

The PAX detector

Polarized **A**ntiproton **E**Xperiments

<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

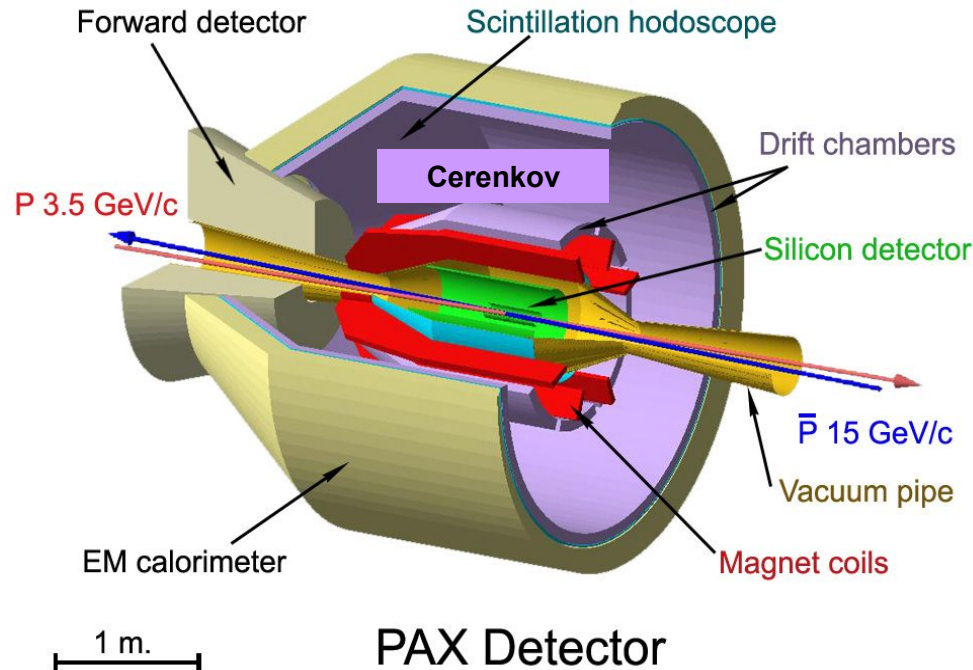
$$p^{(\uparrow)} \bar{p}^\uparrow \rightarrow e^+ e^-$$

Drell-Yan

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

SSA

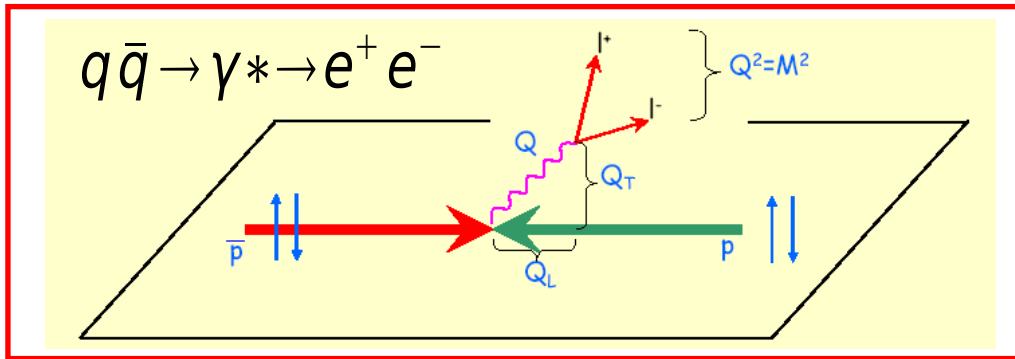
$$\bar{p} p^\uparrow \rightarrow e^+ e^- X$$



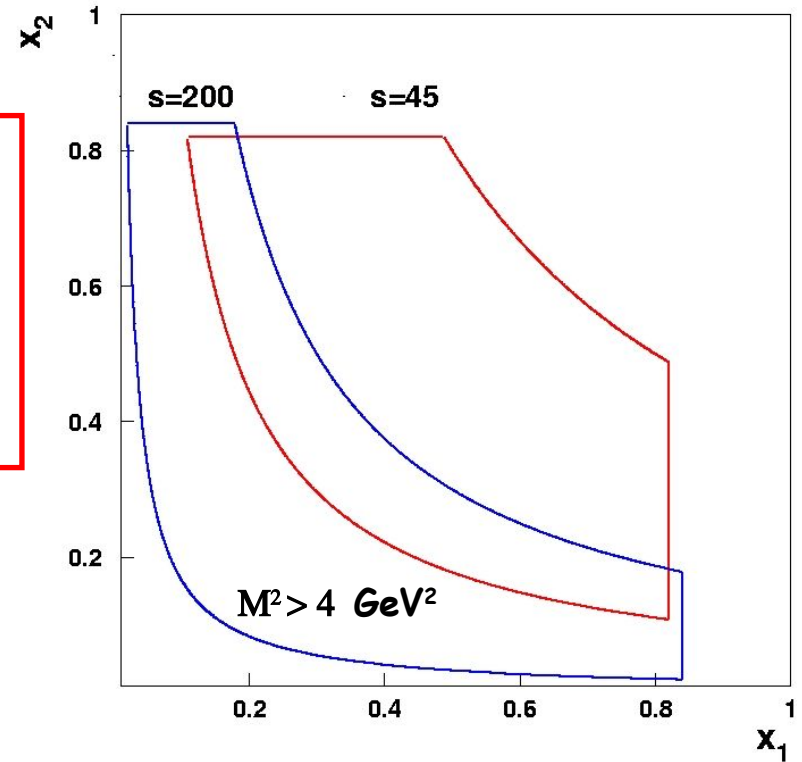
Fixed target experiment ($\sqrt{s} < 2 \text{ GeV}$):
 pol./unpol. pbar beam ($p < 4 \text{ GeV}/c$)
 internal H polarized target

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

Drell-Yan



H. Shimizu et al., hep-ph/0503270
V. Barone et al., in preparation



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

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

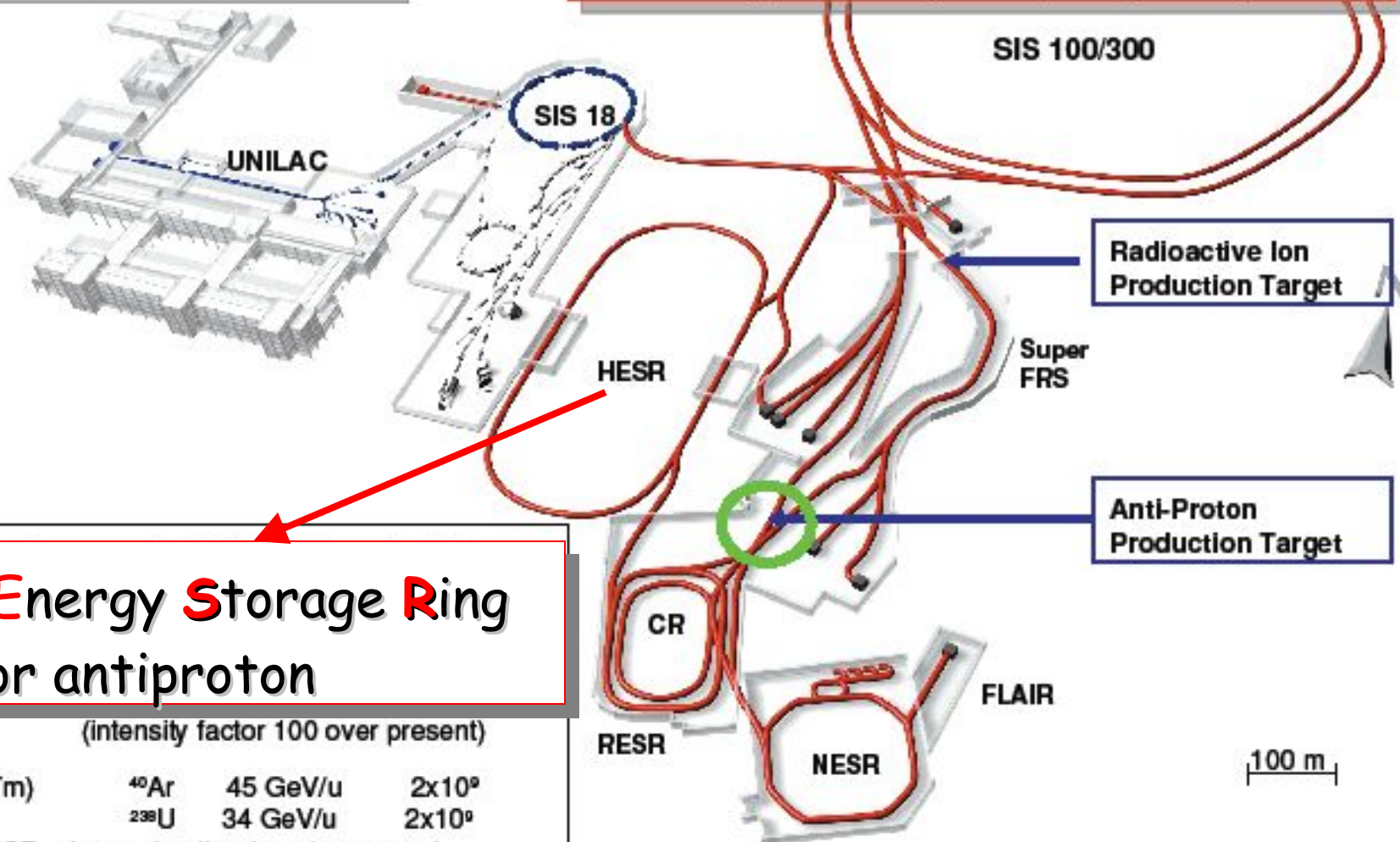
$q = u, \bar{u}, d, \bar{d}, \dots$

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

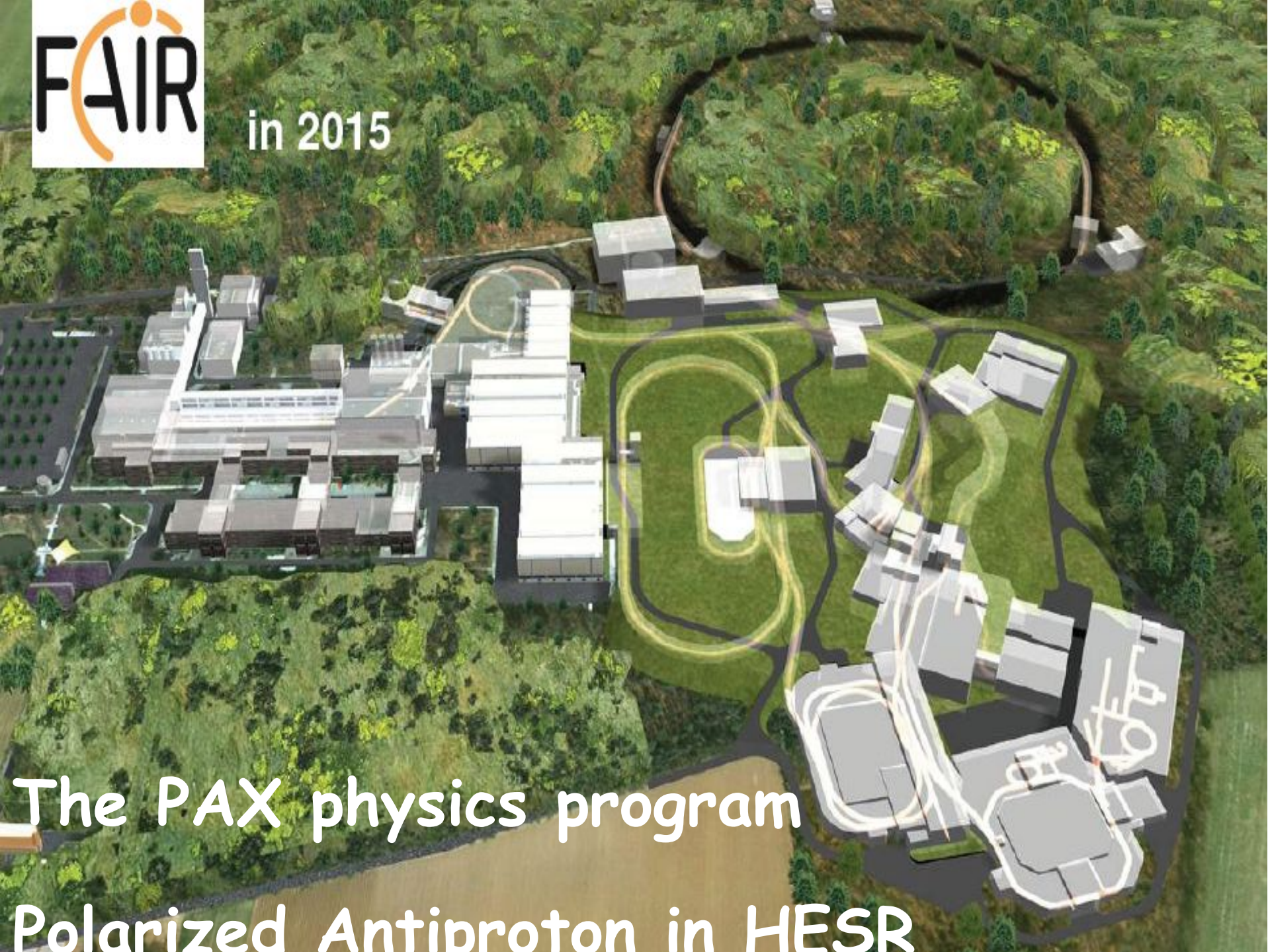


High **E**nergy **S**torage **R**ing for antiproton

		(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	$< 10^9$



in 2015

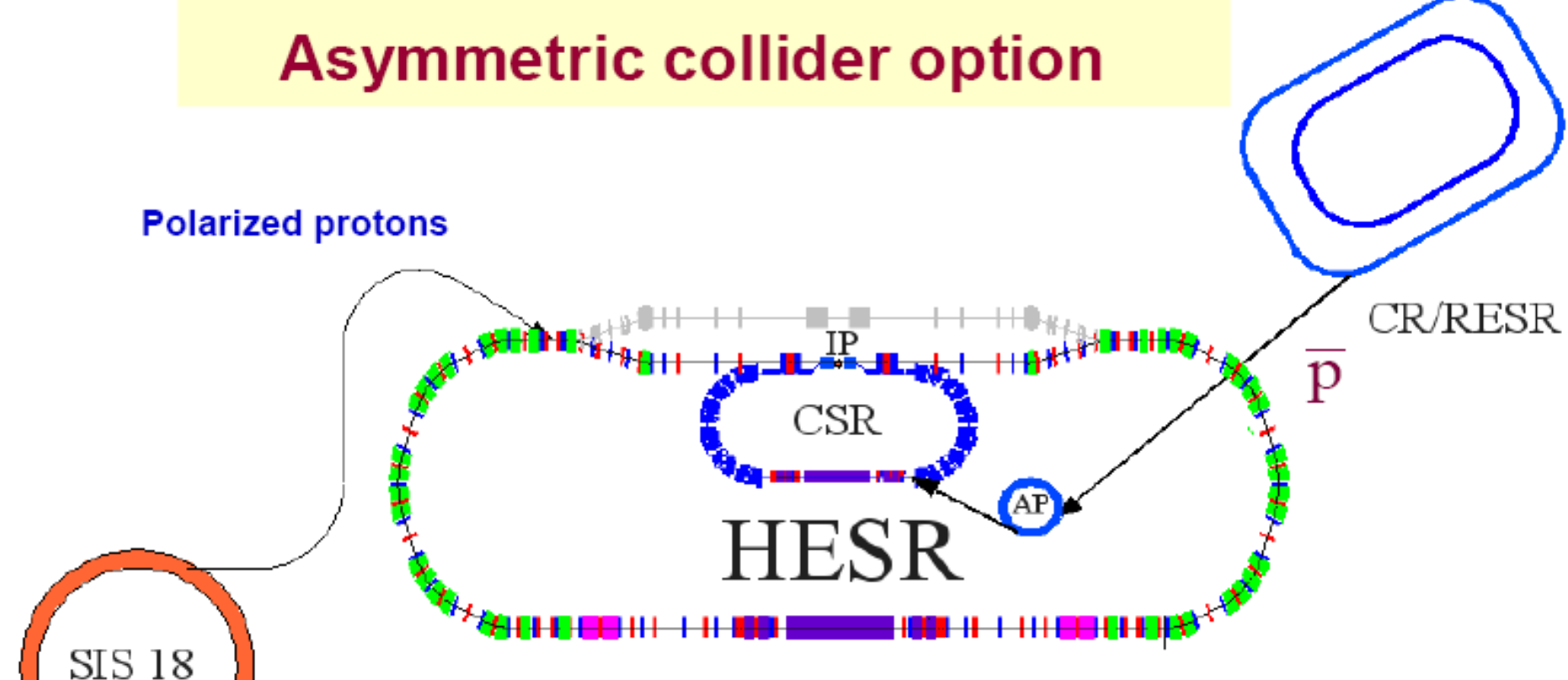


The PAX physics program

Polarized Antiproton in HESR

Asymmetric collider option

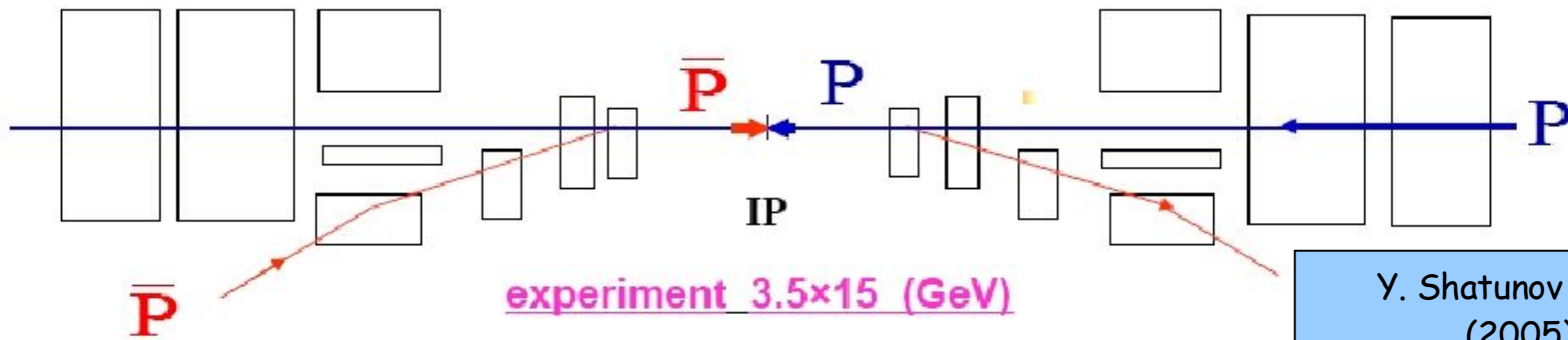
Polarized protons



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

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

Sketch of the interaction area



Y. Shatunov et al.,
(2005)

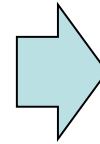
Ring circumferences,	l_1 / l_2	536 / 134	m
Beam energies	$E_p / E_{\bar{p}}$	15 / 3.5	GeV
Total number of antiprotons,	$N_{\bar{p}}$	0.1 / 0.3 / 1	10^{12}
Total number of protons,	N_p	7 / 7 / 7	10^{12}
Proton beam emittance,	ϵ_p	2.5 / 2.5 / 2.5	10^{-6} cm · rad.
Antiproton beam emittance,	$\epsilon_{\bar{p}}$	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 · s ⁻¹

Asymmetric collider

Luminosity up to $5 \cdot 10^{31}$ cm⁻² · s⁻¹

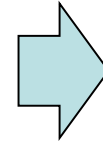
PAX Detector Concept

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

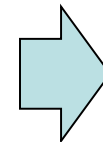
Experiment: Flexible Facility



e^+e^-

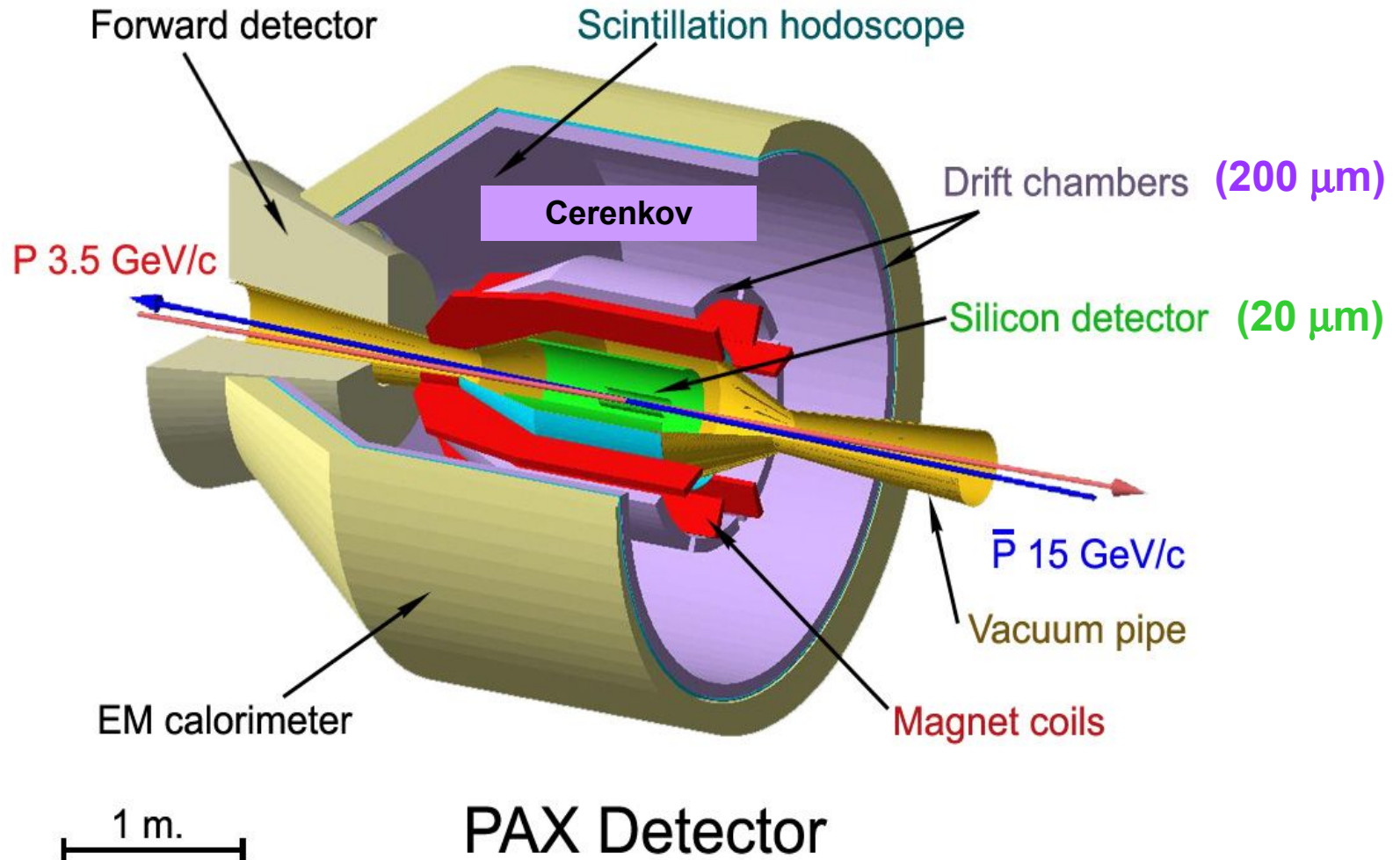
Detector: Extremely rare DY signal (10^{-7} p-pbar)
Excellent PID (hadron/e rejection $\geq 10^4$)
High mass resolution ($\leq 2\%$)
Maximum Bjorken-x coverage (M interval)
Moderate lepton energies (0.5-5 GeV)

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



TOROID
NO FRINGE FIELD

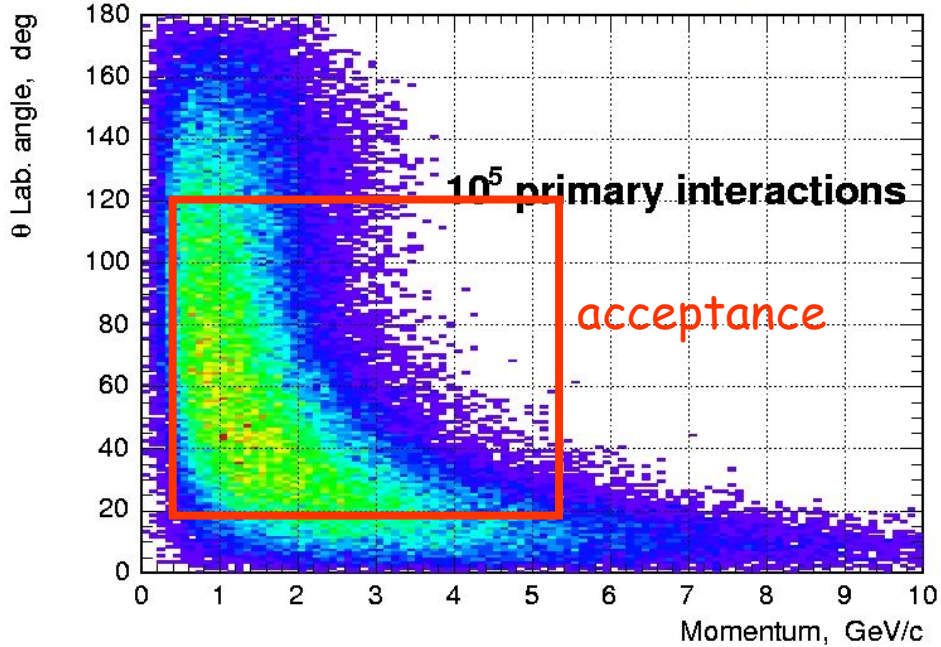
PAX Detector Concept



Designed for Collider but compatible with fixed target

θ -p Phase Space

p vs θ for primary Drell-Yan leptons

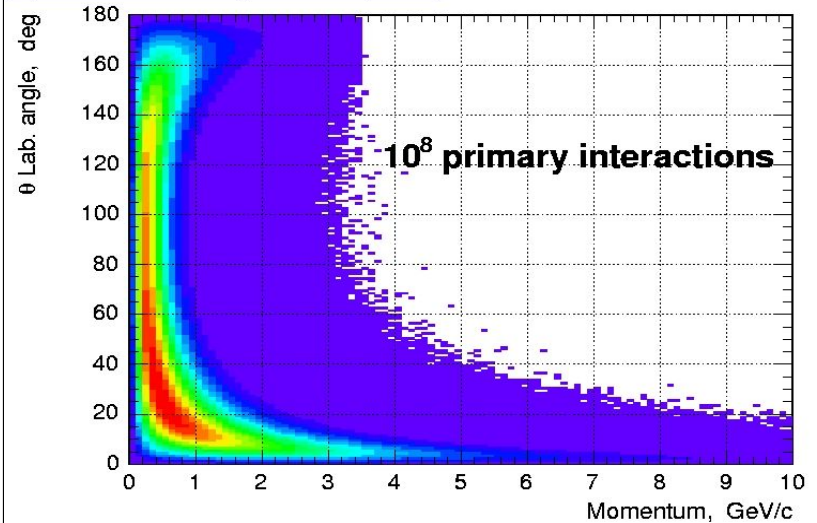


GEANT simulations

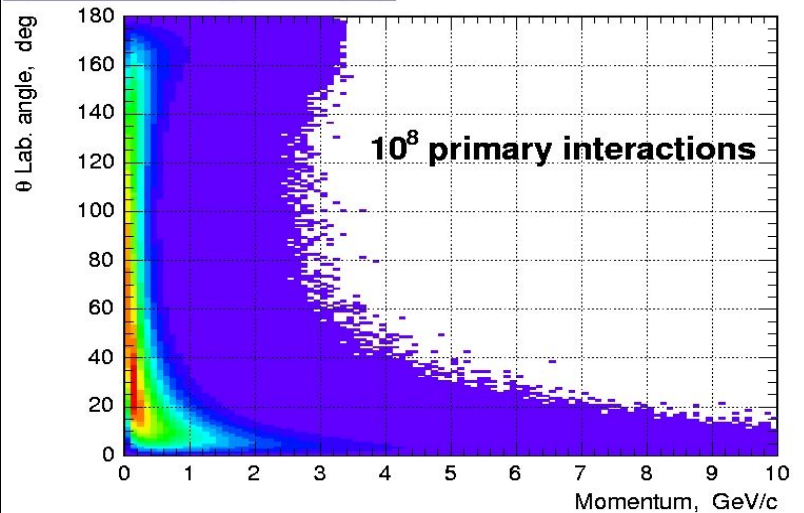
Background peaks at

- * low energy
- * forward direction

p vs θ for primary π^\pm



p vs θ for primary γ



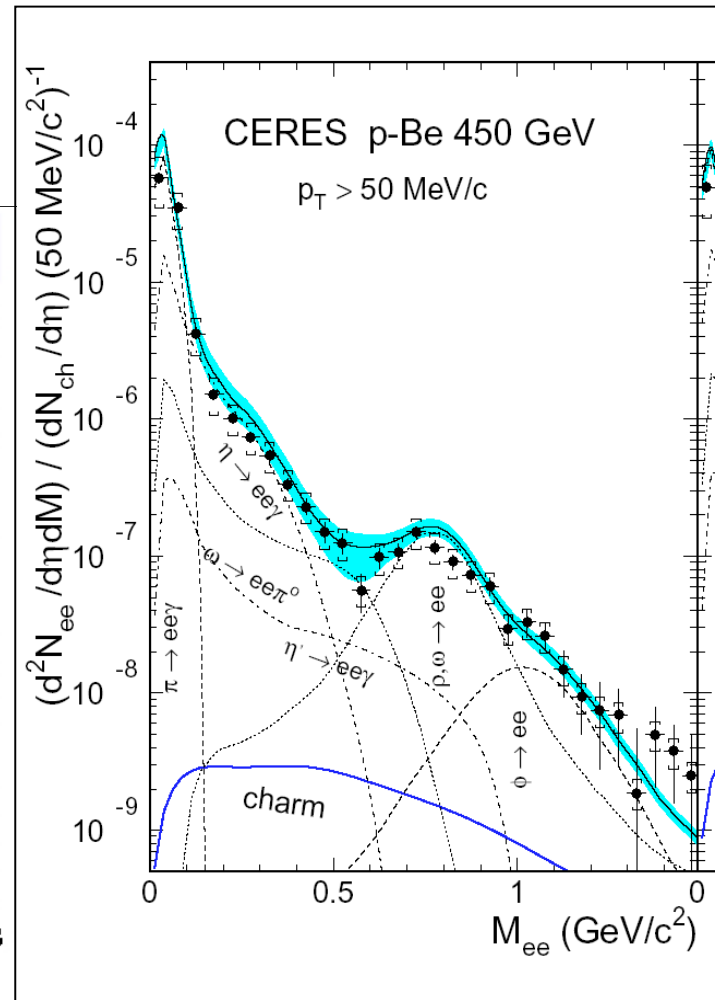
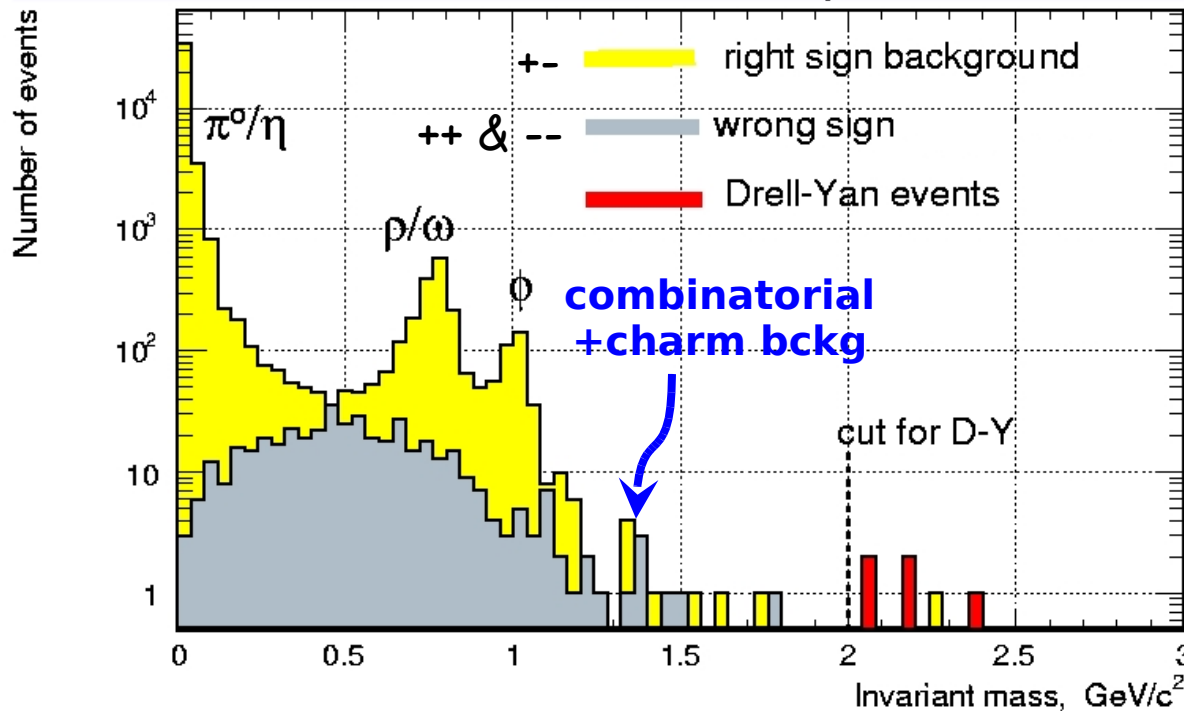
Background to Drell-Yan e^+e^-

Few min. experiment:

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

several DY events

Invariant mass of ee pair

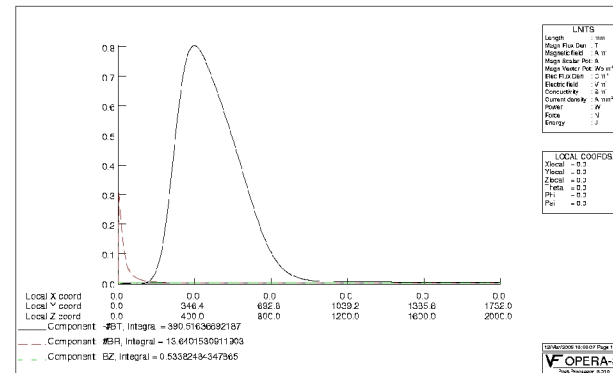
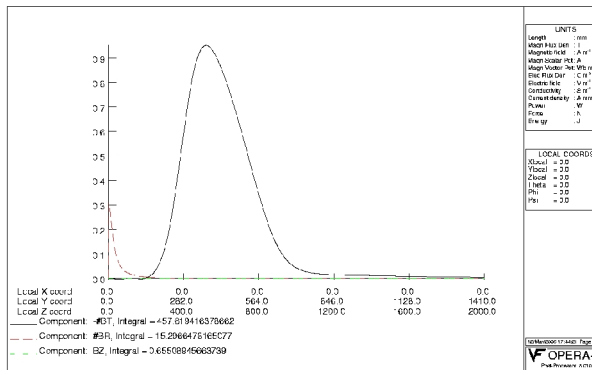
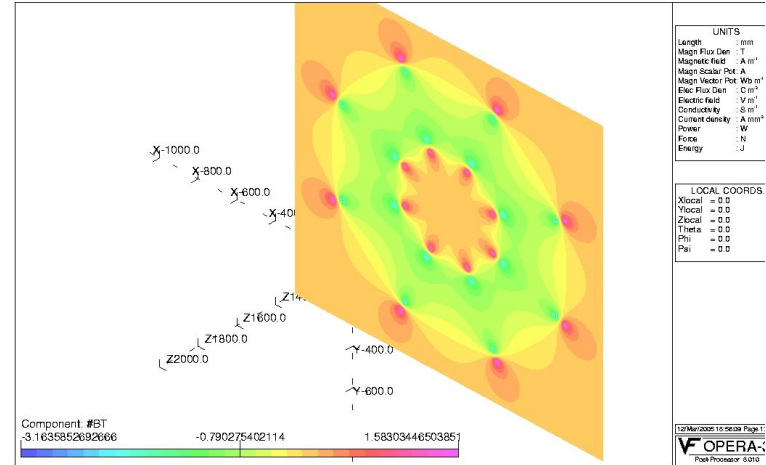
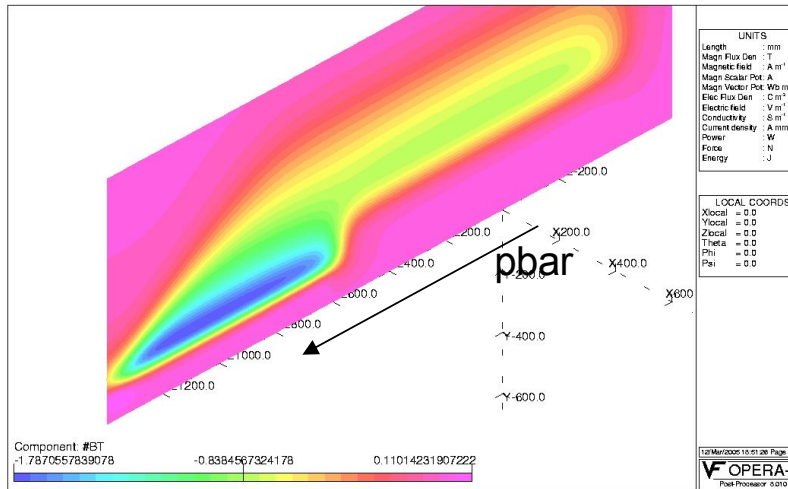


Background 1:1 to signal after PID, $E > 300 \text{ MeV}$, conversion veto, mass cut

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

Toroid field

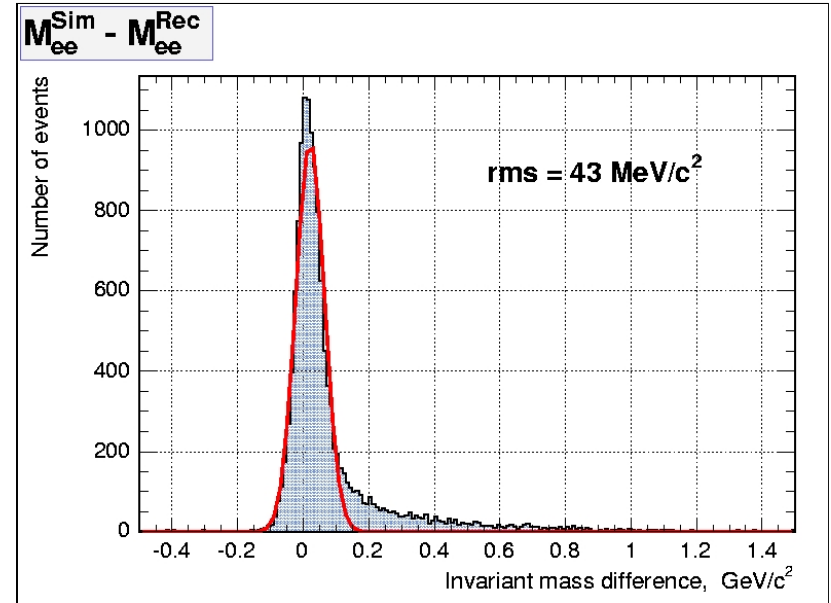
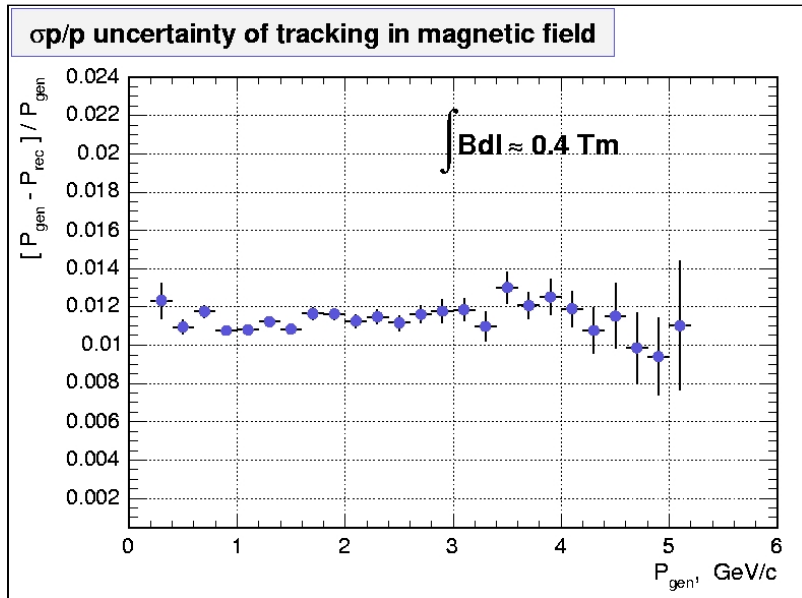
Transverse field matching the momentum, no fringe field



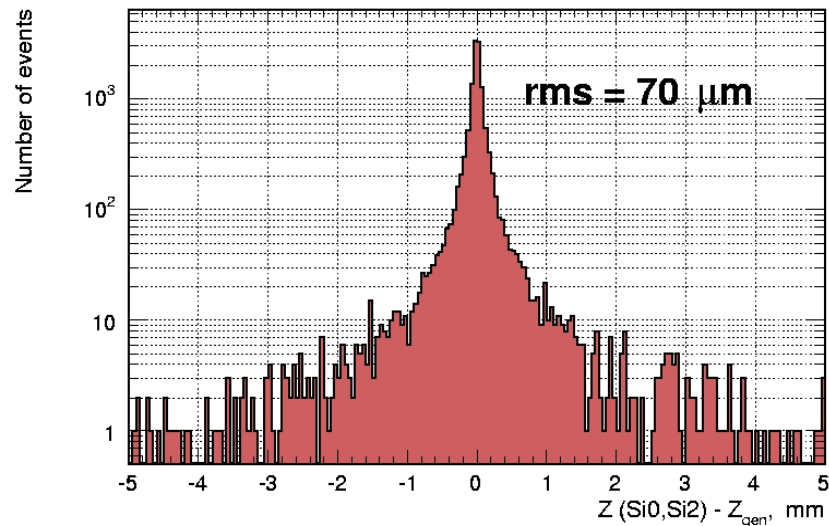
$$\int B dl = 0.46 \text{ Tm at } 35^\circ$$

$$\int B dl = 0.39 \text{ Tm at } 60^\circ$$

θ -p Phase Space



Vertex measurement uncertainty (R,Z plane)



Better than 2% mass resol

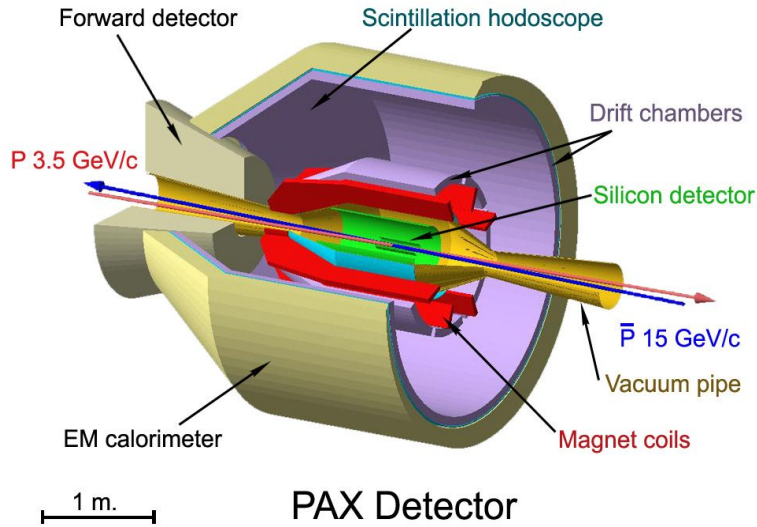
* x dependence of h_1

* resonance vs continuum

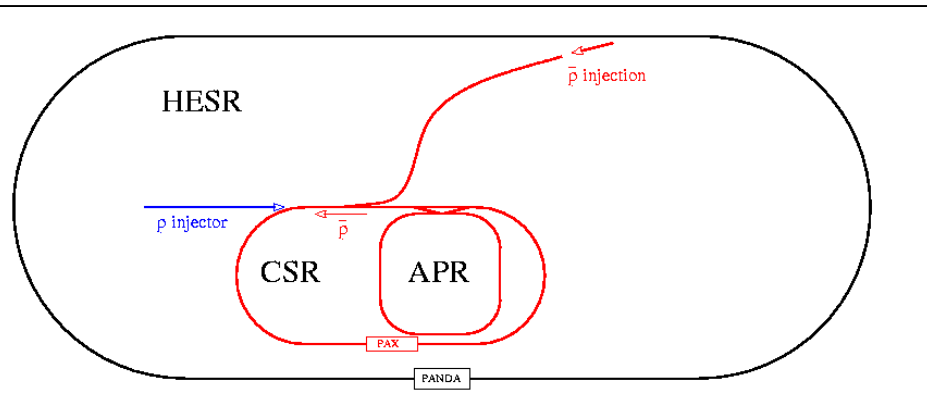
Mandatory to study M below J/ψ mass

Vertex resolution high enough
to study charm background

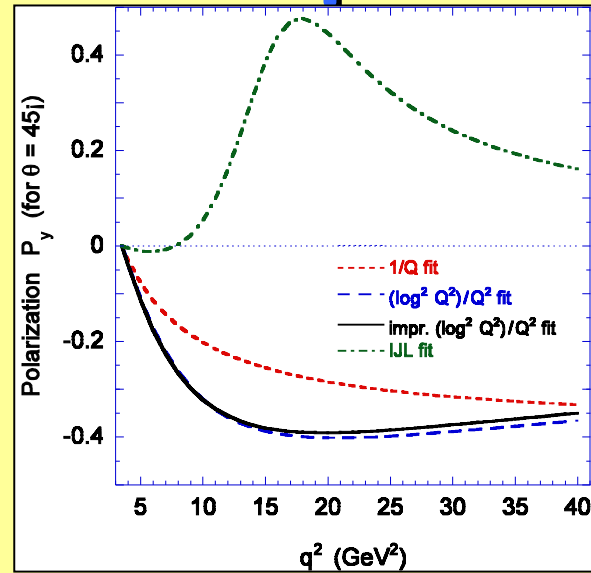
Polarized Antiproton eXperiments



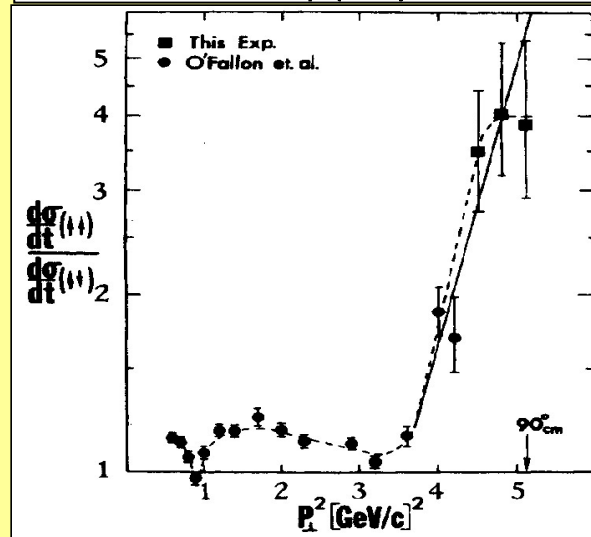
Phase I: Proton time-like FFs
Hard pbar-p elastic scatt.



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



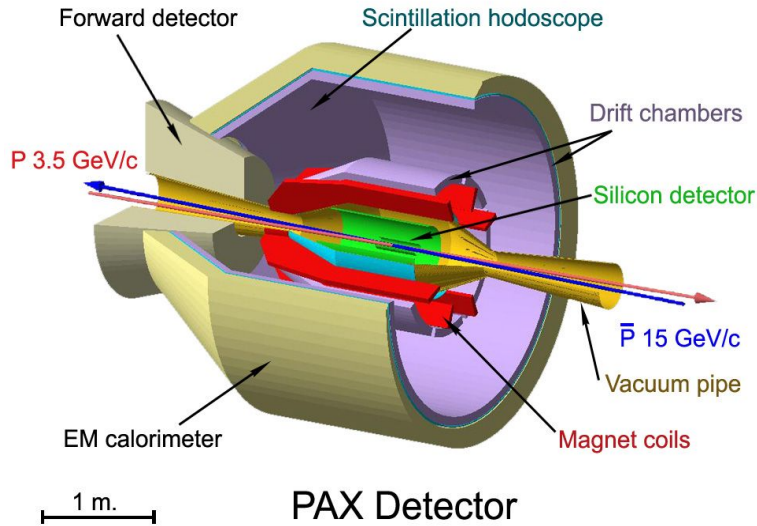
$$p^\uparrow \bar{p} \rightarrow e^+ e^-$$



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

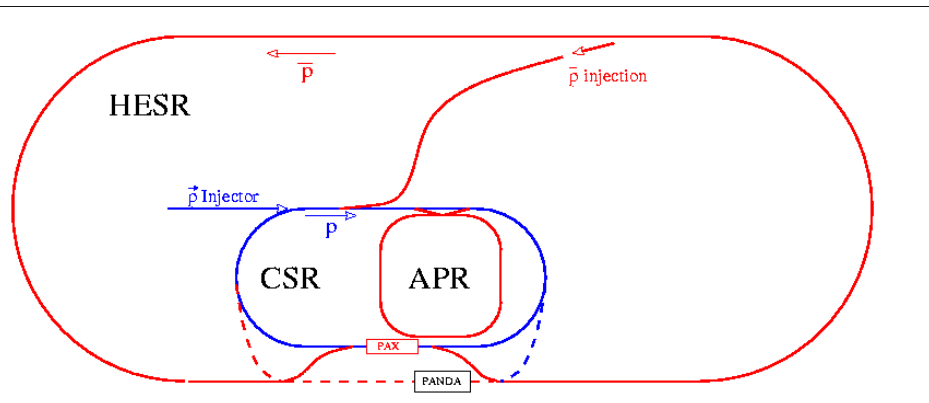
From few hours to few weeks measurements

Polarized Antiproton eXperiments



PAX Detector

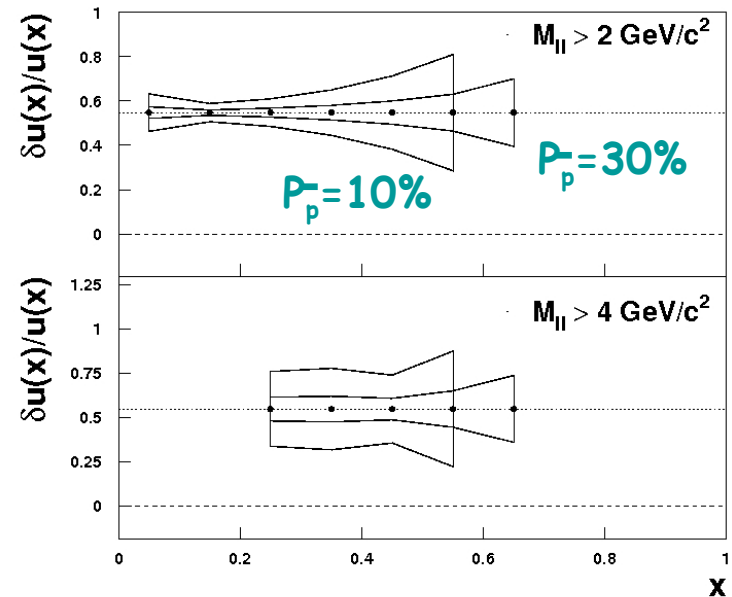
Phase II: Transversity Distribution



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

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

1 year of run



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 flexible 2nd IP really matched to the physics items
 - * lots of interesting physics in PAX Phase-I
 - * asymmetric collider ideal to map transversity (Phase-II)