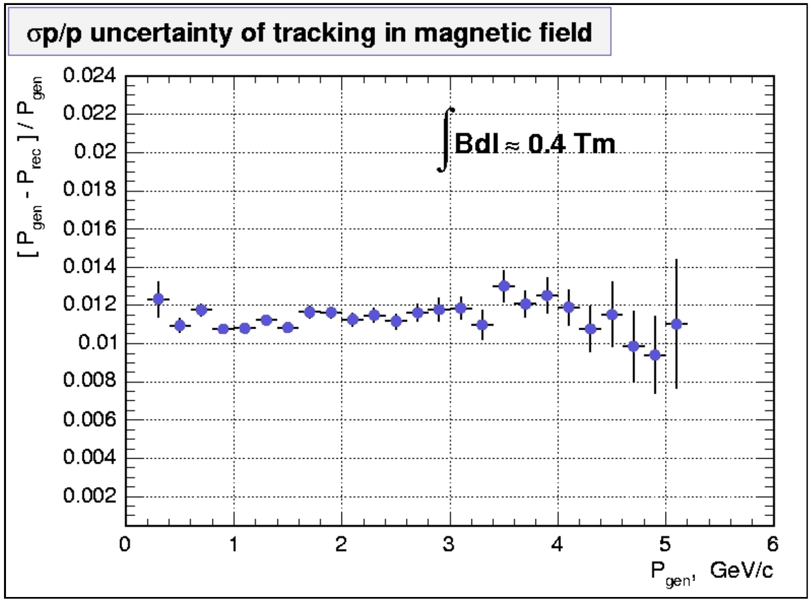


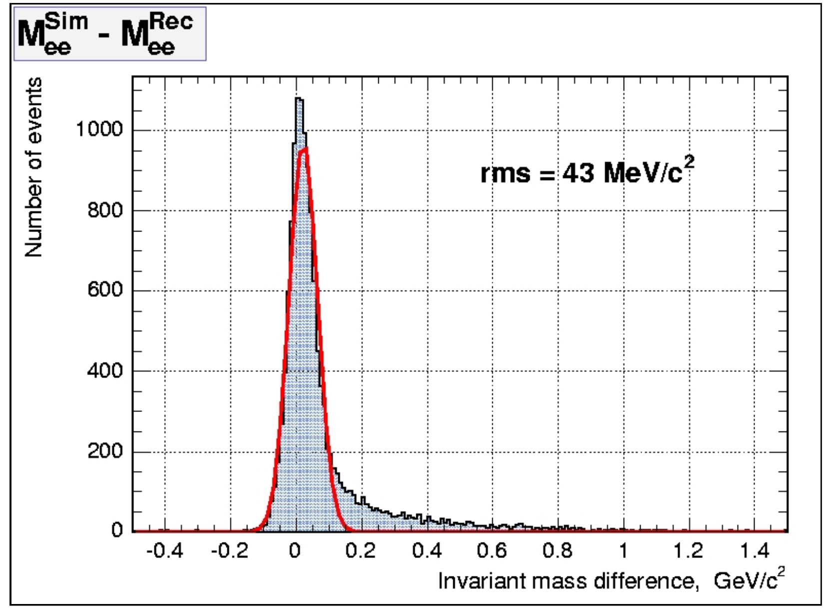


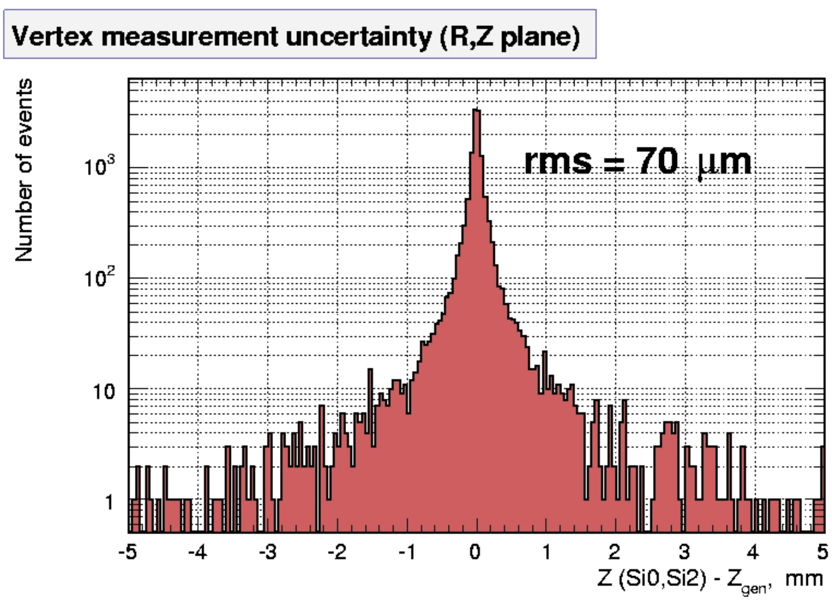
$\int Bdl = 0.46$ Tm at 35^{o}

$\int Bdl = 0.39$ Tm at 60^{o}

θ-p Phase Space







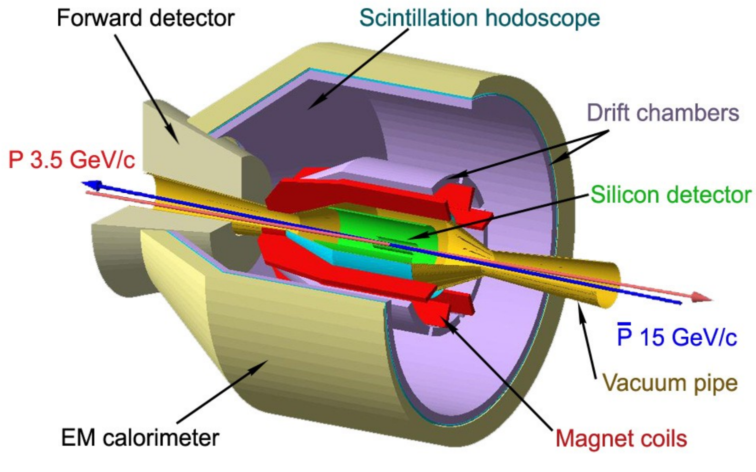
Better than 2% mass resol

- * x dependence of h_1
- * resonance vs continuum

Mandatory to study M below J/ψ mass

Vertex resolution high enough to study charm background

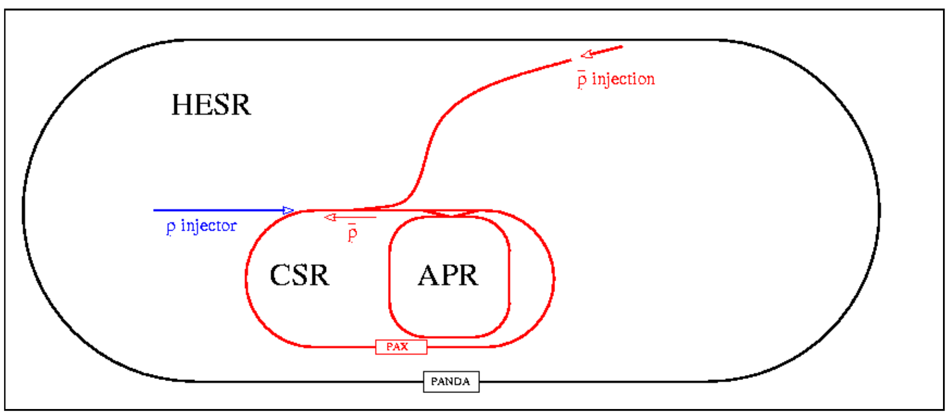
Polarized Antiproton eXperiments



1 m.

PAX Detector

Phase I: Proton time-like FFs
Hard pbar-p elastic scatt.



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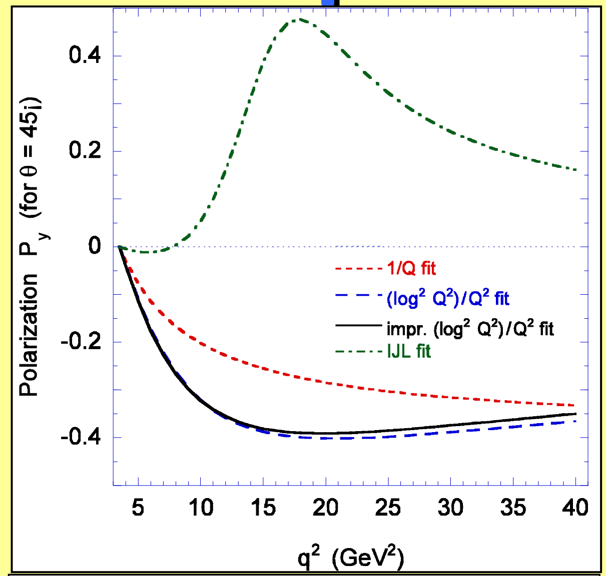
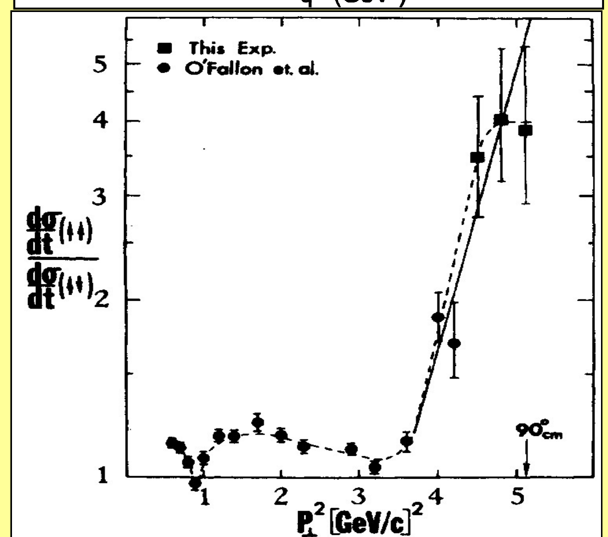


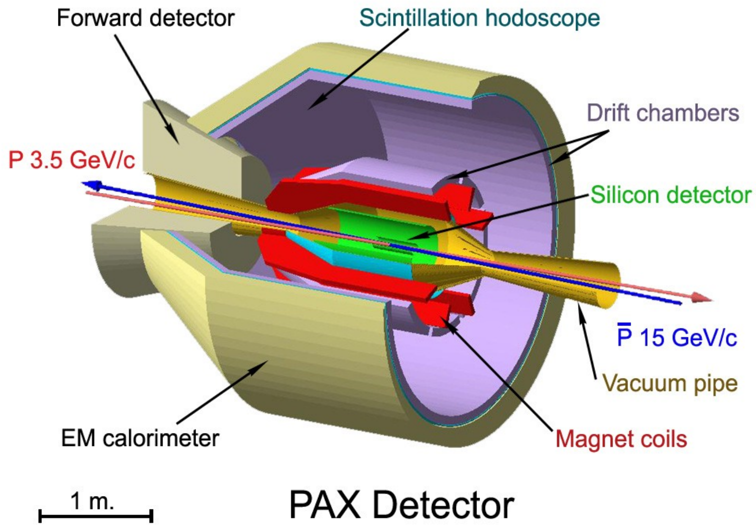
$$p^{\uparrow}\bar{p}\rightarrow e^{+}e^{-}$$



$$p^{\uparrow}\bar{p}^{\uparrow}\rightarrow p\,\bar{p}$$

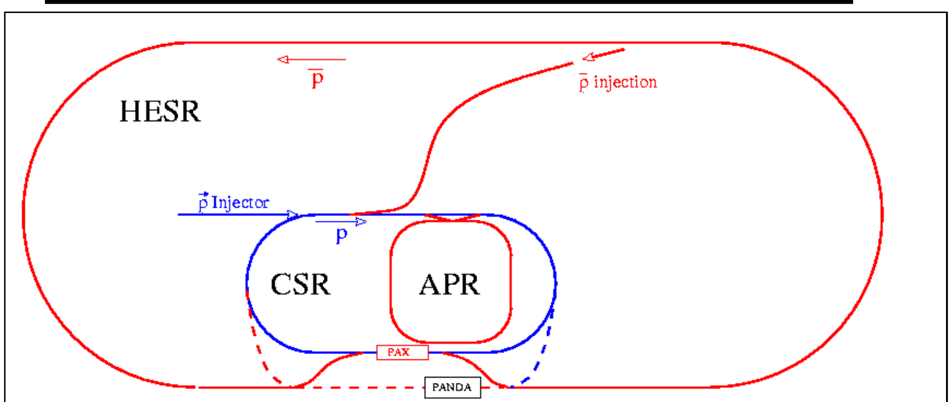
From few hours to few weeks measurements

Polarized Antiproton eXperiments



PAX Detector

Phase II: Transversity Distribution



Asymmetric collider (√s=15 GeV):
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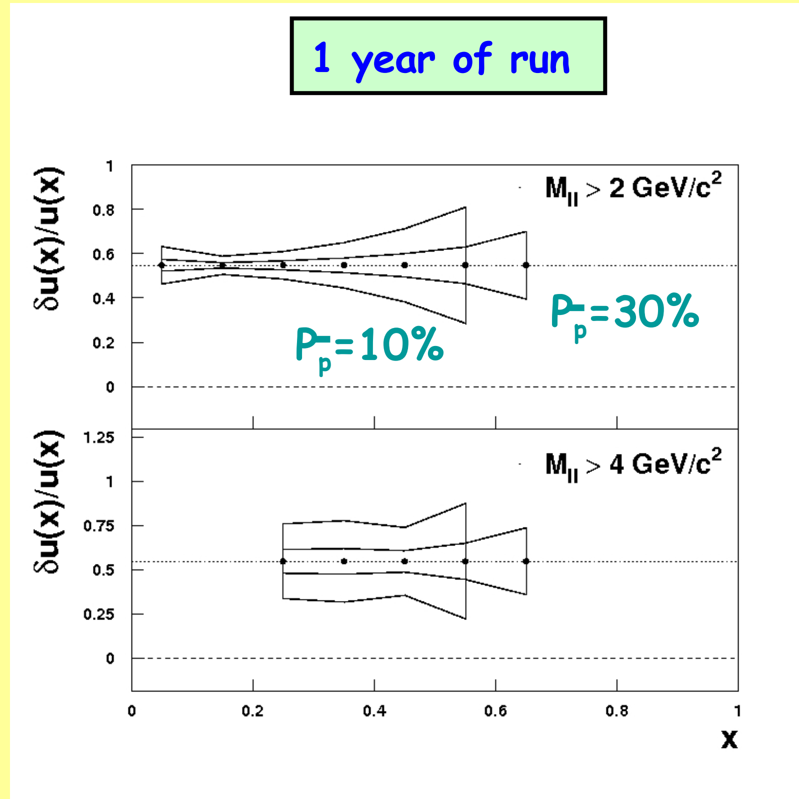
$$p^{\uparrow}\bar{p}^{\uparrow} \to e^{+}e^{-}X$$



10 % precision on the $h_{1u}(x)$ in the valence region

Summary

- PAX project has an innovative spin physics program
  * transversity
  * SSA
  * EMFF
  * hard p-pbar scatterings

- A method to obtain an antiproton beam with high degree of polarization has to be optimized (APR)

- PAX viable experimental setup at FAIR provides fexible 2nd IP really matched to the physics items
  * lots of interesting physics in PAX Phase-I
  * asymmetric collider ideal to map transversity (Phase-II)