SPIN Physics at GSI

Frank Rathmann
Institut für Kernphysik
Forschungszentrum Jülich

16th International Spin Physics Symposium, Trieste, Oktober 2004

Outline

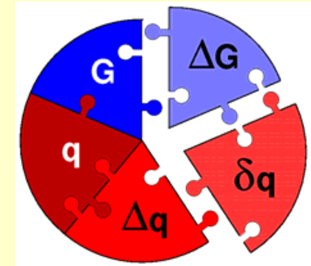
WHY?	Physics Case
HOW?	Polarized Antiprotons
WHERE?	FAIR Project at Darmstadt
WHAT?	Transversity Measurement
WHEN?	Time Schedule
	Conclusion

Central Physics Issue

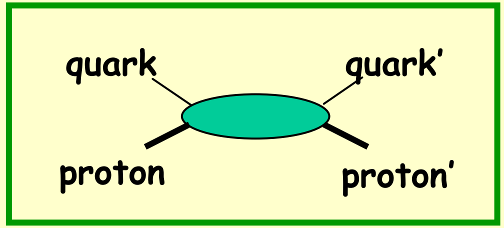
Transversity distribution of the nucleon:

- last leading-twist missing piece of the QCD description of the partonic structure of the nucleon
- directly accessible uniquely via the double transverse spin asymmetry A_{TT} in the Drell-Yan production of lepton pairs
- theoretical expectations for A_{TT} in DY, 30-40%
  - transversely polarized antiprotons
  - transversely polarized proton target
- definitive observation of $h_1^q(x,Q^2)$ of the proton for the valence quarks

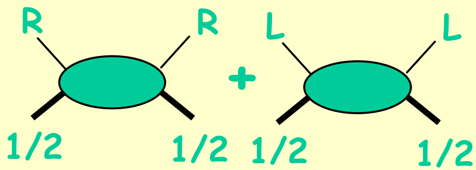
Leading Twist Distribution Functions

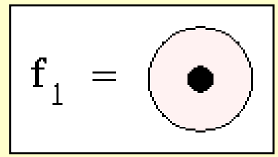


Probabilistic interpretation in helicity base:



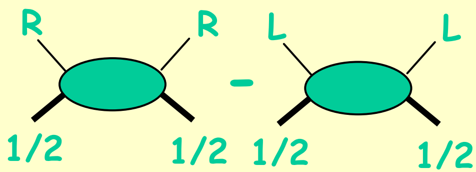
$f_1(x)$

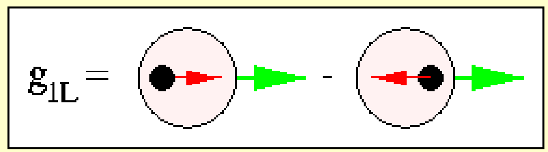




q(x) spin averaged
(well known)

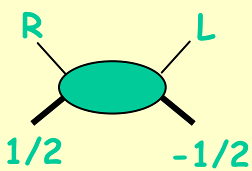
$g_1(x)$





Δq(x) helicity diff.
(known)

$h_1(x)$

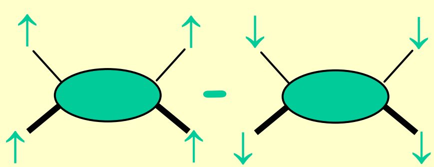


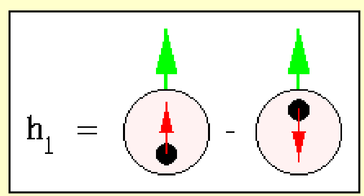
No probabilistic interpretation in the helicity base (off diagonal)

Transversity base

$u_\uparrow = 1/\sqrt{2}(u_R + u_L)$

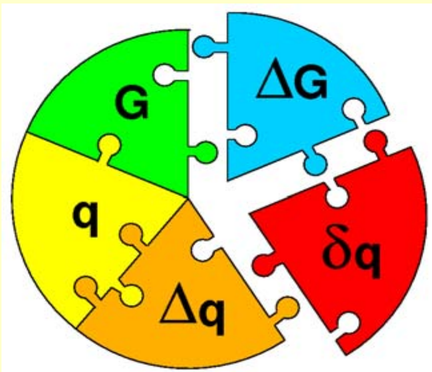
$u_\downarrow = 1/\sqrt{2}(u_R - u_L)$





δq(x) helicity flip
(unknown)

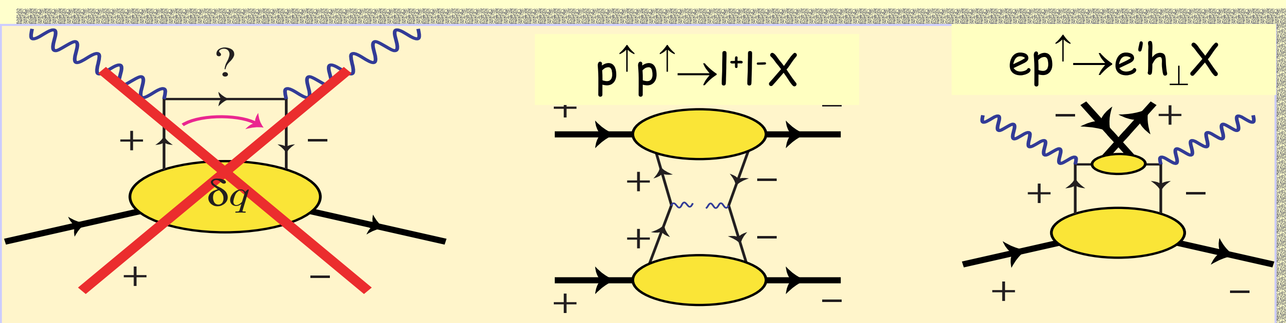
Transversity



Properties:

- Probes relativistic nature of quarks
- No gluon analog for spin-1/2 nucleon
- Different Q^2 evolution than Δq
- Sensitive to valence quark polarization

Chiral-odd: requires another chiral-odd partner



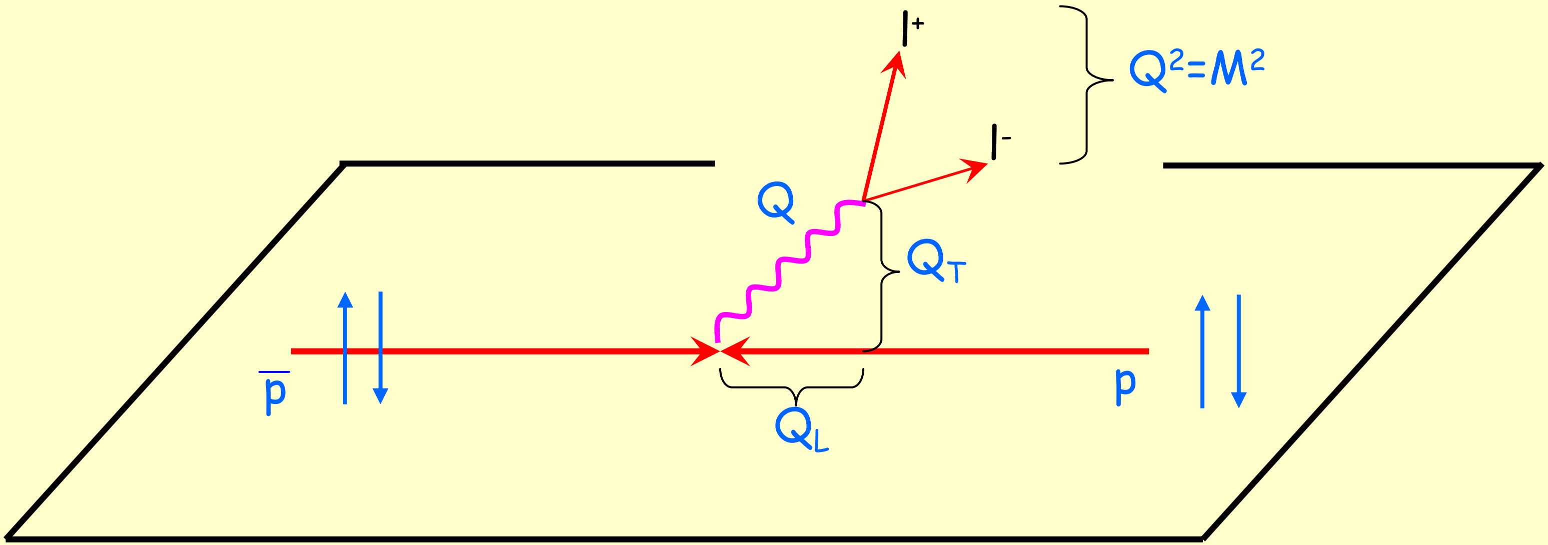
Impossible in DIS

Direct Measurement

Indirect Measurement: Convolution of with unknown fragment. fct.

Transversity in Drell-Yan processes

Polarized Antiproton Beam → Polarized Proton Target
(both transversely polarized)



$$A_{TT} \equiv \frac{d\sigma^{\uparrow\uparrow} - d\sigma^{\uparrow\downarrow}}{d\sigma^{\uparrow\uparrow} + d\sigma^{\uparrow\downarrow}} = \hat{a}_{TT} \frac{\sum_q e_q^2 h_1^q(x_1, M^2) h_1^{\bar{q}}(x_2, M^2)}{\sum_q e_q^2 q(x_1, M^2) \bar{q}(x_2, M^2)}$$

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

M invariant Mass of lepton pair

Other Topics

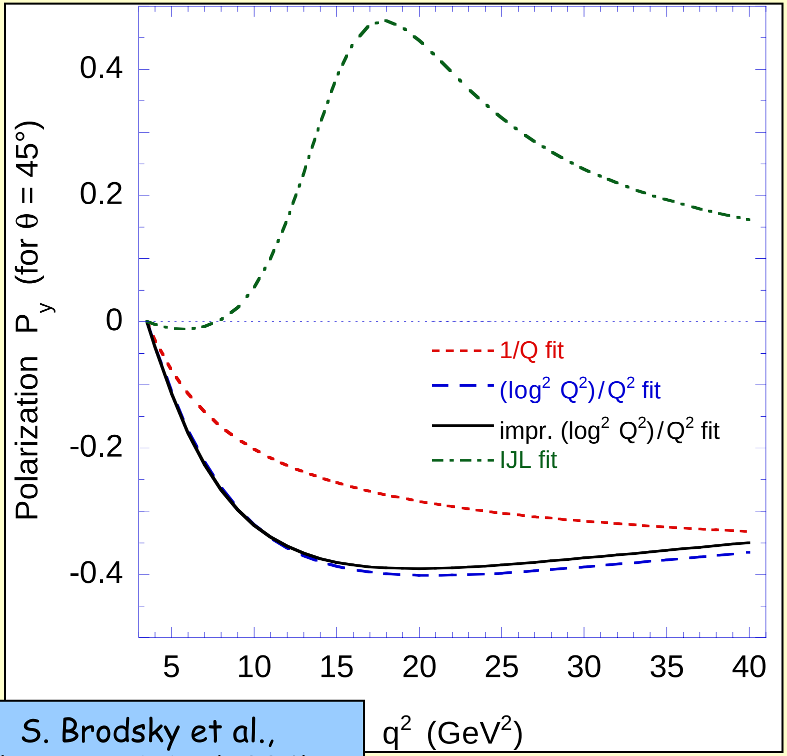
- Single-Spin Asymmetries
- Electromagnetic Form Factors
- Hard Scattering Effects
- Soft Scattering
  - Low-t Physics
  - Total Cross Section
  - pbar-p interaction

Proton Electromagnetic Formfactors

- Measurement of relative phases of magnetic and electric FF in the time-like region
  - Possible only via SSA in the annihilation $\bar{p}p \to e^+e^-$

$$A_y = \frac{\sin(2\theta)\cdot \mathrm{Im}(G_E^* \cdot G_M)}{\left[\left(1+\cos^2(\theta)\right)|G_M|^2 + \sin^2(\theta)|G_E|^2/\tau\right]\sqrt{\tau}}$$

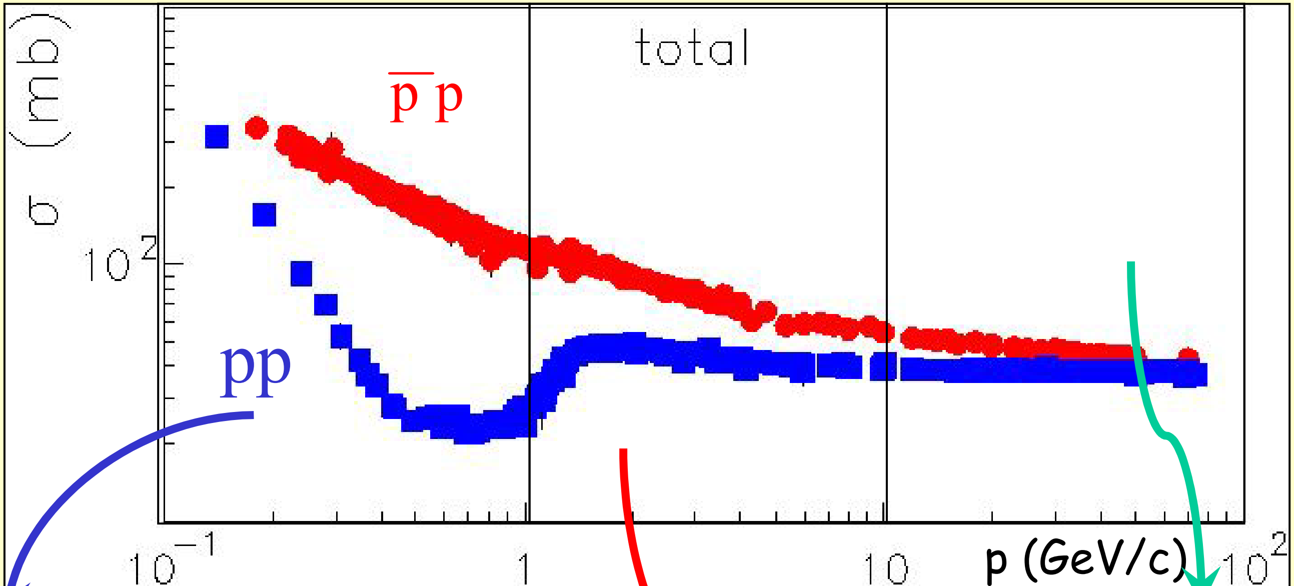
$$\tau = q^2/4m_p^2$$



S. Brodsky et al., Phys. Rev. D69 (2004)

- Double-spin asymmetry
  - independent G_E-G_m separation
  - test of Rosenbluth separation in the time-like region

Study onset of Perturbative QCD



Pure Meson Land
- Meson exchange
- Δ excitation
- NN potential models

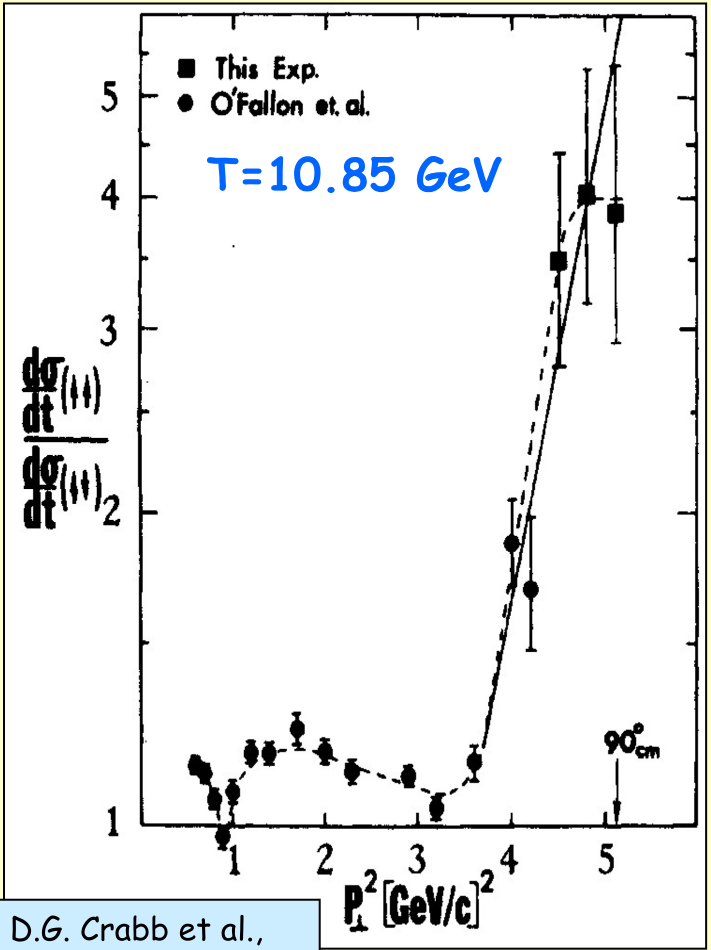
High Energy
- small t: Reggeon Exchange
- large t: perturbative QCD

Transition Region
- Uncharted Territory
- Huge Spin-Effects in pp elastic scattering
- **large t: non- and perturbative QCD**

pp elastic scattering from ZGS

Spin-dependence at large-$P_\perp$ (90°_{cm}):
Hard scattering takes place only with spins ↑↑.

Similar studies in $\bar{p}p$ elastic scattering



D.G. Crabb et al., PRL 41, 1257 (1978)

Outline

WHY?	Physics Case
HOW?	**Polarized Antiprotons**
WHERE?	FAIR Project at Darmstadt
WHAT?	Transversity Measurements
WHEN?	Time Schedule
	Conclusion

Spin Filter Method

$$\sigma_{tot} = \sigma_0 + \sigma_\perp \cdot \vec{P} \cdot \vec{Q} + \sigma_{||} \cdot (\vec{P} \cdot \vec{k})(\vec{Q} \cdot \vec{k})$$

P beam polarization
Q target polarization
k || beam direction

For initially equally populated spin states: ↑ ($m=+\frac{1}{2}$) and ↓ ($m=-\frac{1}{2}$)

transverse case:

$$\sigma_{tot\pm} = \sigma_0 \pm \sigma_\perp \cdot Q$$

longitudinal case:

$$\sigma_{tot\pm} = \sigma_0 \pm (\sigma_\perp + \sigma_{||}) \cdot Q$$

$$\tau_{beam} = \frac{1}{(\sigma_0 + \Delta\sigma_c) \cdot d_t \cdot f_{rev}}$$

$$\tau_{pol} = \frac{1}{\sigma_{pol} \cdot Q \cdot d_t \cdot f_{rev}}$$

$$I_+(t) = \frac{I_0}{2} \cdot e^{-\frac{t}{\tau_{beam}}} \cdot e^{-\frac{t}{\tau_{pol}}}$$

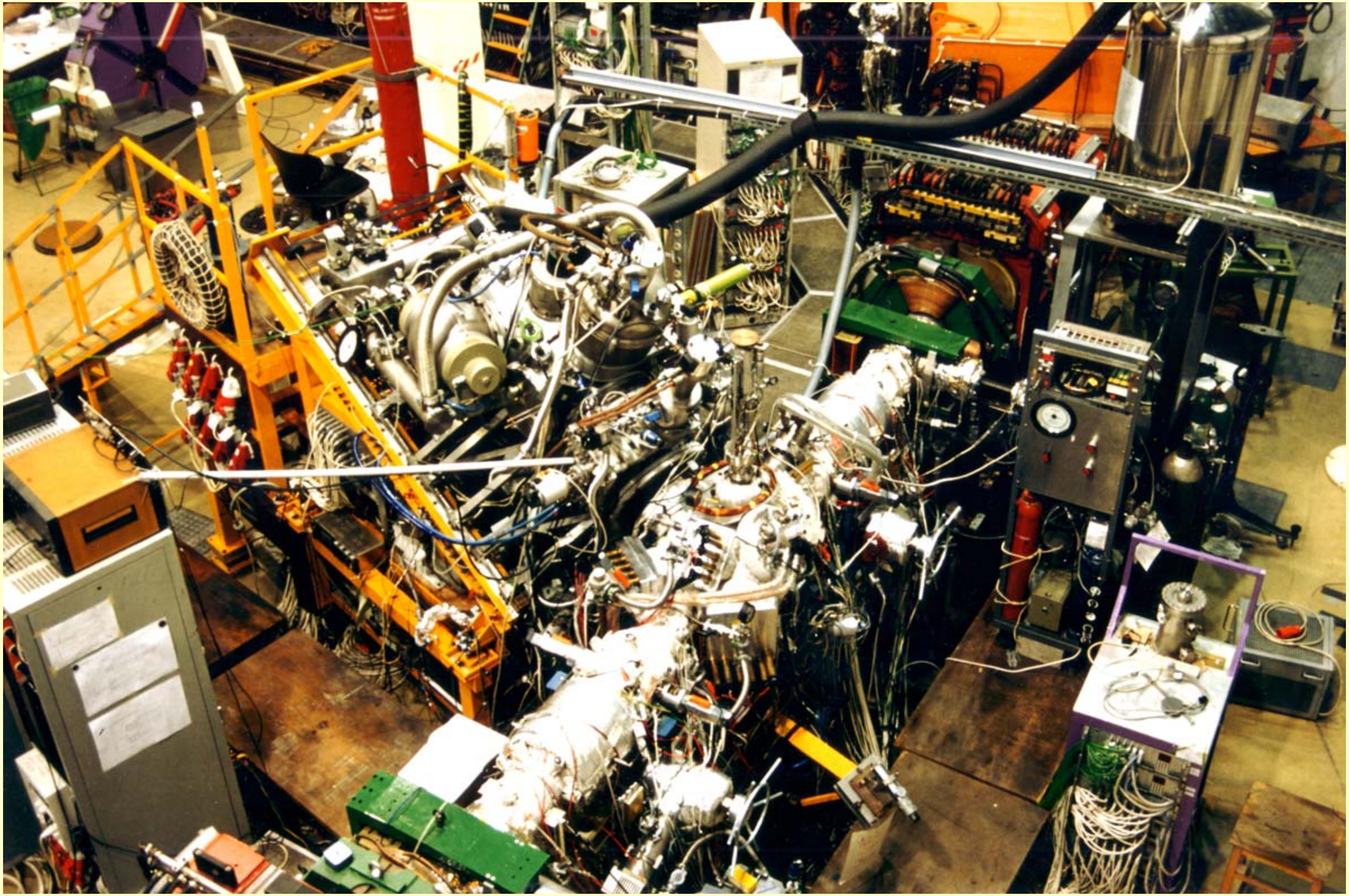
$$I_-(t) = \frac{I_0}{2} \cdot e^{-\frac{t}{\tau_{beam}}} \cdot e^{+\frac{t}{\tau_{pol}}}$$

Time dependence of P and I

$$P(t) = \frac{I_+ - I_-}{I_+ + I_-} = -\tanh\left(\frac{t}{\tau_{pol}}\right)$$

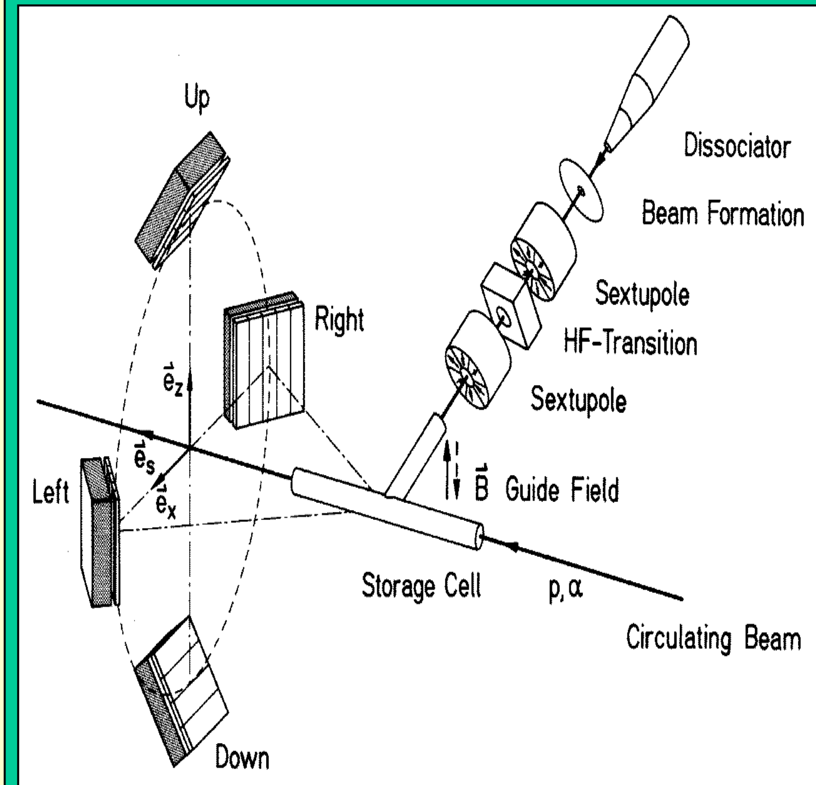
$$I(t) = I_+ + I_- = I_0 \cdot e^{-\frac{t}{\tau_{beam}}} \cdot \cosh\left(\frac{t}{\tau_{pol}}\right)$$

1992 Filter Test at HD-TSR with protons

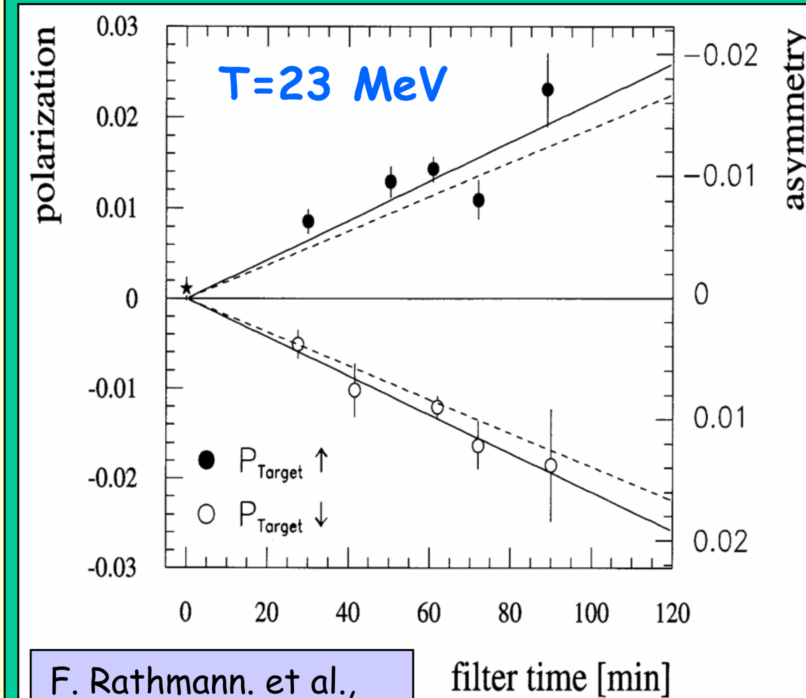


Experimental Results from Filter Test

Experimental Setup



Results



F. Rathmann. et al.,
PRL 71, 1379 (1993)

Low energy pp scattering

$\sigma_1 < 0 \Rightarrow \sigma_{tot+} < \sigma_{tot-}$

Expectation	
Target	Beam
↑	↑
↓	↓

Puzzle from FILTEX Test

Observed polarization build-up: $dP/dt = \pm (1.24 \pm 0.06) \times 10^{-2}\ h^{-1}$

Expected build-up: $P(t)=\tanh(t/\tau_{pol})$,
$1/\tau_{pol}=\sigma_1 Q d_t f = 2.4\times10^{-2}\ h^{-1}$
$\Rightarrow$ **about factor 2 larger!**

σ_1 = 122 mb (pp phase shifts)
$Q = 0.83 \pm 0.03$
$d_t = (5.6 \pm 0.3) \times 10^{13} cm^{-2}$
f = 1.177 MHz

Three distinct effects:

1. **Selective removal through scattering beyond Ψ_{acc}=4.4 mrad**
   $\sigma_{R\perp}$=83 mb
2. **Small angle scattering of target protons into ring acceptance**
   $\sigma_{S\perp}$=52 mb
3. **Spin transfer from polarized electrons of the target atoms to the stored protons**
   $\sigma_{EM\perp}$=70 mb (-)

Horowitz & Meyer, PRL 72, 3981 (1994)
H.O. Meyer, PRE 50, 1485 (1994)

Spin Transfer from Electrons to Protons

$$p + \vec{e} \rightarrow \vec{p} + e$$

$$\sigma_{EM\perp} = -\frac{1}{2}\left[\frac{4\pi\alpha^2(1+\lambda_p)m_e}{p^2 m_p}\right] C_0^2 \left[\frac{\nu}{2\alpha}\right] \times \sin\left[\frac{2\alpha \ln(2pa_0)}{\nu}\right]$$

Horowitz & Meyer, PRL 72, 3981 (1994)
H.O. Meyer, PRE 50, 1485 (1994)

$$\sigma_{EM||} = 2 \cdot \sigma_{EM\perp}$$

α	fine structure constant
$\lambda_p=(g-2)/2=1.793$	anomalous magnetic moment
m_e, m_p	rest masses
p	cm momentum
a_0	Bohr radius
$C_0^2=2\pi\eta/[\exp(2\pi\eta)-1]$	Coulomb wave function
$\eta=z\alpha/v$	Coulomb parameter (negative for antiprotons)
v	relative lab. velocity between p and e
z	beam charge number

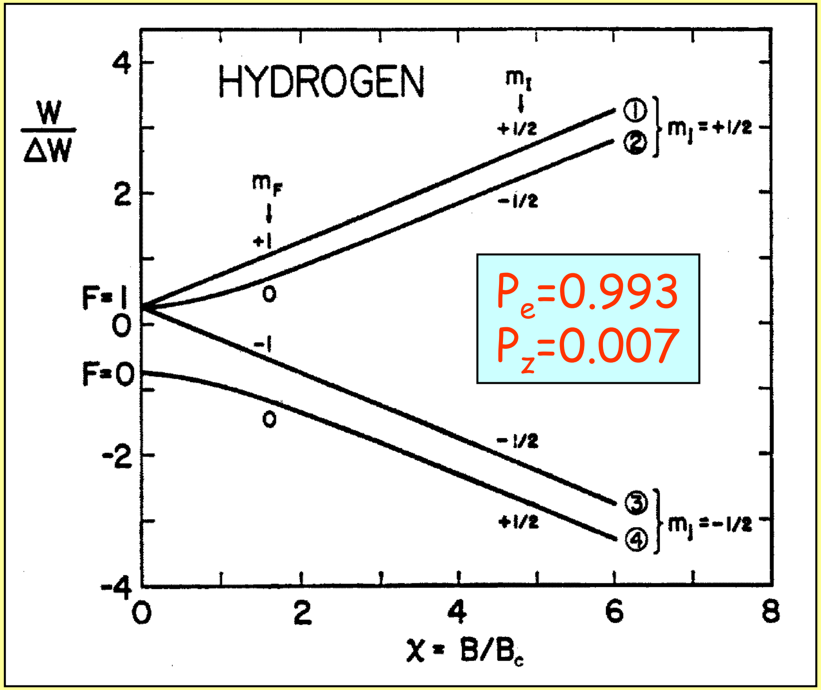
Exploitation of Spin Transfer

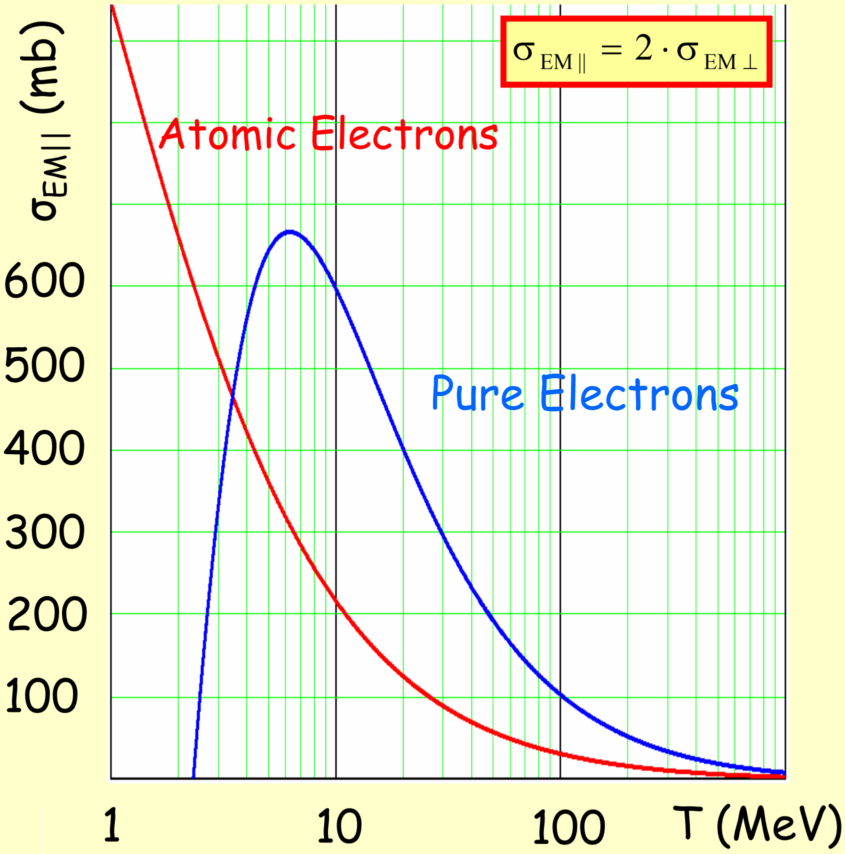
PAX will employ spin-transfer from polarized electrons of the target to antiprotons

$$\overline{p} + \vec{e} \rightarrow \vec{\overline{p}} + e$$

(QED Process: **calculable**)

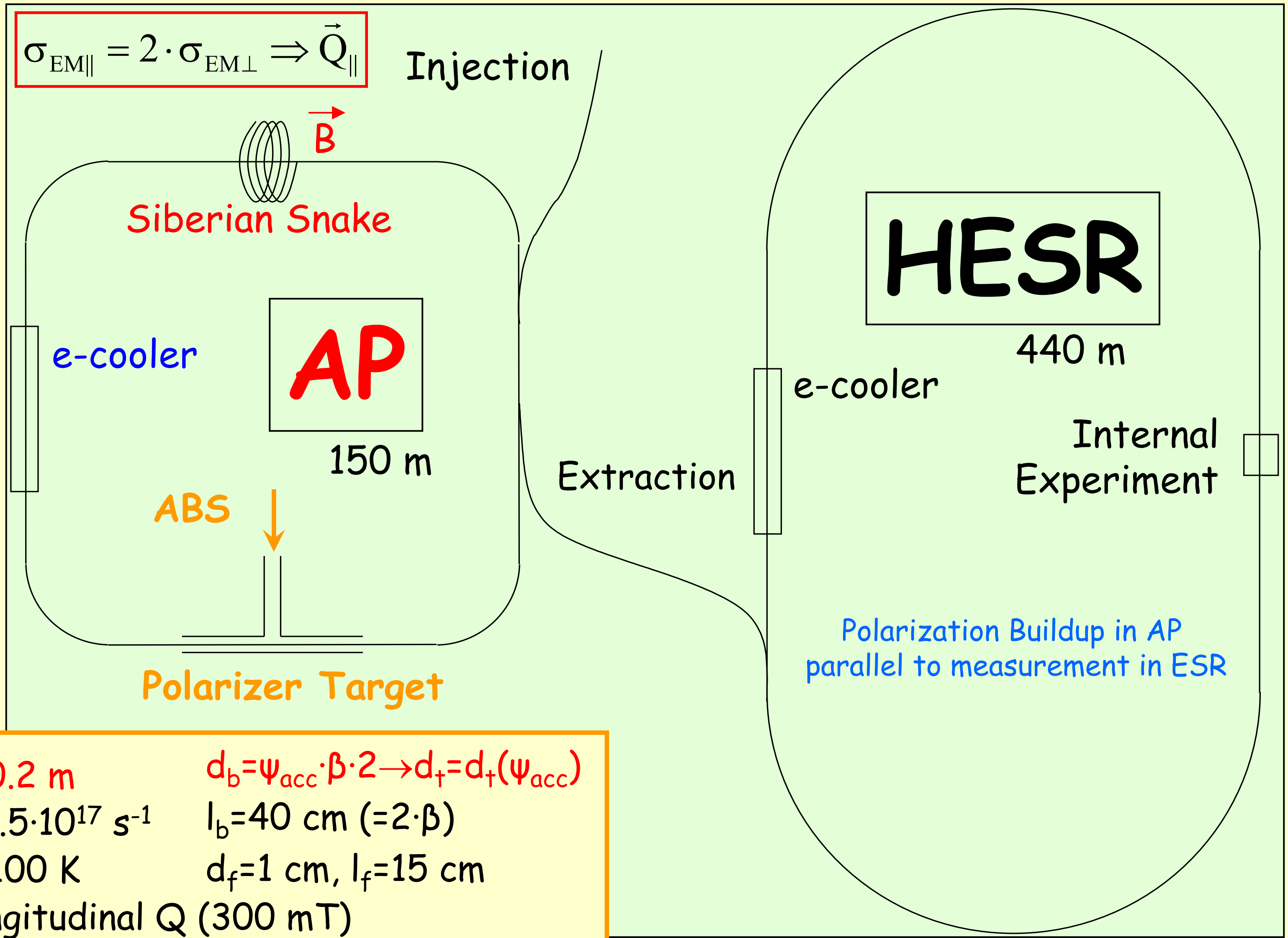
Hydrogen gas target:
①+② in strong field (300 mT)





Dedicated Antiproton Polarizer (AP)

$\sigma_{EM\parallel} = 2 \cdot \sigma_{EM\perp} \Rightarrow \vec{Q}_{\parallel}$



β=0.2 m

$d_b=\psi_{acc}\cdot\beta\cdot 2 \rightarrow d_t=d_t(\psi_{acc})$

$q=1.5\cdot 10^{17}\ s^{-1}$

l_b=40 cm (=2·β)

T=100 K

d_f=1 cm, l_f=15 cm

Longitudinal Q (300 mT)

Beam lifetimes in the AP

Beam Lifetime

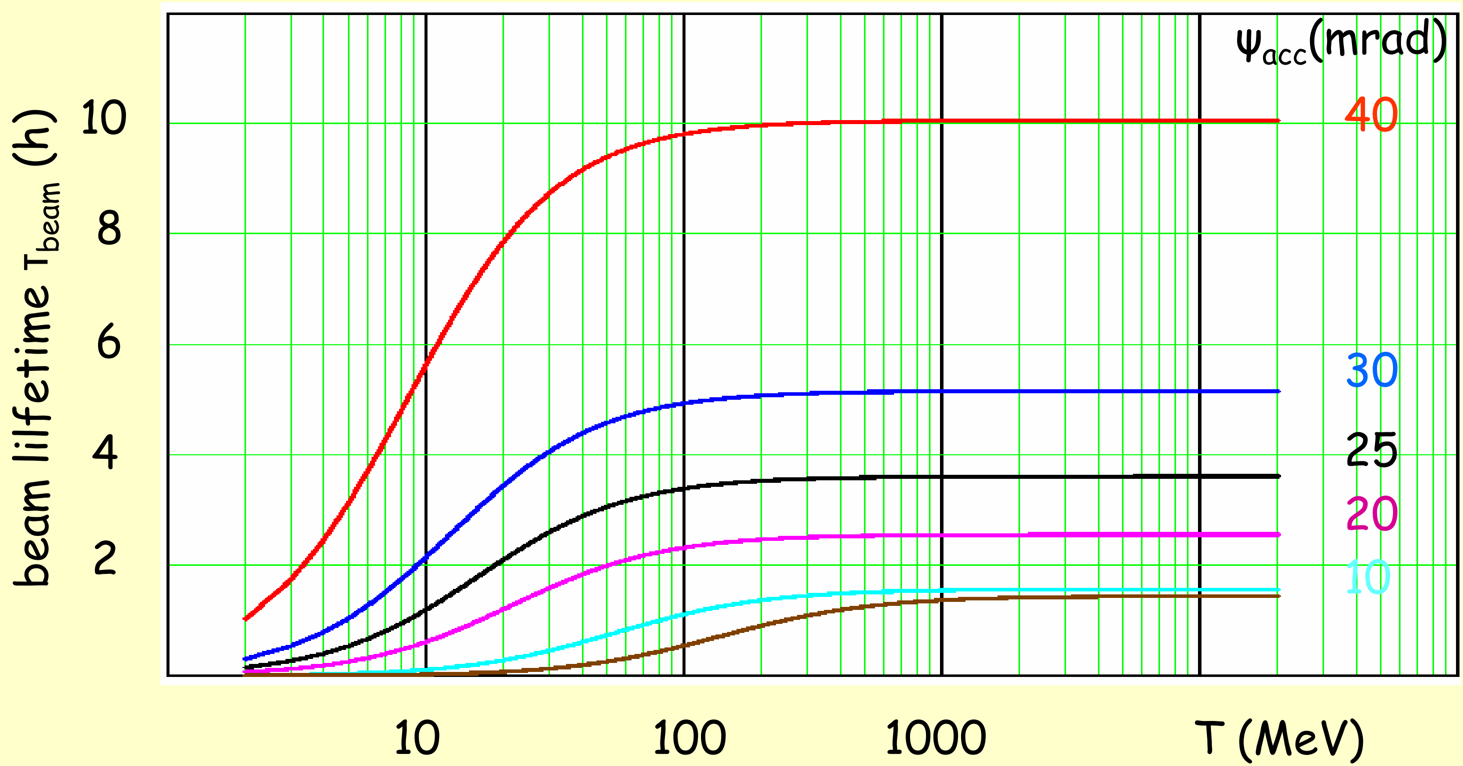
$$\tau_{beam}(T,\Psi_{acc}) = \frac{1}{(\Delta\sigma_C(T,\Psi_{acc}) + \sigma_0(T)) \cdot d_t(\Psi_{acc}) \cdot f_{rev}(T)}$$

Coulomb Loss

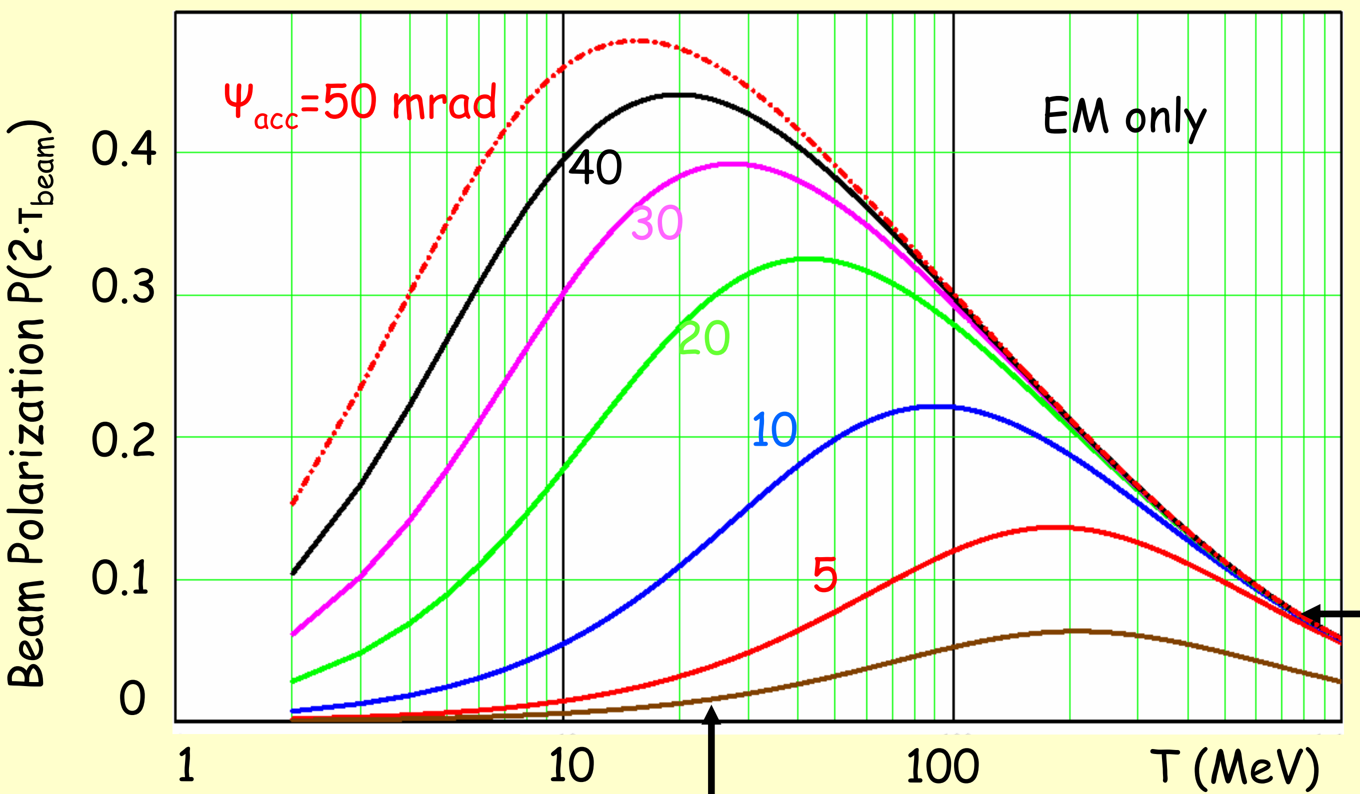
$$\Delta\sigma_C(T,\Psi_{acc}) = \int_{\theta_{min}}^{\theta_{max}} \left(\frac{d\sigma}{d\Omega}\right)_{Ruth.} d\Omega = 4\pi\alpha^2 \frac{(s(T)-2m_p{}^2)^2 4m_p{}^2}{s(T)^2(s(T)-4m_p{}^2)^2} \left(\frac{1}{\psi_{acc}^2} - \frac{s(T)}{4m_p{}^2}\right)$$

Total Hadronic

$$\sigma_0(T) = \sigma_{tot\, p\bar{p}}(T)$$



Beam Polarization



Filter Test: T = 23 MeV
Ψ_{acc}= 4.4 mrad

Buildup in HESR (800 MeV)

Polarization Buildup: Optimum Interaction Time

statistical error of a double polarization observable (A_{TT})

$$\delta_{A_{TT}} = \frac{1}{P \cdot Q \cdot \sqrt{N}}$$

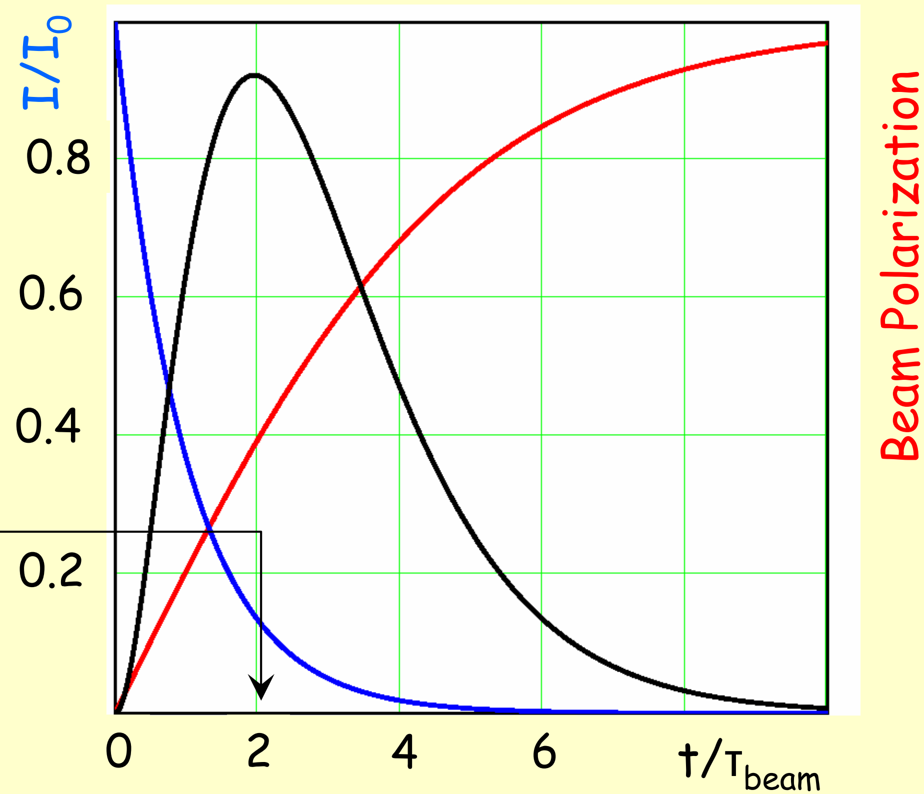
(N ~ I)

Measuring time t to achieve a certain error

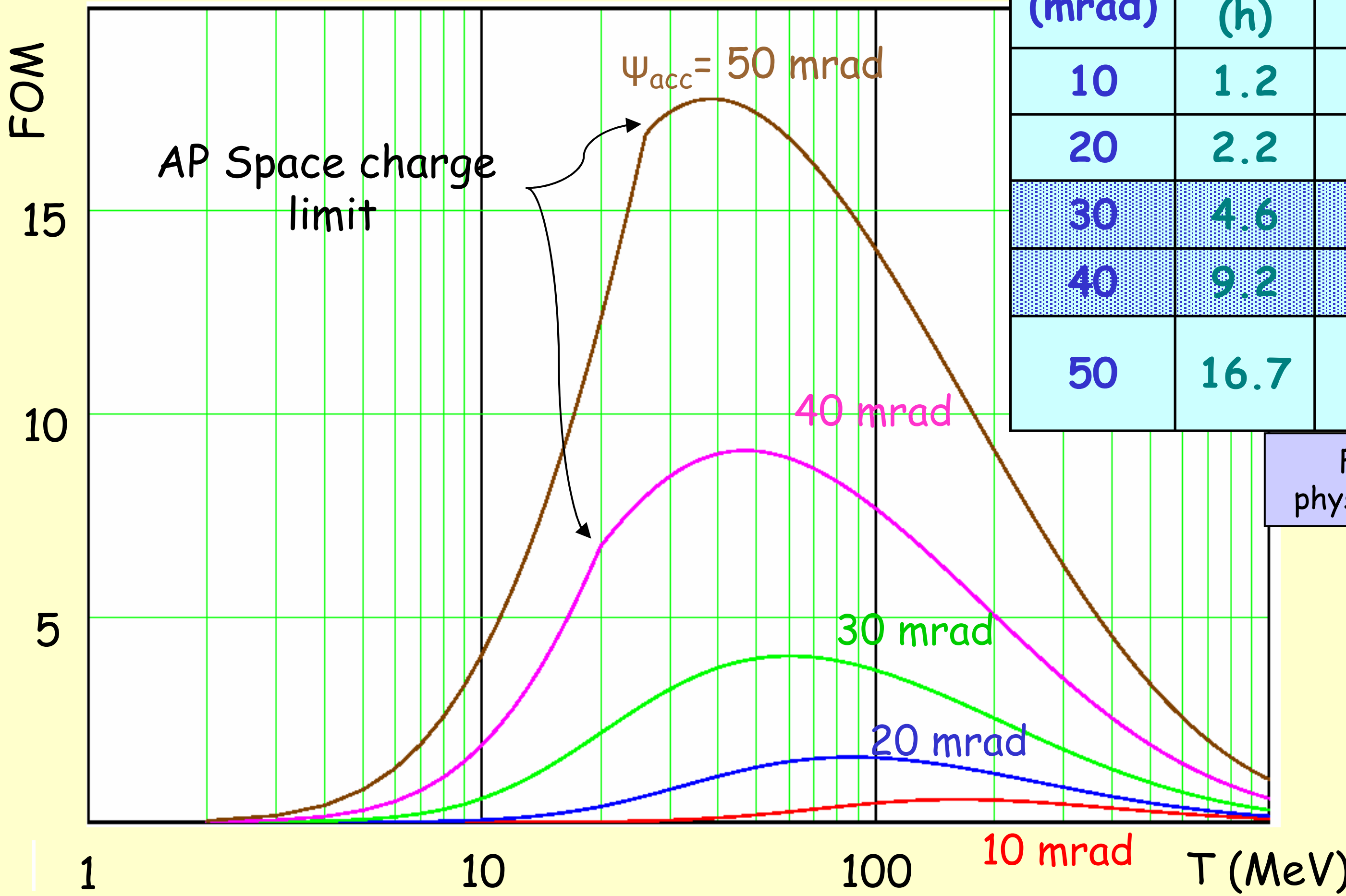
$\delta_{A_{TT}} \sim$ **FOM = $P^2 \cdot I$**

Optimimum time for Polarization Buildup given by maximum of FOM(t)

$$t_{filter} = 2 \cdot \tau_{beam}$$



Optimum Beam Energies for Buildup in AP

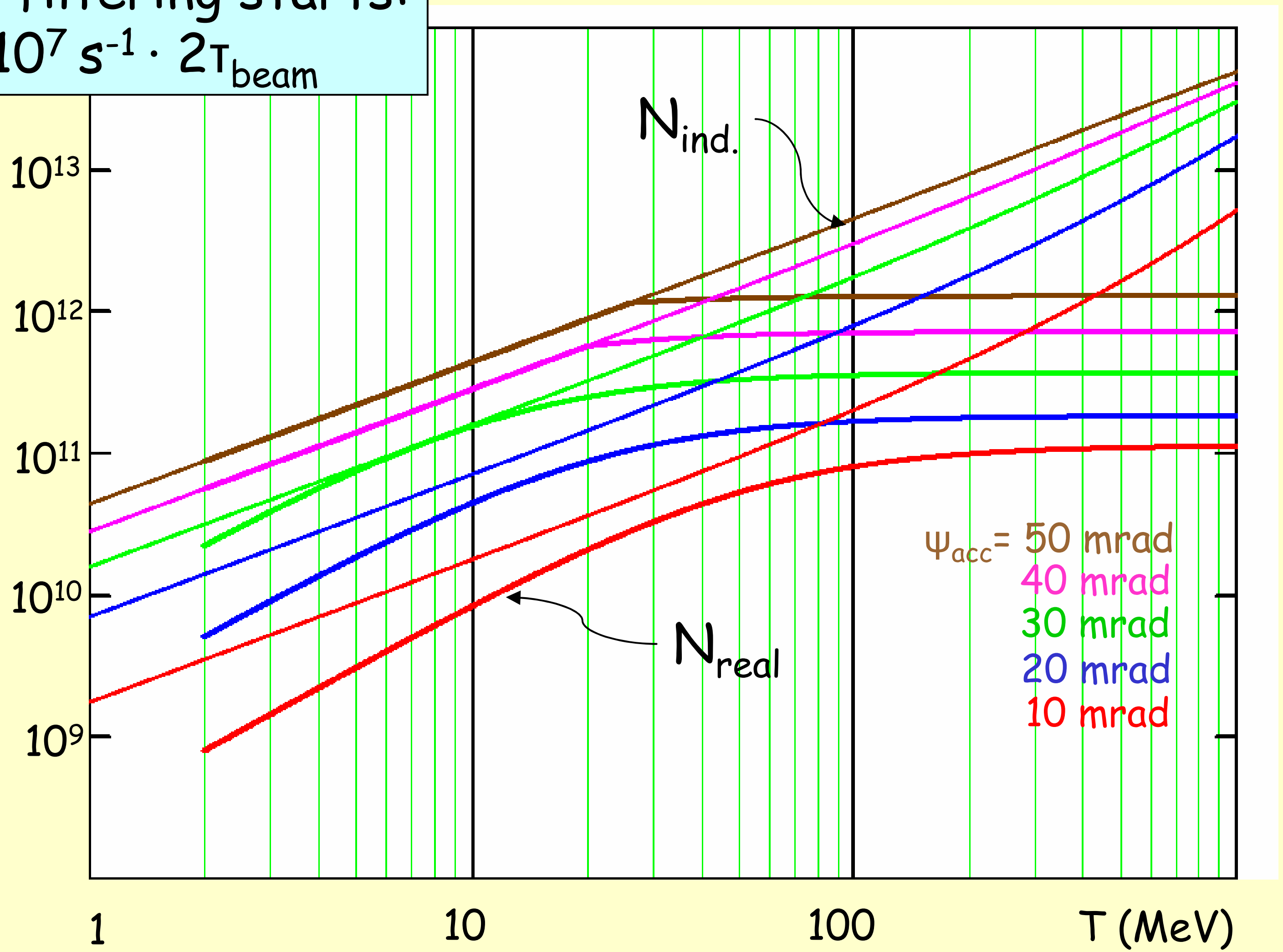


Maximum FOM			
Ψ_{acc} (mrad)	T_{beam} (h)	$P(2 \cdot \tau_{beam})$	T (MeV)
10	1.2	0.19	163
20	2.2	0.29	88
30	4.6	0.35	61
40	9.2	0.39	47
50	16.7	0.42	38

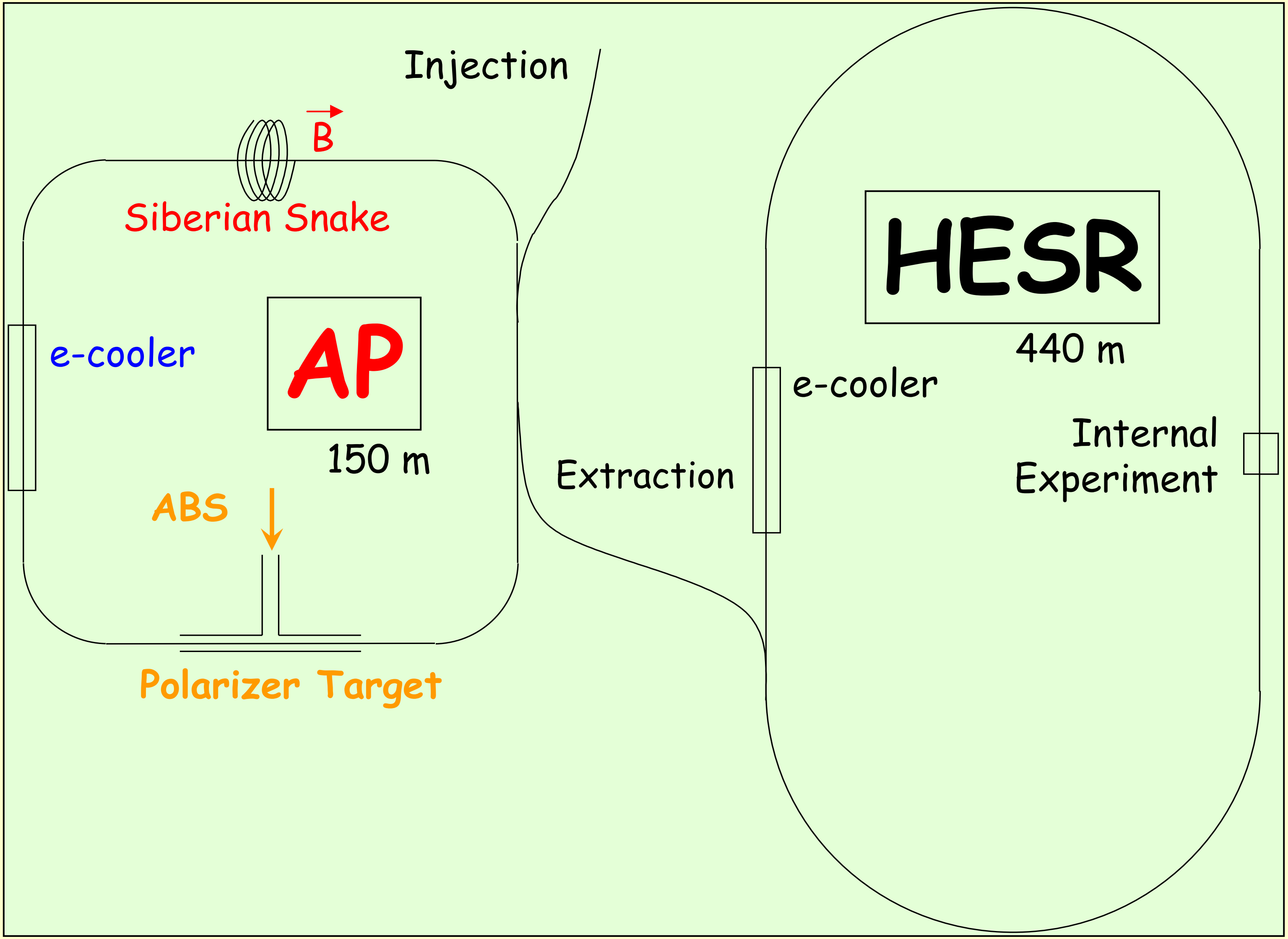
F. Rathmann et al., physics/0410067 (2004)

Space-Charge Limitation in the AP

Before filtering starts:
$N_{real} = 10^7\ s^{-1} \cdot 2\tau_{beam}$



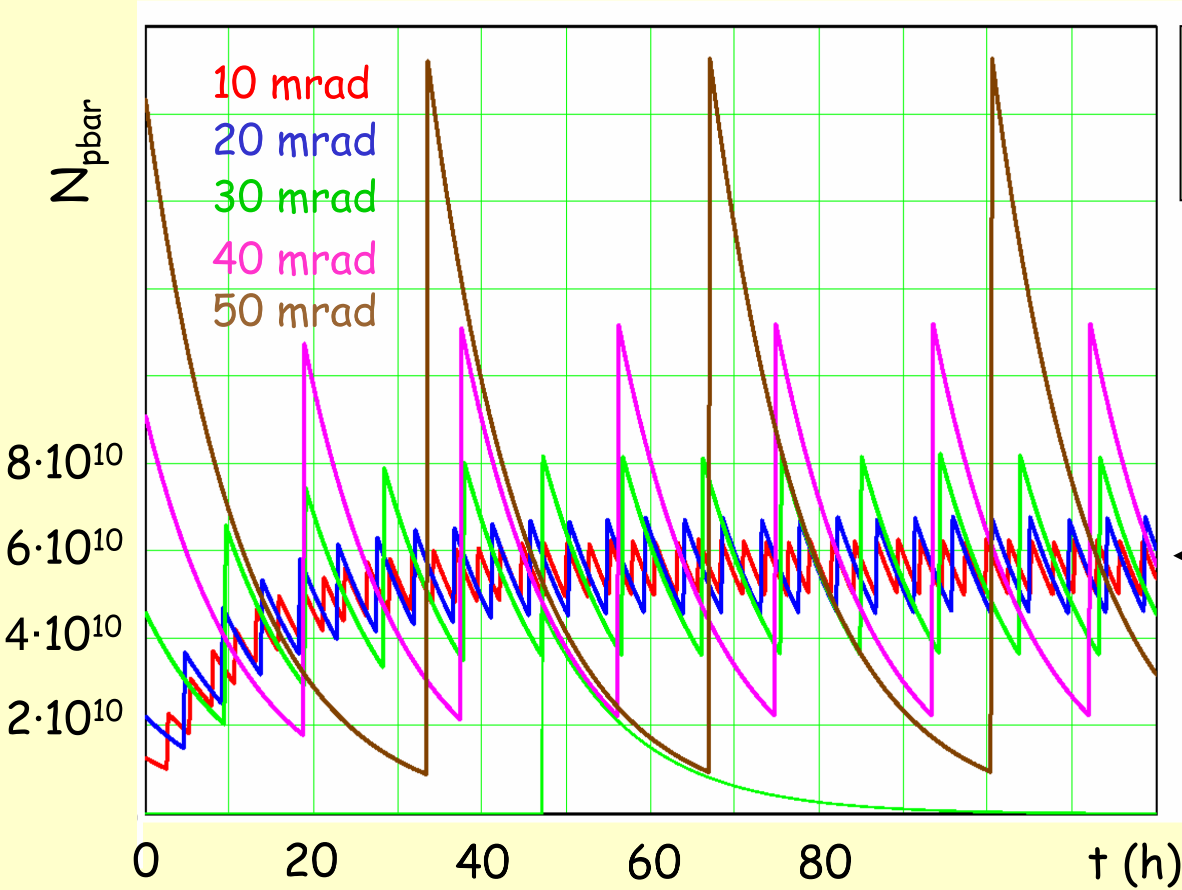
Transfer from AP to HESR and Accumulation



Accumulation of Polarized Beam in HESR

PIT: $d_t = 7.2 \cdot 10^{14}$ atoms/cm^2

$\tau_{HESR} = 11.5$ h



Number accumulated in **equilibrium** independent of acceptance

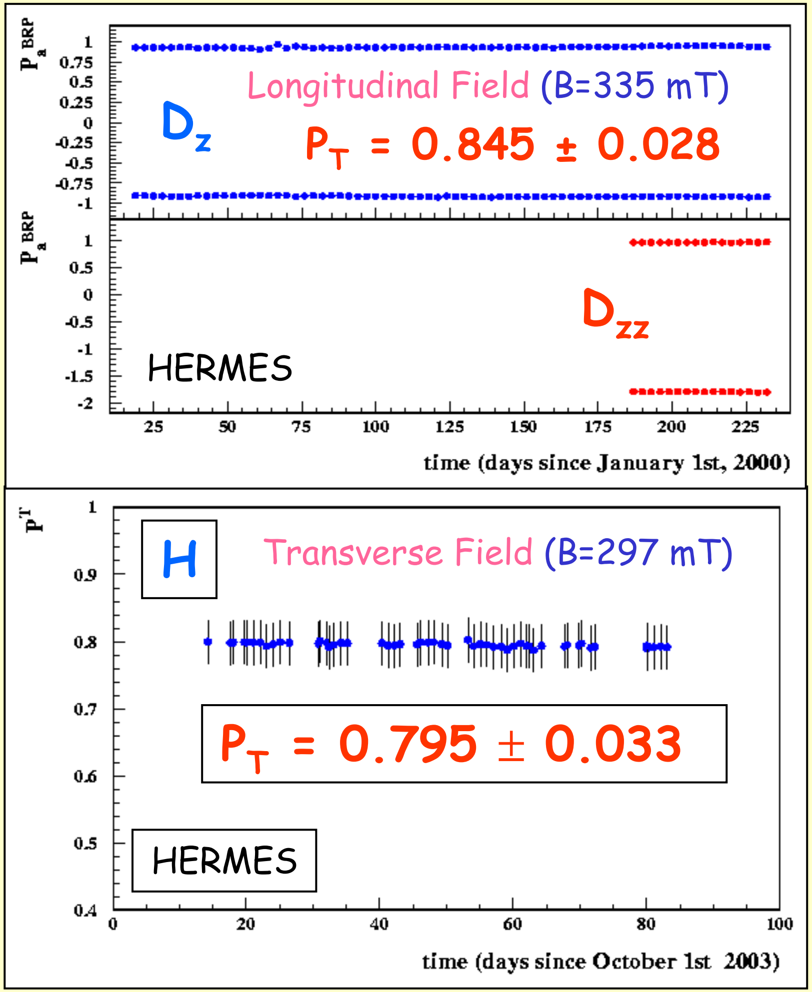
$$\overline{N}_{\bar{p}} = \frac{10^7\,\overline{p}/s}{e^2} \cdot \tau_{HESR}$$

$$= 5.6 \cdot 10^{10}$$

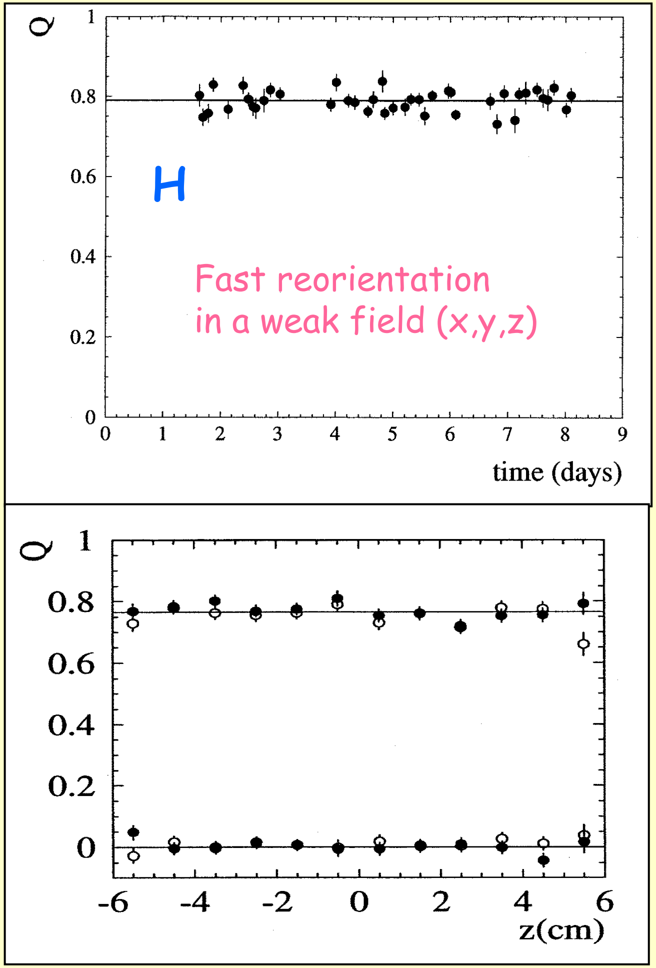
No Depolarization in HESR during energy change

Performance of Polarized Internal Targets

HERMES: Stored Positrons



PINTEX: Stored Protons



Targets work very reliably (many months of stable operation)

Estimated Luminosity for Double Polarization

Polarized Internal Target in HESR

$L = d_t \times f_{rev} \times N_{pbar}$

d_t = areal density
f_{rev} = revolution frequency
N_{pbar} = number of pbar stored in HESR

In equilibrium:

$$L = 7.2 \cdot 10^{14} \times 6.8 \cdot 10^{5} \times 5.6 \cdot 10^{10} = 2.7 \cdot 10^{31} \mathrm{cm}^{-2} \mathrm{s}^{-1}$$

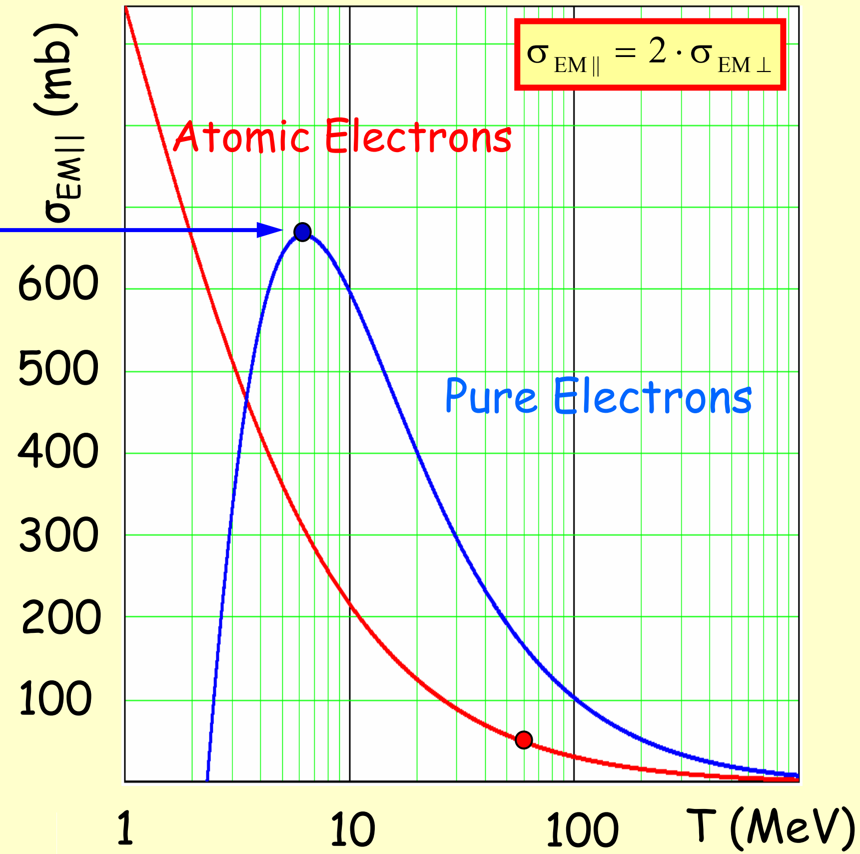
$$= \frac{10^7 \bar{p} / s}{e^2} \cdot \frac{1}{\sigma_{tot}}$$

Q_{target} = 0.85
P_{beam} = 0.3
σ_{tot}(15 GeV) = 50 mb

(factor >70 in measuring time for A_{TT} with respect to beam extracted on solid target)

How about a Pure Polarized Electron Target?

Maxiumum $\sigma_{EM||}$ for electrons at rest:
(675 mb ,T_{opt} = 6.2 MeV):
Gainfactor ~15 over atomic e^- in a PIT



Density of an Electron-Cooler fed by 1 mA DC polarized electrons:

- $I_e = 6.2 \cdot 10^{15}$ e/s
- $A = 1$ cm^2
- $l = 5$ m

$d_t = I_e \cdot l \cdot (\beta \cdot c \cdot A)^{-1} = 5.2 \cdot 10^8$ cm^{-2}

Electron target density by factor ~10^6 smaller,
→ no match for a PIT (>10^{14} cm^{-2})

Outline

WHY?	Physics Case
HOW?	Polarized Antiprotons
WHERE?	**FAIR Project at Darmstadt**
WHAT?	Transversity Measurement
WHEN?	Time Schedule
	Conclusion

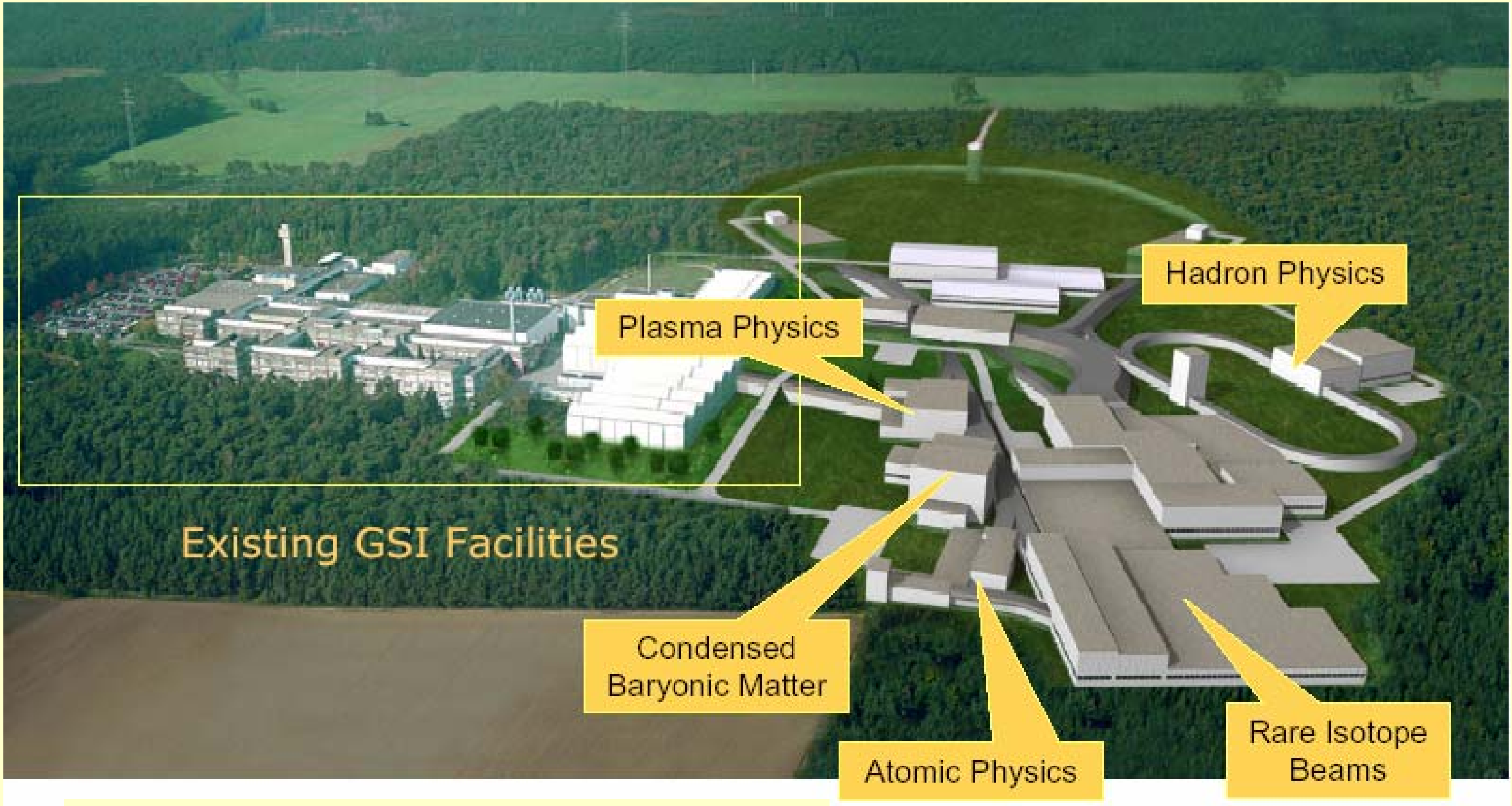
NEW Facility

- An "International Accelerator Facility for Beams of Ions and Antiprotons":
  - Top priority of German hadron and nuclear physics community (KHuK-report of 9/2002) and NuPECC
  - Favourable evaluation by highest German science committee ("Wissenschaftsrat" in 2002)
  - Funding decision from German government in 2/2003 – staging and at least 25% foreign funding
  - to be build at GSI Darmstadt; should be finished in > 2011 (depending on start)

FAIR

(Facility for Antiproton and Ion Research)

Facilty for Antiproton and Ion Research
(GSI, Darmstadt, Germany)



-Proton linac (injector)
-2 synchrotons (30 GeV p)
-A number of storage rings
→ Parallel beams operation

FAIR – Prospects and Challenges

- FAIR is a facility, which will serve a large part of the nuclear physics community (and beyond):
  - Nuclear structure ←→ Radioactive beams
  - Dense Matter ←→ Relativistic ion beams
  - Hadronic Matter ←→ Antiprotons, (polarized)
  - Atomic physics
  - Plasma physics

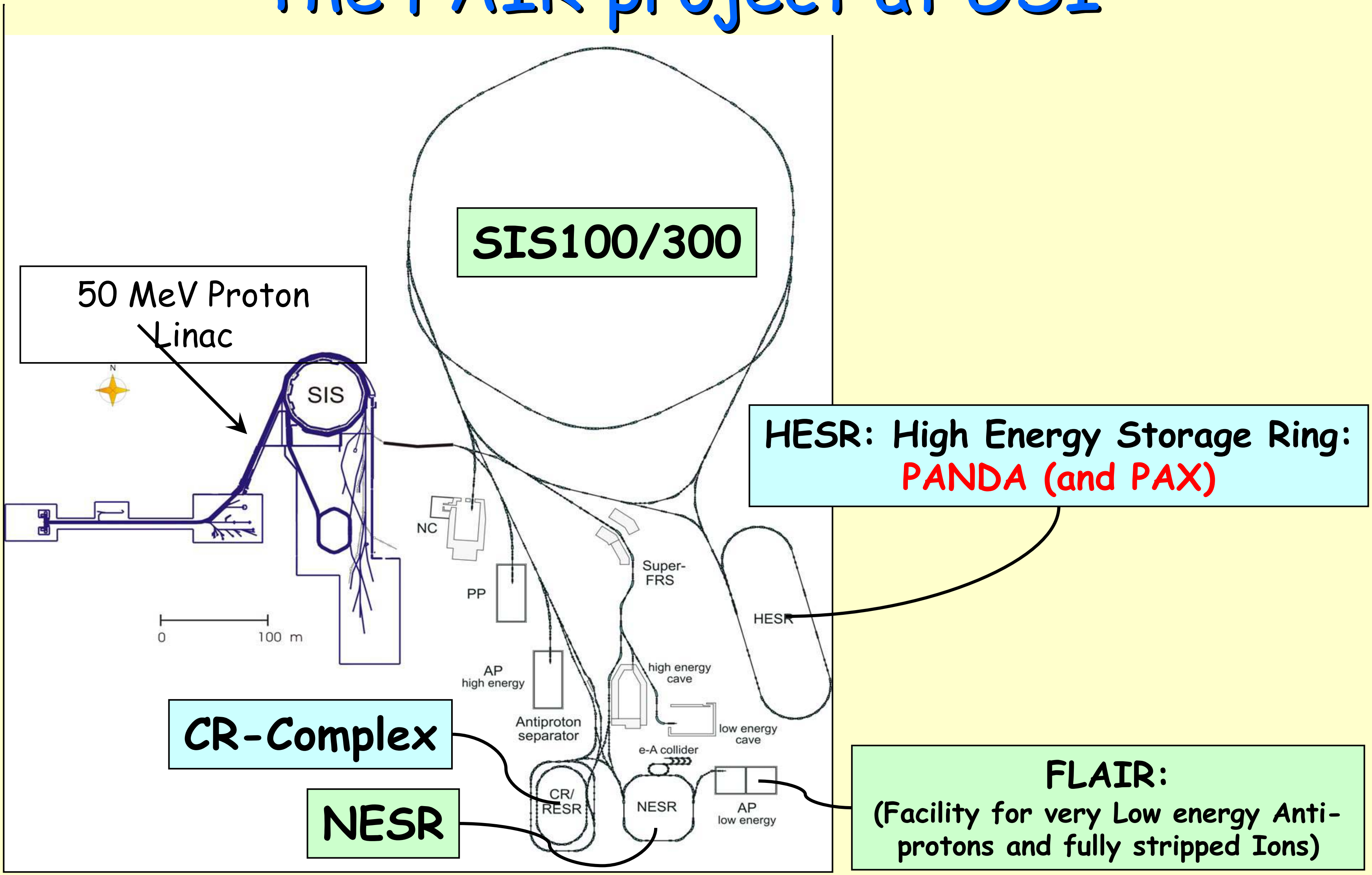
- FAIR will need a significant fraction of the available man-power and money in the years to come:

  1 G€ ←→ 10 000 man-years = 100 "man" for 100 years

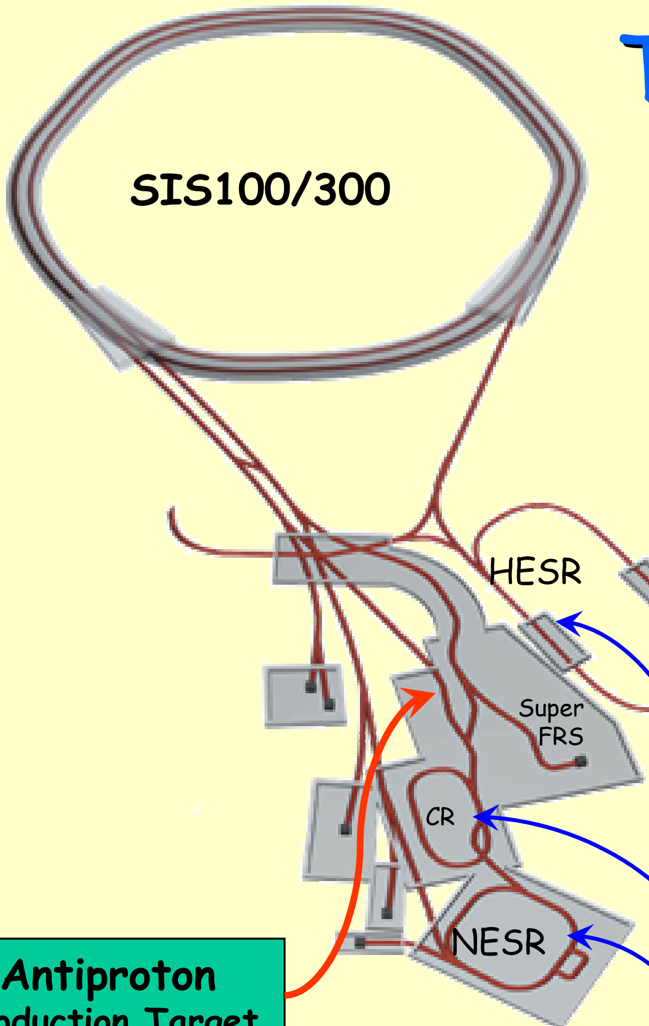
  or (1000 x 10)

- FAIR will have a long lead-time (construction, no physics)
  → staging (3 phases)

The FAIR project at GSI



The Antiproton Facility



Antiproton Production Target

HESR (High Energy Storage Ring)
- Length 442 m
- Bρ = 50 Tm
- N = 5 x 10^{10} antiprotons

High luminosity mode
- Luminosity = 2 x 10^{32} $cm^{-2}s^{-1}$
- $\Delta p/p$ ~ 10^{-4} (stochastic-cooling)

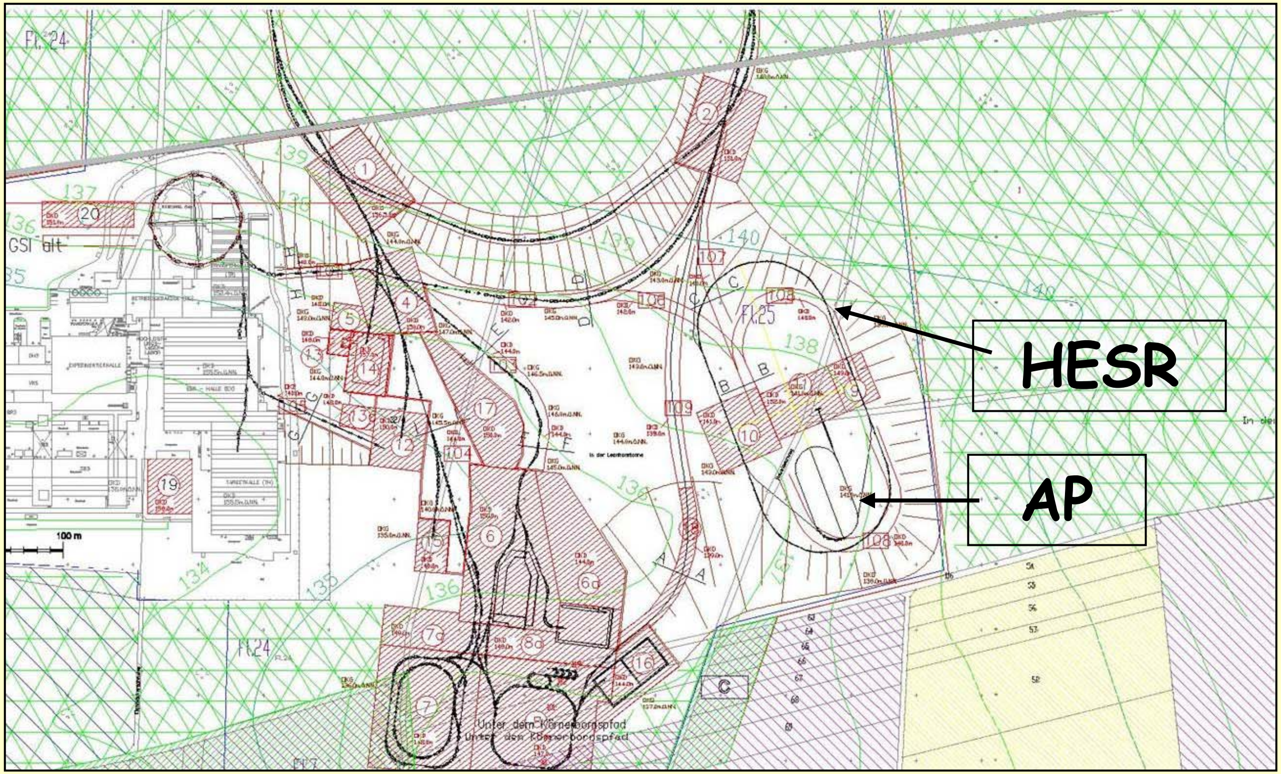
High resolution mode
- $\Delta p/p$ ~ 10^{-5} (8 MV HE e-cooling)
- Luminosity = 10^{31} $cm^{-2}s^{-1}$

Gas Target and Pellet Target:
cooling power determines thickness

Beam Cooling:
e^- and/or stochastic
2MV prototype e-cooling at COSY

- Antiproton production similar to CERN
- Production rate 10^7/sec at 30 GeV
- T = 1.5 - 15 GeV/c (22 GeV)

The New Polarization Facility



Conceptual Design Report for FAIR did not include Spin Physics:

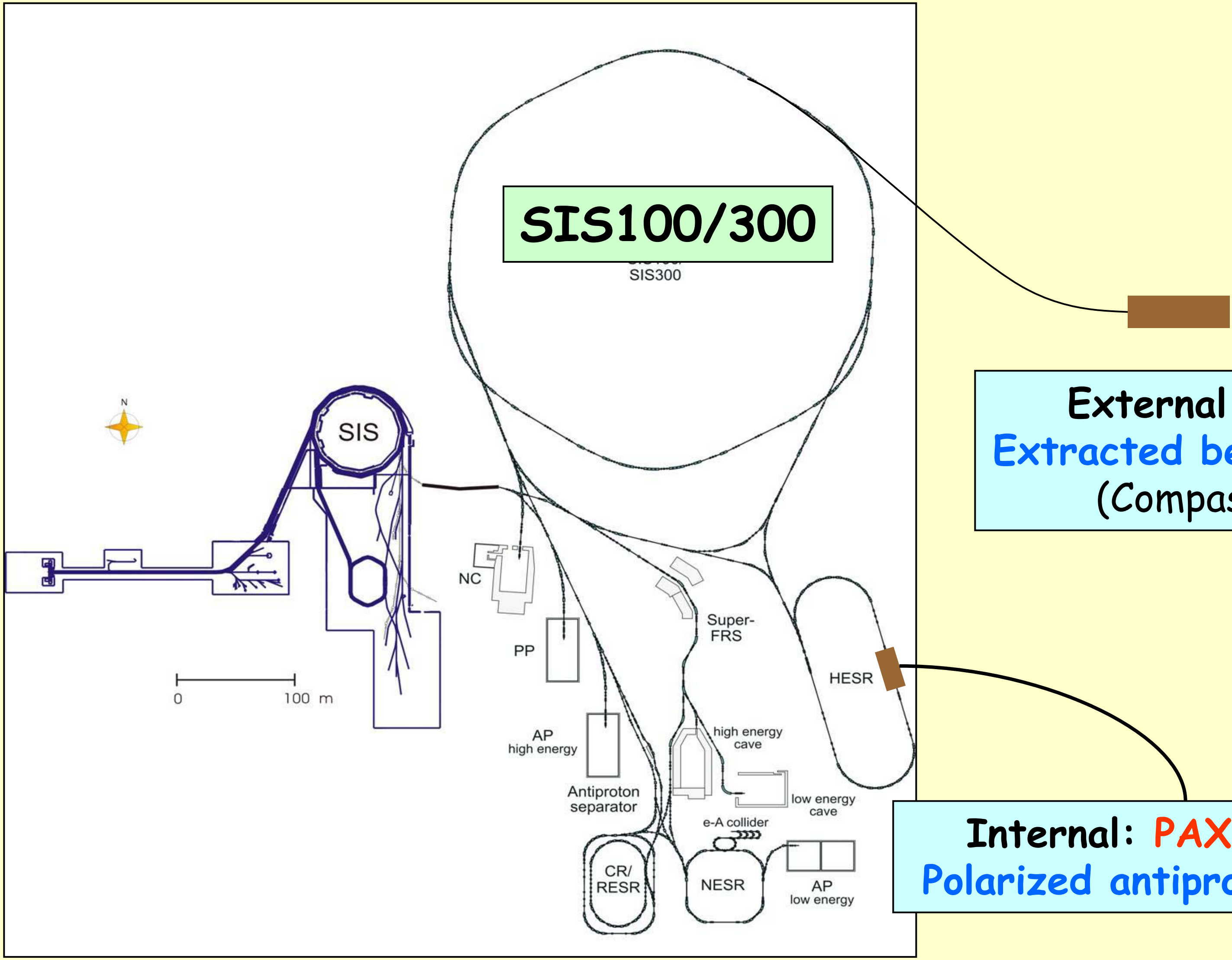
→ Jan. '04: 2 Letters of Intent for Spin Physics

- ASSIA (R. Bertini)
- PAX (P. Lenisa, FR)

210 collaborators
25 institutions

WE NEED MORE COLLABORATORS!

LoI's for Spin Physics at FAIR



External: ASSIA
Extracted beam on PET
(Compass-like)

Internal: PAX in HESR
Polarized antiprotons + PIT

Evaluation by QCD Program Advisory Committee (July 2004)

STI Report:

Your LoI has convinced the QCD-PAC

a) **that Polarization must be included into the design of FAIR from the beginning**, and

b) that the presently proposed scheme is not optimized as to the physics. **You** [...] **are invited and encouraged to design a world-class facility with unequalled degree of polarization of antiprotons.**

Common Report:

[...] The PAC considers the **spin physics of extreme interest and the building of an antiproton polarized beam as a unique possibility for the FAIR Project.**

[...] The **unique physics opportunities**, made possible with polarized antiproton beams and/or polarized target are **extremely exciting**, **especially in double spin measurements**.

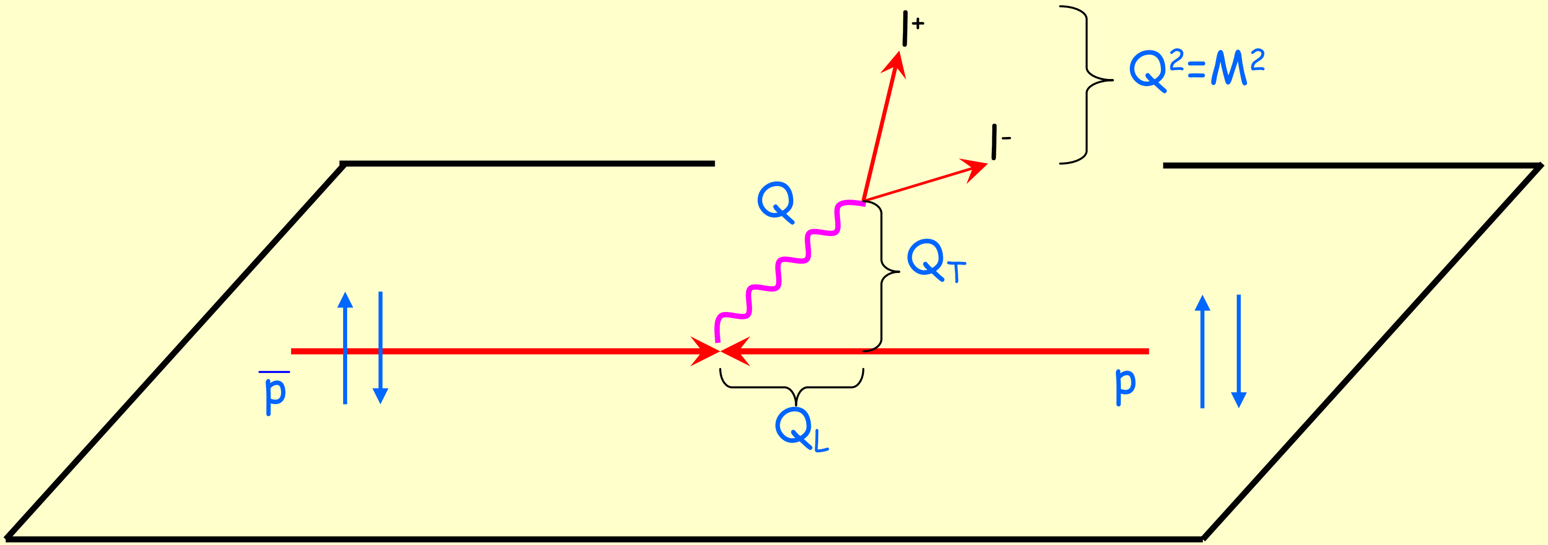
[...] **It would be very unfortunate if decisions about the facility, made now, later preclude the science.**

Outline

WHY?	Physics Case
HOW?	Polarized Antiprotons
WHERE?	FAIR Project at Darmstadt
WHAT?	**Transversity Measurement at PAX**
	– **Rates**
	– **Angular Distribution**
	– **Background**
	– **Detector Concept**
WHEN?	Time Schedule
	Conclusion

Transversity in Drell-Yan processes at PAX

Polarized Antiproton Beam → Polarized Proton Target
(both transversely polarized)



$$A_{TT} \equiv \frac{d\sigma^{\uparrow\uparrow} - d\sigma^{\uparrow\downarrow}}{d\sigma^{\uparrow\uparrow} + d\sigma^{\uparrow\downarrow}} = \hat{a}_{TT} \frac{\sum_q e_q^2 h_1^q(x_1, M^2) h_1^{\bar{q}}(x_2, M^2)}{\sum_q e_q^2 q(x_1, M^2) \bar{q}(x_2, M^2)}$$

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

M invariant Mass of lepton pair

A_{TT} for PAX kinematic conditions

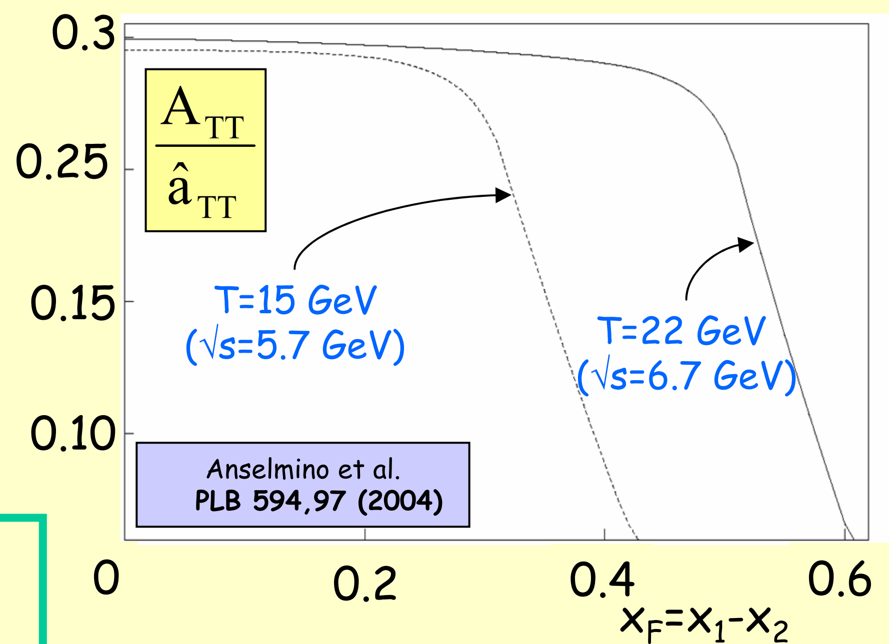
RHIC: $\tau = x_1 x_2 = M^2/s \sim 10^{-3}$
→ Exploration of the sea quark content (polarizations small!)
A_{TT} very small (~ 1 %)

PAX: $M^2 \sim 10$ GeV^2, $s \sim 30\text{-}50$ GeV^2, $\tau = x_1 x_2 = M^2/s \sim 0.2\text{-}0.3$
→ Exploration of valence quarks ($h_1^q(x,Q^2)$ large)

$A_{TT}/a_{TT} > 0.3$
Models predict $|h_1^u| >> |h_1^d|$

$$A_{TT} = \hat{a}_{TT} \frac{h_1^u(x_1, M^2) h_1^u(x_1, M^2)}{u(x_1, M^2) u(x_1, M^2)}$$

$$(\text{where } \bar{q}^{\bar{p}} = q^p = q)$$

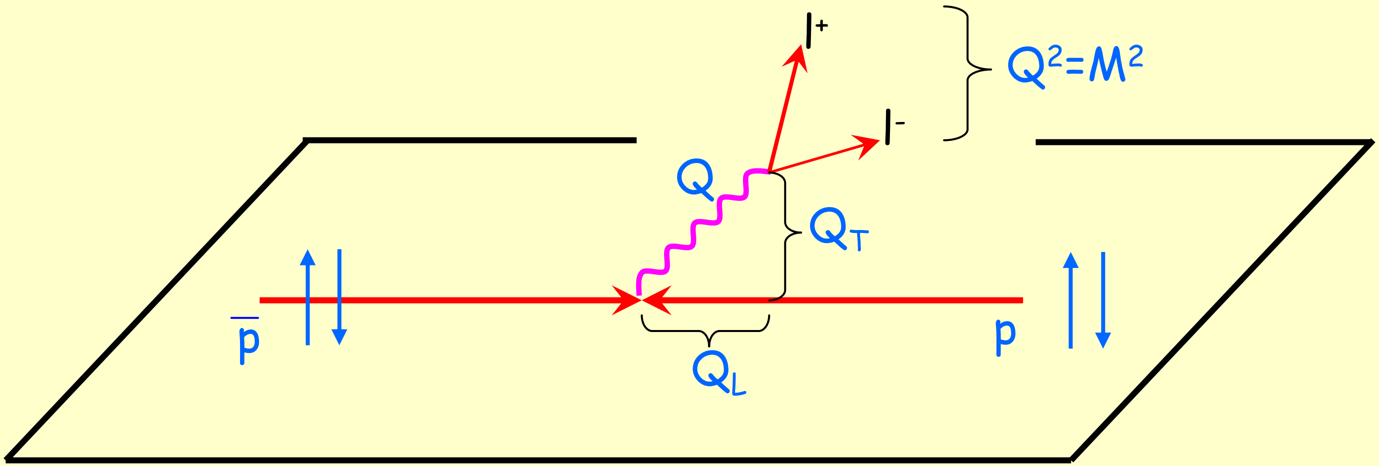


Similar predictions by Efremov et al.,
Eur. Phys. J. C35, 207 (2004)

Main contribution to Drell-Yan events at PAX from $x_1 \sim x_2 \sim \sqrt{\tau}$:
deduction of x-dependence of $h_1^u(x,M^2)$

Signal Estimate

Polarized Antiproton Beam → Polarized Proton Target
(both transversely polarized)



1) Count rate estimate.

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

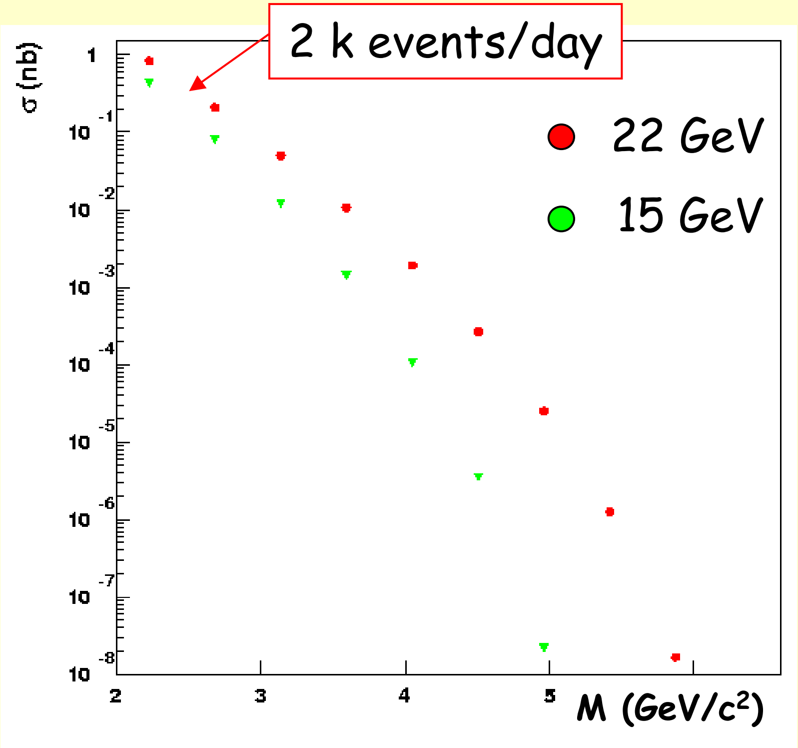
2) Angular distribution of the asymmetry.

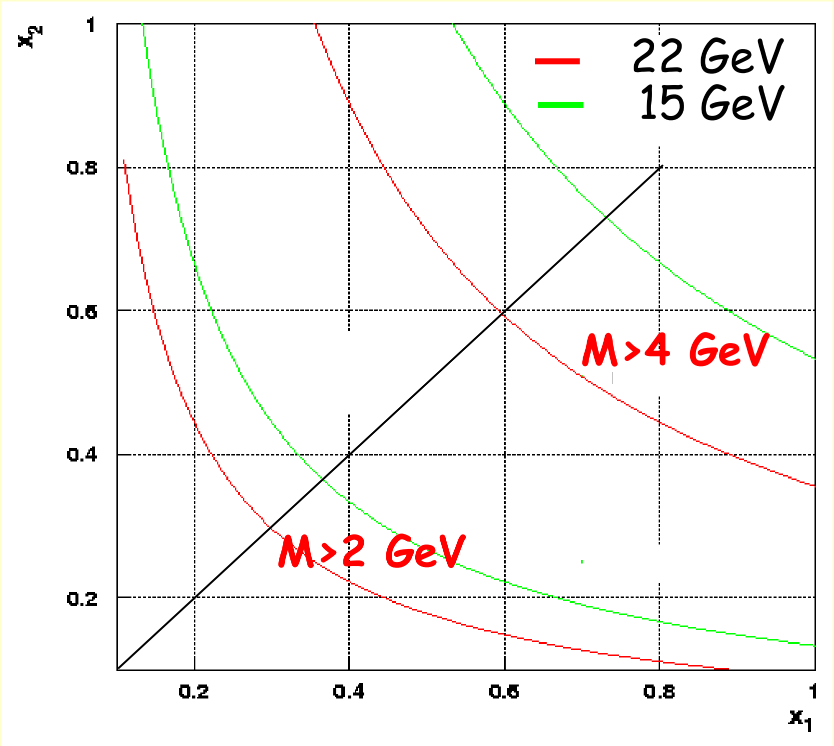
$$A_{TT} \equiv \frac{d\sigma^{\uparrow\uparrow} - d\sigma^{\uparrow\downarrow}}{d\sigma^{\uparrow\uparrow} + d\sigma^{\uparrow\downarrow}} = \hat{a}_{TT} \frac{h_1^u(x_1,M^2)h_1^u(x_2,M^2)}{u(x_1,M^2)u(x_2,M^2)}$$

Drell-Yan cross section and event rate

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

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





- $x_1 x_2 = M^2/s$

- Mandatory use of the invariant mass region below the J/ψ (2 to 3 GeV).
- 22 GeV preferable to 15 GeV

Extension of the “safe” region

Determination of $h_1^q(x,Q^2)$ not confined to the „safe“ region (M > 4 GeV)

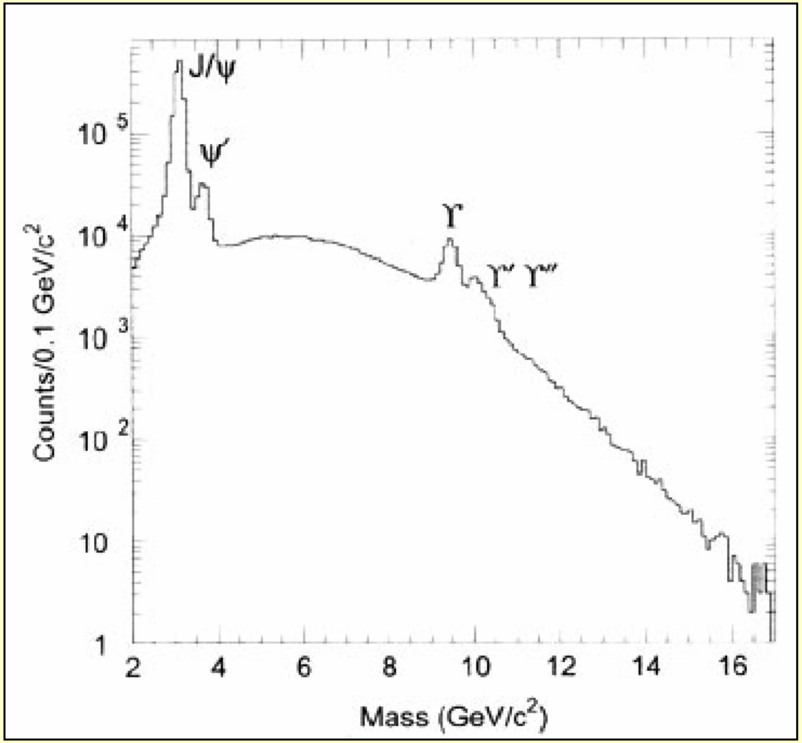
$$q\bar{q} - J/\Psi$$
$$q\bar{q} - \gamma^*$$
$$q\bar{q} - e^+e^-$$

→ unknown vector coupling, but same Lorentz and spinor structure as other two processes

Unknown quantities cancel in the ratios for A_{TT}, but helicity structure remains!

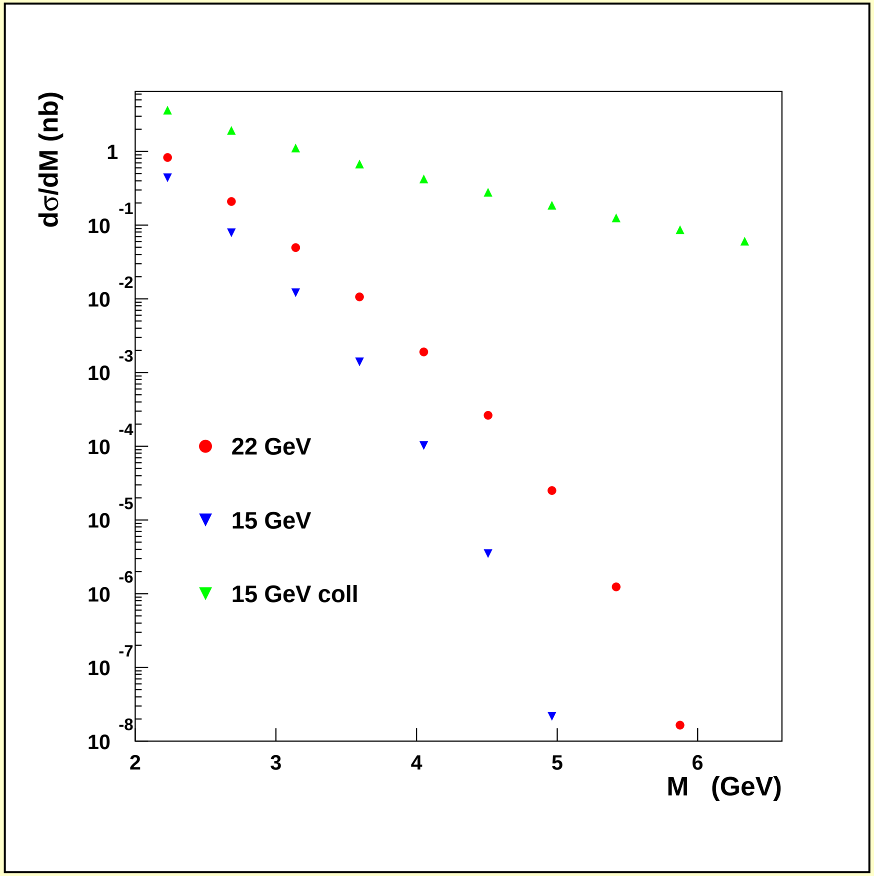
Anselmino et al.
PLB 594,97 (2004)

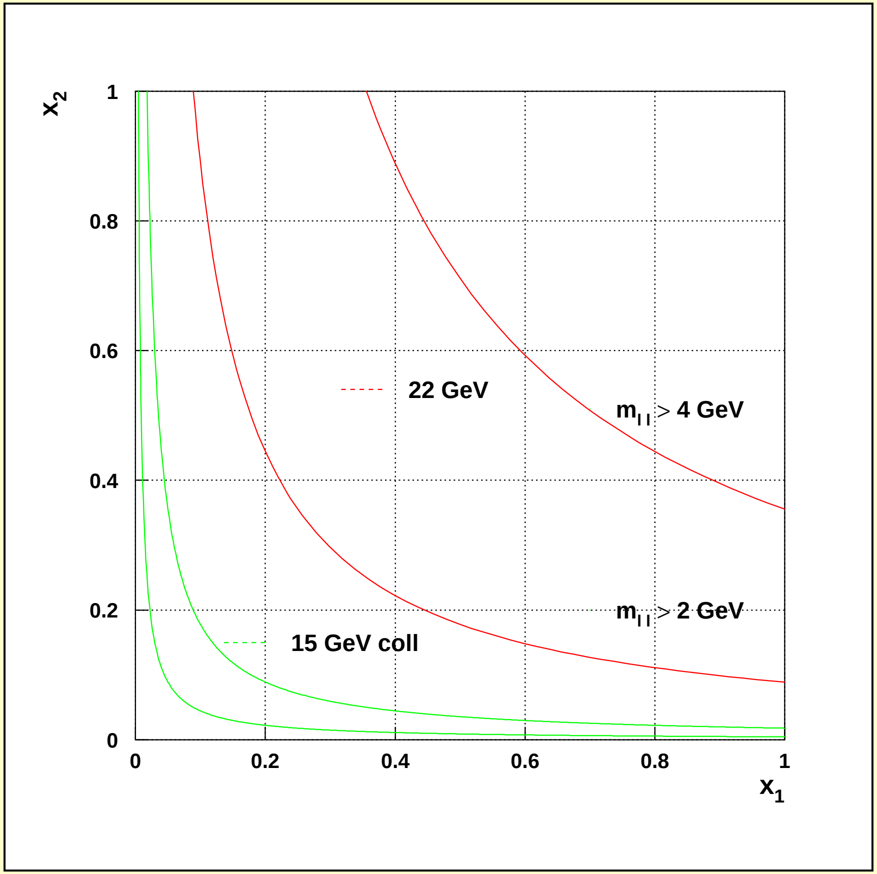
Efremov et al.,
Eur.Phys.J. C35,207 (2004)



Cross section increases by two orders from M=4 to M=3 GeV
→ Drell-Yan continuum enhances sensitivity of PAX to A_{TT}

Dream Option: Collider (15 GeV)



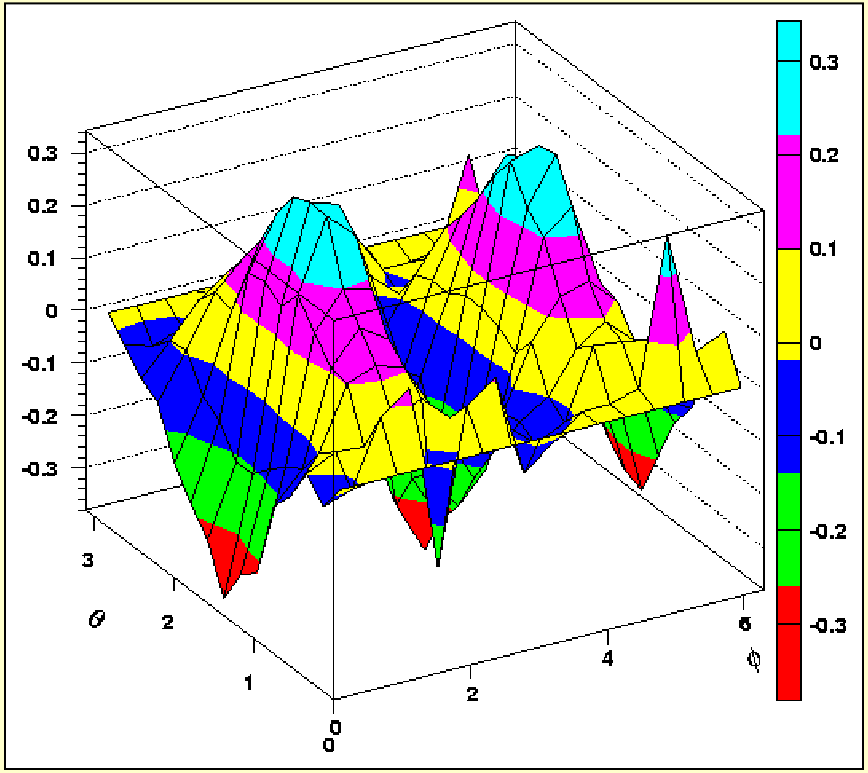


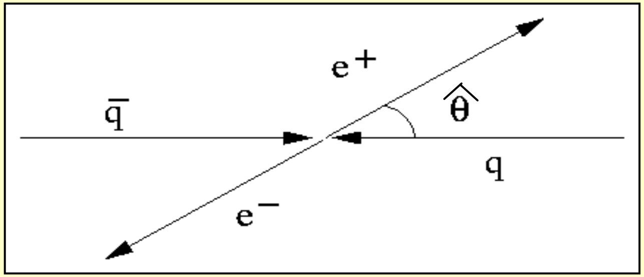
$L > 10^{30} cm^{-2} s^{-1}$ to get comparable rates

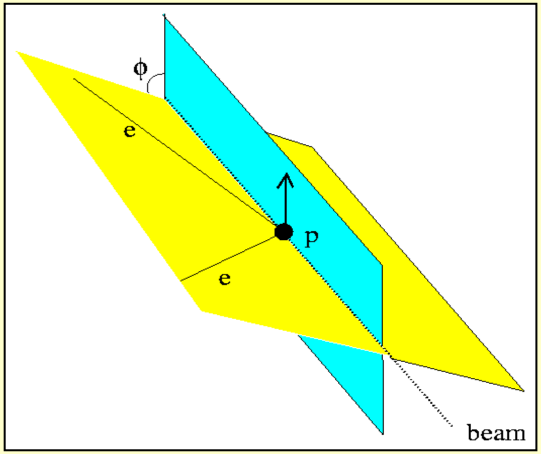
A_{TT} asymmetry: angular distribution

$$A_{TT} = \hat{a}_{TT} \frac{h_1^u(x_1, M^2) h_1^u(x_2, M^2)}{u(x_1, M^2) u(x_2, M^2)}$$

$$\hat{a}_{TT}(\hat{\theta}, \phi) = \frac{\sin^2 \hat{\theta}}{(1 + \cos^2 \hat{\theta})} \bullet \cos(2\phi)$$





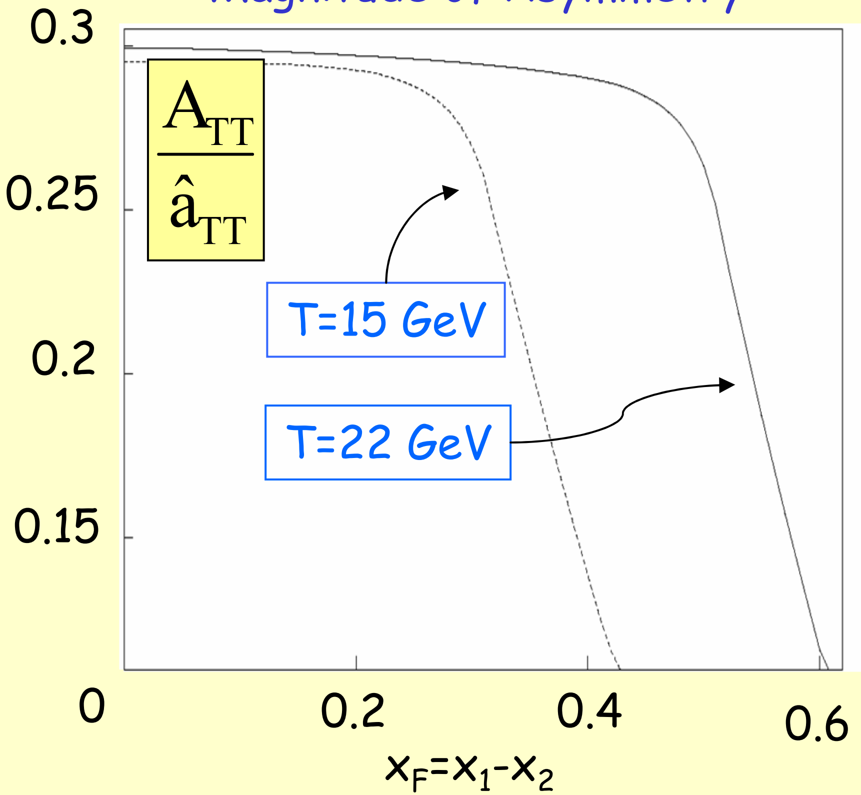


- Asymmetry is largest for angles $\hat{\theta}$ =90°
- Asymmetry varies like cos(2ϕ).

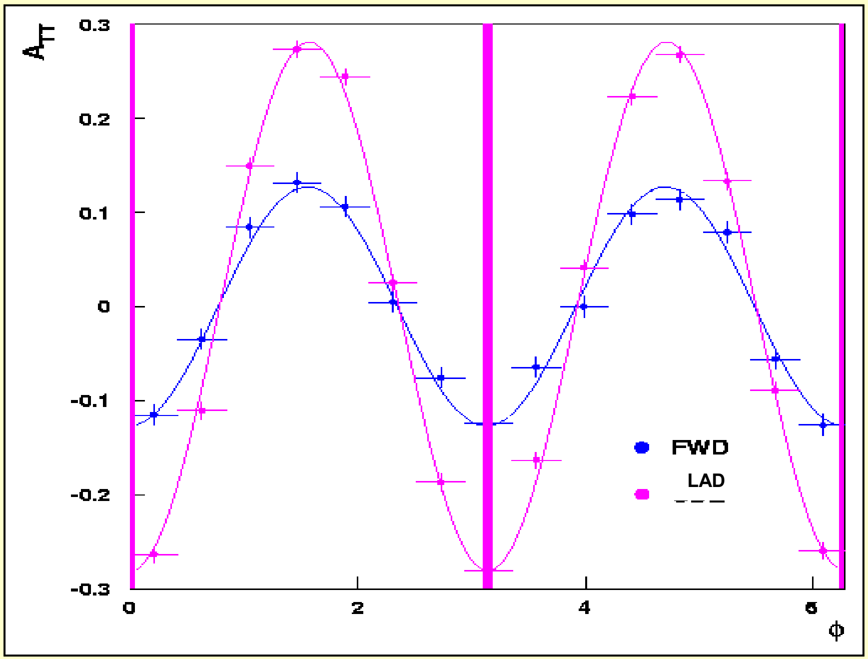
Needs a large acceptance detector (LAD)

Theoretical prediction

Magnitude of Asymmetry



Angular modulation



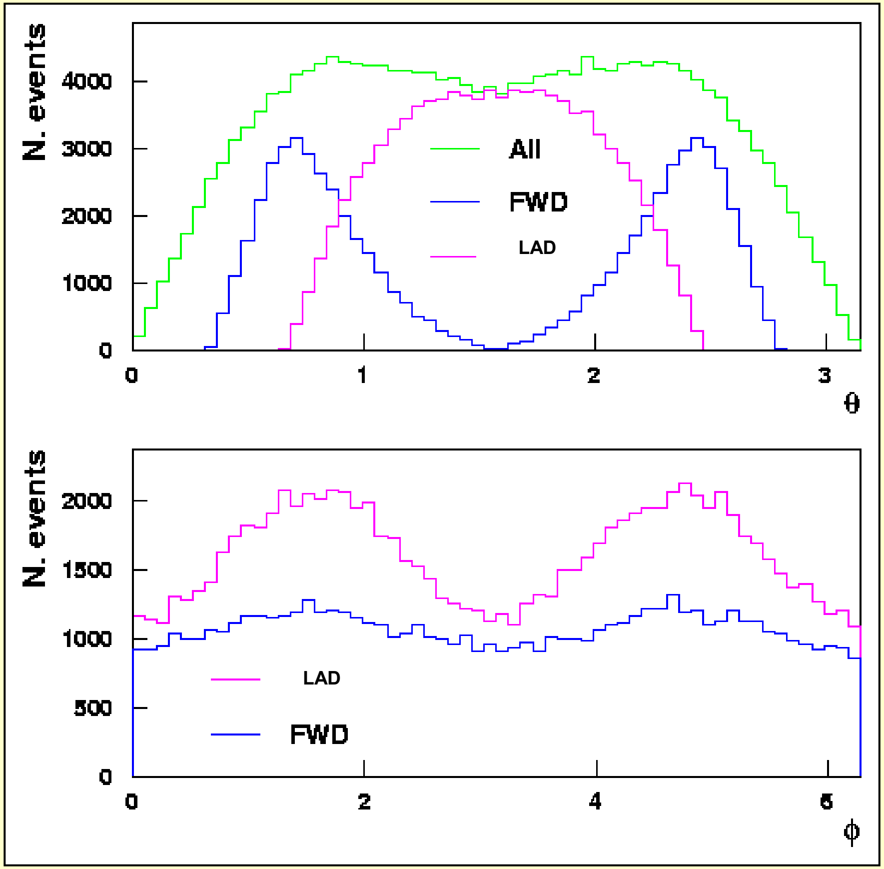
FWD: θ_{lab} < 8°

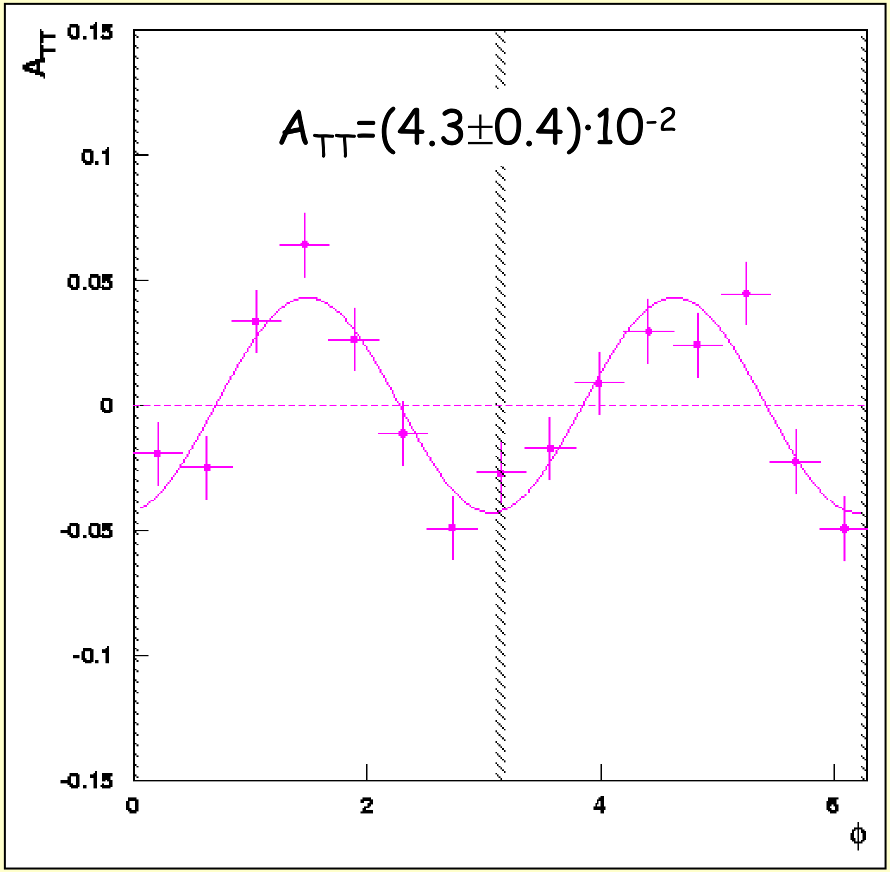
LAD: 8° < θ_{lab} < 50°

P=Q=1

Estimated signal

- 120k event sample
- 60 days at $L=2.1\cdot 10^{31}\ cm^2\ s^{-2}$, P = 0.3, Q = 0.85





Events under J/y can double the statistics.
→ Good momentum resolution requested

Detector concept

- **Drell-Yan process requires a large acceptance detector**
- Good hadron rejection needed
  - 10^2 at trigger level, 10^4 after data analysis for single track.
- Magnetic field envisaged
  - Increased invariant mass resolution compared to calorimeter
  - Improved PID through Energy/momentum ratio
  - Separation of wrong charge combinatorial background
  - Toroidal Field:

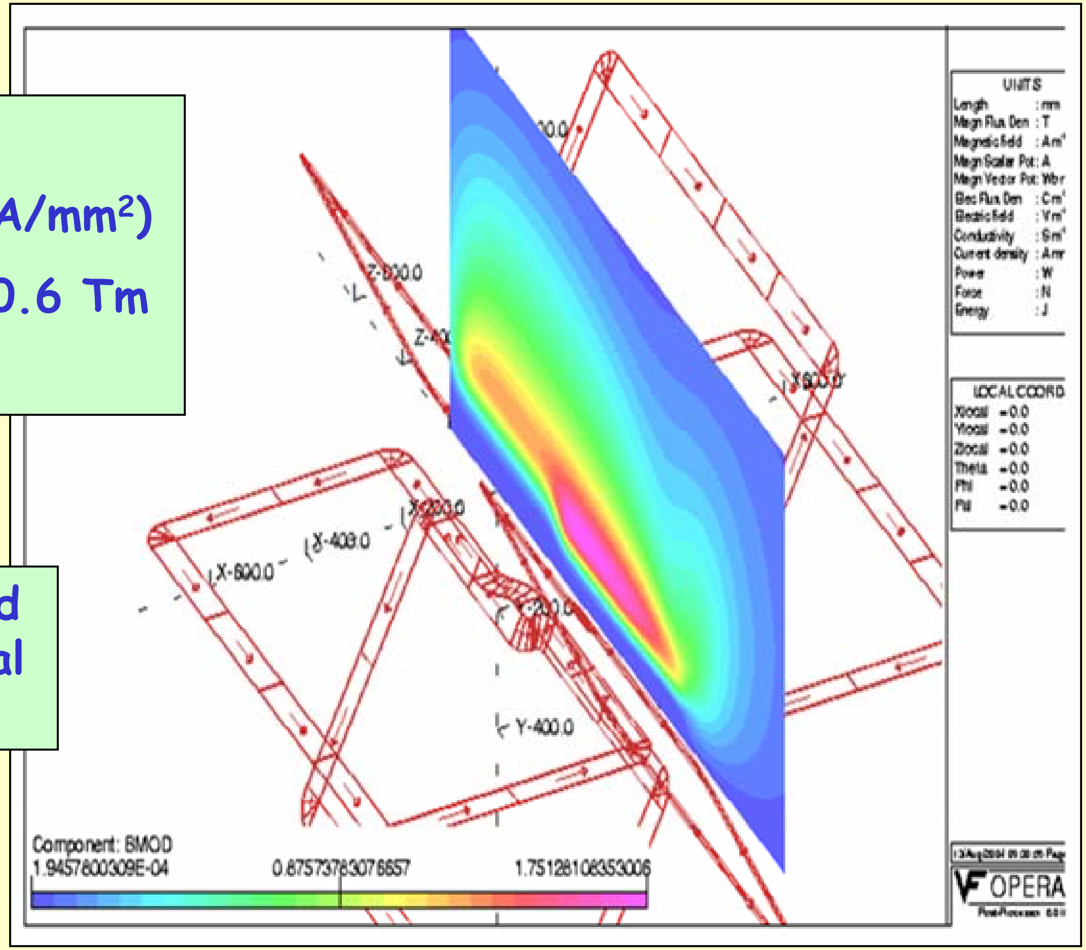
    Zero field on axis compatible with polarized target.

Double Polarization Experiments → Azimuthal Symmetry

Possible solution: Toroid (6 superconducting coils)

- 800 x 600 mm coils
- 3 x 50 mm section (1450 A/mm^2)
- average integrated field: 0.6 Tm
- free acceptance > 80 %

Superconducting target field coils do not affect azimuthal acceptance.



(8 coil system under study)

Outline

WHY?	Physics Case
HOW?	Polarized Antiprotons
WHERE?	FAIR Project at Darmstadt
WHAT?	Transversity Measurement
WHEN?	**Time Schedule**
	Conclusion

Time schedule

Jan. 04	LOI submitted
15.06.04	QCD PAC meeting at GSI
18-19.08.04	Workshop on polarized antiprotons at GSI
15.09.04	Additional PAX document on polarization at GSI: • F. Rathmann et al., physics/0410067 (2004)
15.01.05	**Technical Report (with Milestones)** o Experimental confirmation of spin transfer cross section at COSY (Snake, Electron Polarimeter, strong $B_{\|\|}$) o Design and Construction of AP at COSY . . . . . Evaluations & Green Light for Construction
2005-2008	Technical Design Reports (for Milestones)
>2012	Commissioning of HESR

ASSIA Collaboration:

Spokesperson:
Raimondo Bertini bertini@to.infn.it

Participating Institutions

*Dzhelepov Laboratory of Nuclear Problems, JINR, Dubna, **Russia***
*Dipartimento di Fisica "A. Avogadro" and INFN, Torino, **Italy***
*Dipartimento di Fisica Teorica and INFN, Torino, **Italy***
*Universita and INFN, Brescia, **Italy***
*Czech Technical Universiy, Prague, **Czech Republic***
*Charles University, Prague, **Czech Republic***
*DAPNIA, CEN, Saclay, **France***
*Institute of Scientific Instruments, Academy of Sciences, Brno, **Czech Republic***
*NSC Kharkov Physical Technical Institute, Kharkov, **Ukraine***
*Laboratoi Nazionali Frascati, INFN, **Italy***
*Universita dell' Insubria, Como and INFN, **Italy***
*University of Trieste and INFN Trieste, **Italy***

92 Collaborators, 12 Institutions (10 EU, 2 outside EU)

PAX Collaboration:

Spokespersons:
Paolo Lenisa lenisa@mail.desy.de
Frank Rathmann f.rathmann@fz-juelich.de

Participating Institutions

Yerevan Physics Institute, Yerevan, ***Armenia***
Department of Subatomic and Radiation Physics, University of Gent, ***Belgium***
University of Science & Technology of China, Beijing, P.R. ***China***
Department of Physics, Beijing, P.R. ***China***
High Energy Physics Institute, Tbilisi State University, Tbilisi, ***Georgia***
Forschungszentrum Jülich, Institut für Kernphysik Jülich, ***Germany***
Institut für Theoretische Physik II, Ruhr Universität Bochum, ***Germany***
Helmholtz-Institut für Strahlen- und Kernphysik, Bonn, ***Germany***
Physikalisches Institut, Universität Erlangen-Nürnberg, ***Germany***
Instituto Nationale di Fisica Nucleare, Ferrara, ***Italy***
Dipartimento di Fisica Teorica, Universita di Torino and INFN, Torino, ***Italy***
Instituto Nationale di Fisica Nucleare, Frascati, ***Italy***
Petersburg Nuclear Physics Institute, Gatchina, ***Russia***
Institute for Theoretical and Experimental Physics, Moscow, ***Russia***
Lebedev Physical Institute, Moscow, ***Russia***
Laboratory of Particle Physics, Joint Institute for Nuclear Research, Dubna, ***Russia***
Laboratory of Nuclear Problems, Joint Institute for Nuclear Research, Dubna, ***Russia***
High Energy Physics Institute, Protvino, ***Russia***
Department of Radiation Sciences, Nuclear Physics Division, Uppsala University, Uppsala, ***Sweden***

123 Collaborators, 19 Institutions (9 EU, 10 outside EU)

Conclusion

Challenging opportunities and new physics accessible at HESR

- Unique access to a wealth of new fundamental physics observables
- Central physics issue: $h_1^q(x,Q^2)$ of the proton in DY processes
- Other issues:
  - Electromagnetic Formfactors
  - Polarization effects in Hard and Soft Scattering processes
  - differential cross sections, analyzing powers, spin correlation parameters

Projections for HESR fed by a dedicated AP:

- $P_{beam} > 0.30$
- $5.6 \cdot 10^{10}$ antiprotons
- $L \approx 2.7 \cdot 10^{31}\ cm^{-2}s^{-1}$

Detector concept: 15 (22) GeV + PIT

- Large acceptance detector with a toroidal magnet

Collider Option: Attractive far future perspective

Final Remark

Polarization data has often been the graveyard of fashionable theories. If theorists had their way, they might just ban such measurements altogether out of self-protection.

J.D. Bjorken
St. Croix, 1987

Background

$$\sigma_{p\bar{p}} = 50mb$$

$$\sigma_{DY} \leq 1nb$$

$\rightarrow$ 10^8-10^9 rejection factor against background

- DY pairs can have non-zero transverse momentum (<p_T> = 0.5 GeV)
  - $\rightarrow$ coplanarity cut between DY and beam not applicable
- Larger Background in Forward Direction (where asymmetry is smaller).
- Background higher for μ than for e (meson decay)
  - $\rightarrow$ hadronic absorber (needed for μ) inhibits other reactions
- Sensitivity to charge avoids background from wrong-charge DY-pairs
  - $\rightarrow$ Magnetic field envisaged

Background for $\bar{p}p \to e^+e^- X$

Average multiplicity: 4 charged + 2 neutral particle per event.
Combinatorial background from meson decay.

$$\bar{p}p \to h_1 h_2 X$$

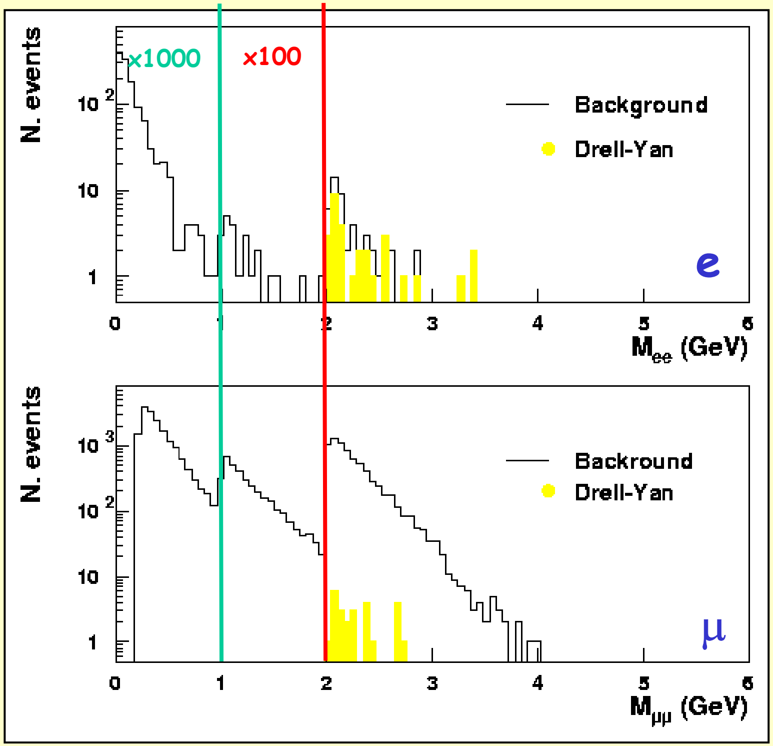
$$h_1 h_2 \equiv \begin{cases} \pi^0 \to e^+e^-\gamma \\ K^{+/-} \to \pi_0 e^{+/-}\nu_e \\ K^0 \to \pi^{+/-}e^{-/+}\nu_e \\ \eta \to \pi^+\pi^-e^+e^- \\ \eta \to \gamma e^+e^- \\ \ldots \end{cases}$$

Estimate shows for most processes background under control.

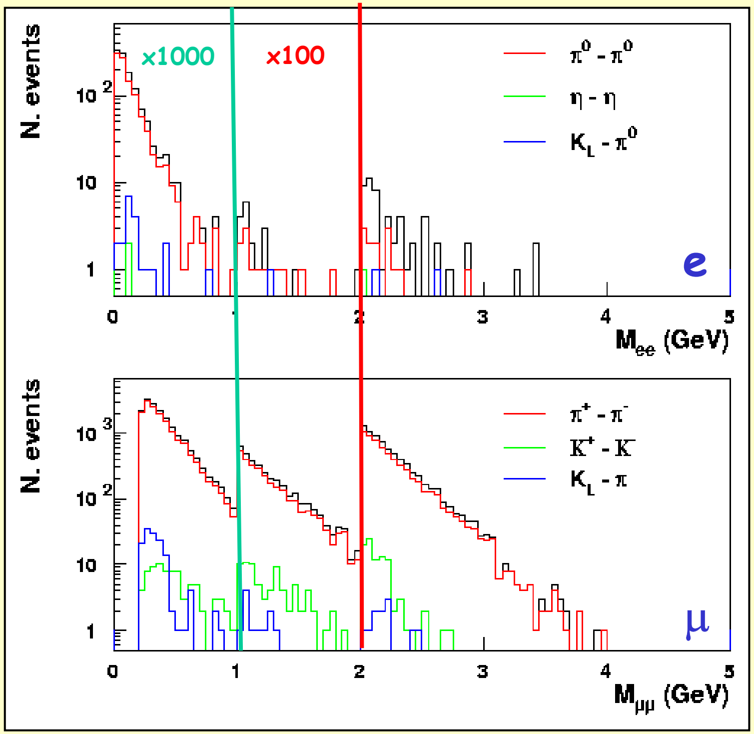
Background for $\bar{p}p \rightarrow e^+e^- X$

Preliminary PYTHIA result ($2{\cdot}10^9$ events)

Total background



Origin of Background



- Background higher for μ than for e
- Background from charge conjugated mesons negligible for e.