

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

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

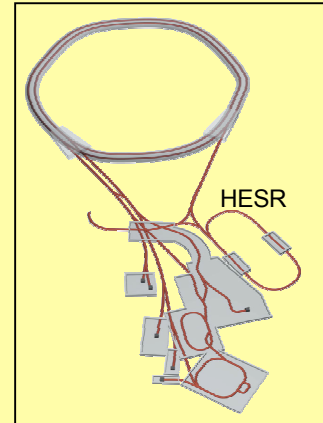
Spin-physics with Polarized Antiprotons at GSI

Frank Rathmann
Forschungszentrum Jülich

"Spin Physics and Beyond", Madison, June 10, 2005

QCD Physics at FAIR (CDR):
unpolarized Antiprotons in

PAX → Polarized Antiprotons



Central PAX Physics Case:

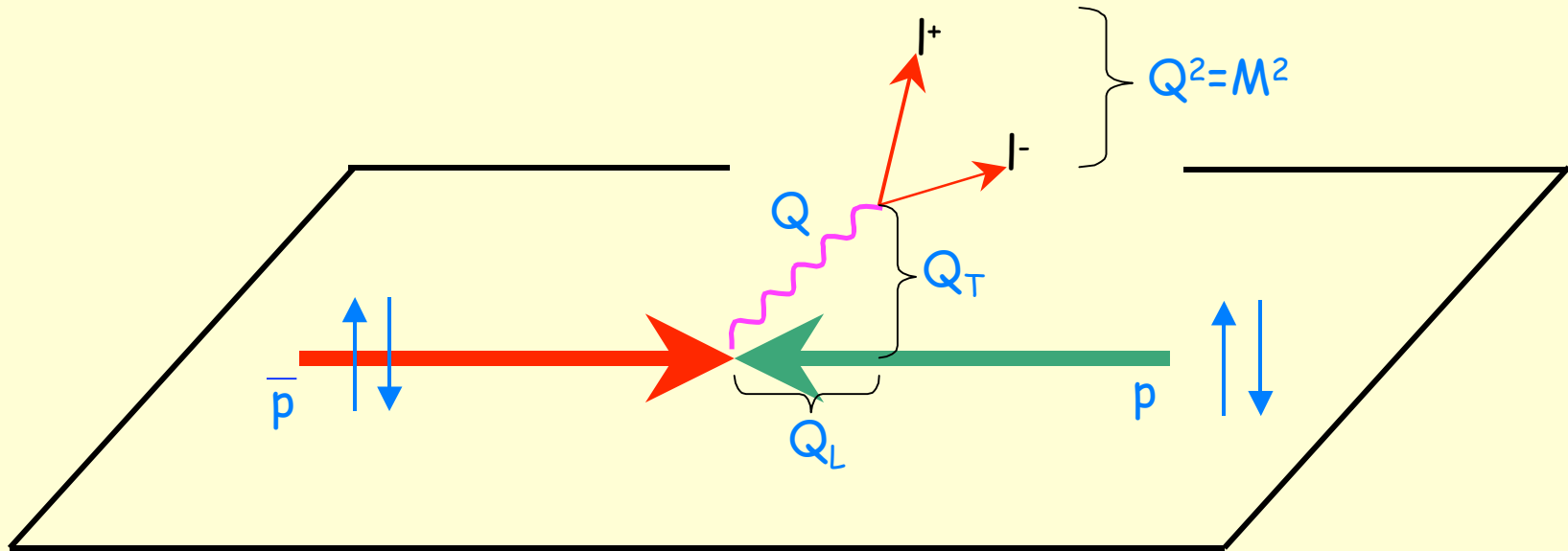
Transversity distribution of the nucleon in Drell-Yan:

→ FAIR as successor of DIS physics

- last leading-twist missing piece of the QCD description of the partonic structure of the nucleon
- observation of $h_1^q(x, Q^2)$ of the proton for valence quarks (A_{TT} in Drell-Yan > 0.2)
 - transversely polarized proton beam or target (✓)
 - transversely polarized antiproton beam (✗)

Transversity in Drell-Yan Processes

Polarized Antiproton Beam _ **Polarized Proton Target**
(both transversely polarized)



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

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

M invariant Mass
of lepton pair

A_{TT} for PAX Kinematic Conditions

RHIC: $x_1 x_2 = M^2/s \sim 10^{-3}$

— Exploration of sea quark content: A_{TT} small ($\sim 1\%$)

PAX: $M^2 \sim 10 \text{ GeV}^2$, $s \sim 200 \text{ GeV}^2$

$x_1 x_2 = M^2/s \sim 0.05$

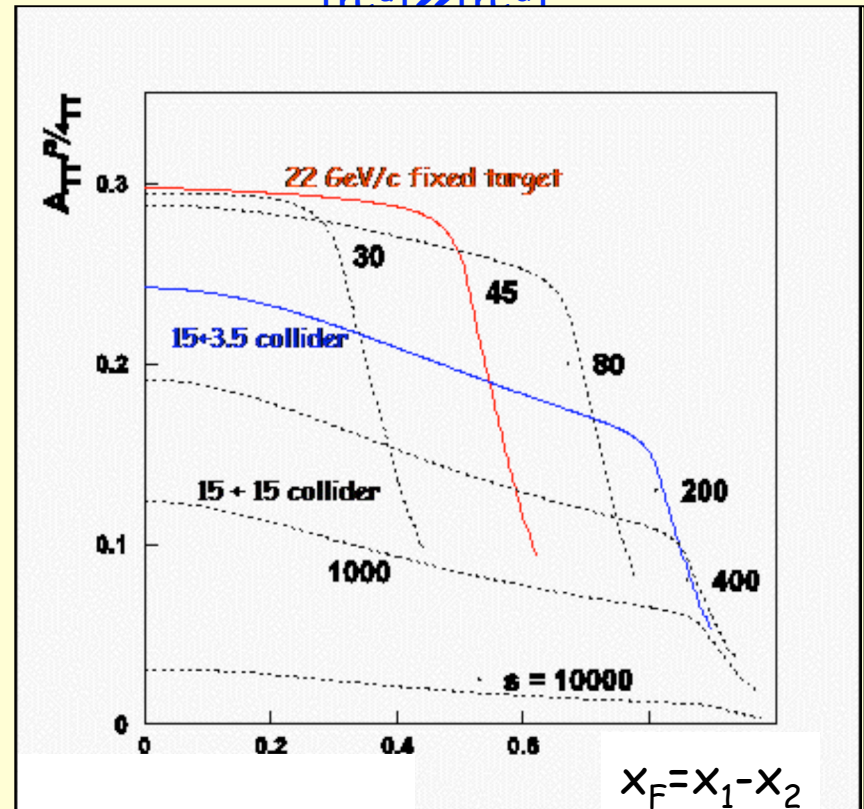
— Exploration of valence quarks
 $h_1^q(x, Q^2)$ large

$s \sim 200 \text{ GeV}^2$ ideal:

- Large range in x_F
- Large asymmetry, $(h_1^u/u)^2 \sim A_{TT}$

$A_{TT}/a_{TT} > 0.2$ Models predict

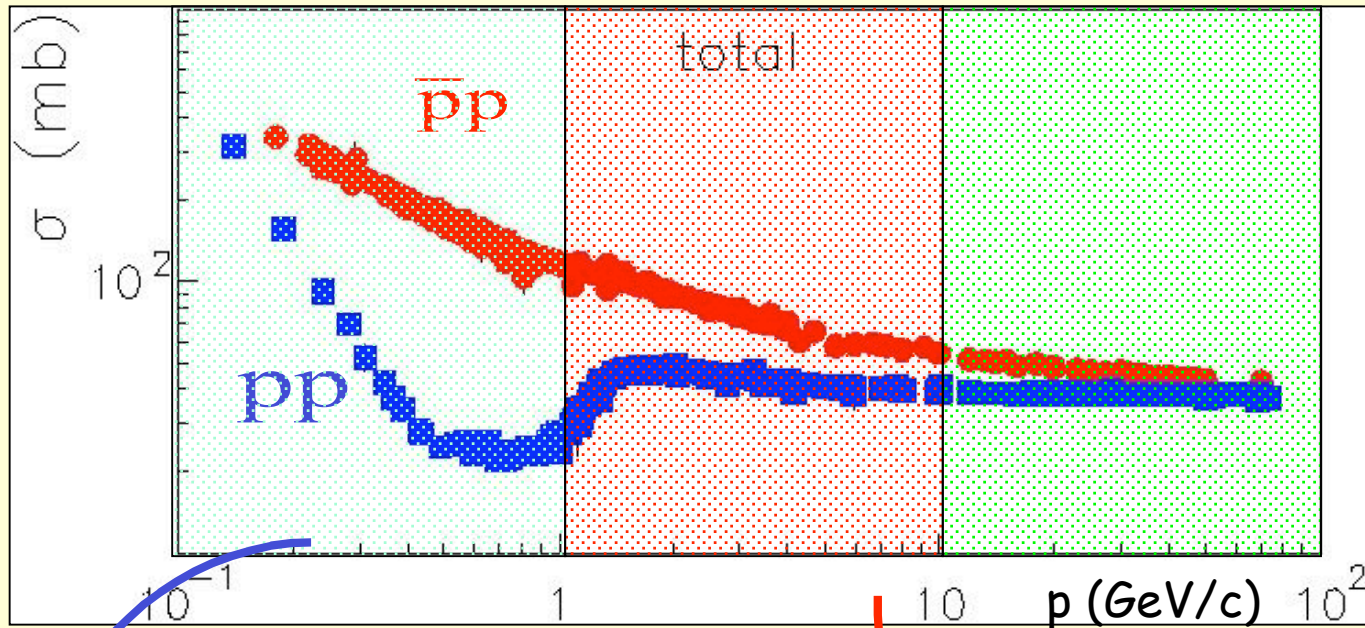
$|h^u| \gg |h^d|$



Anselmino et al., PLB 594,97 (2004)

Similar predictions by Efremov et al., EPJ C35, 207 (2004)

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

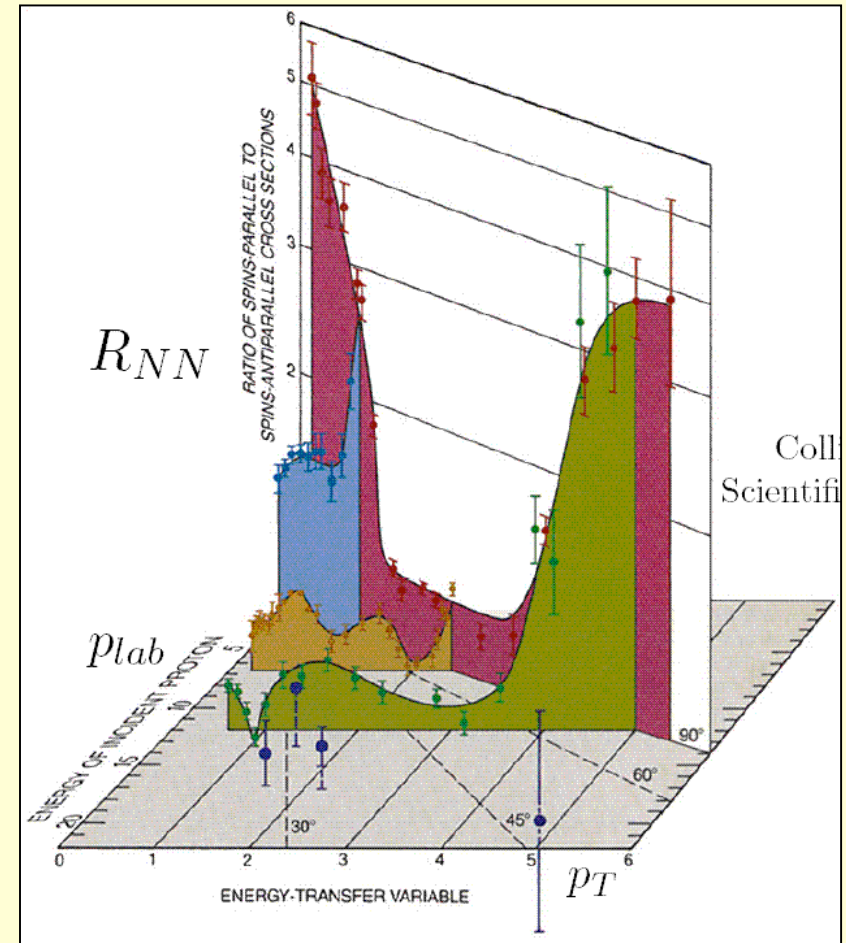
- Uncharted Territory
- Huge Spin-Effects in pp elastic scattering
- large t : non- and perturbative QCD

pp Elastic Scattering from ZGS/AGS

Spin-dependence at large- P_T (90°_{cm}):

Hard scattering takes place only with spins $\uparrow\uparrow$

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



A. Krisch, Sci. Am. 257 (1987)

"The results challenge the prevailing theory that describes the proton's structure and forces"

The PAX proposal

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~180 scientists

35 Institutions (15 EU, 20 Non-EU)

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

F. Rathmann et al., *A Method to polarize stored antiprotons to a high degree* (PRL 94, 014801 (2005))

15.01.05

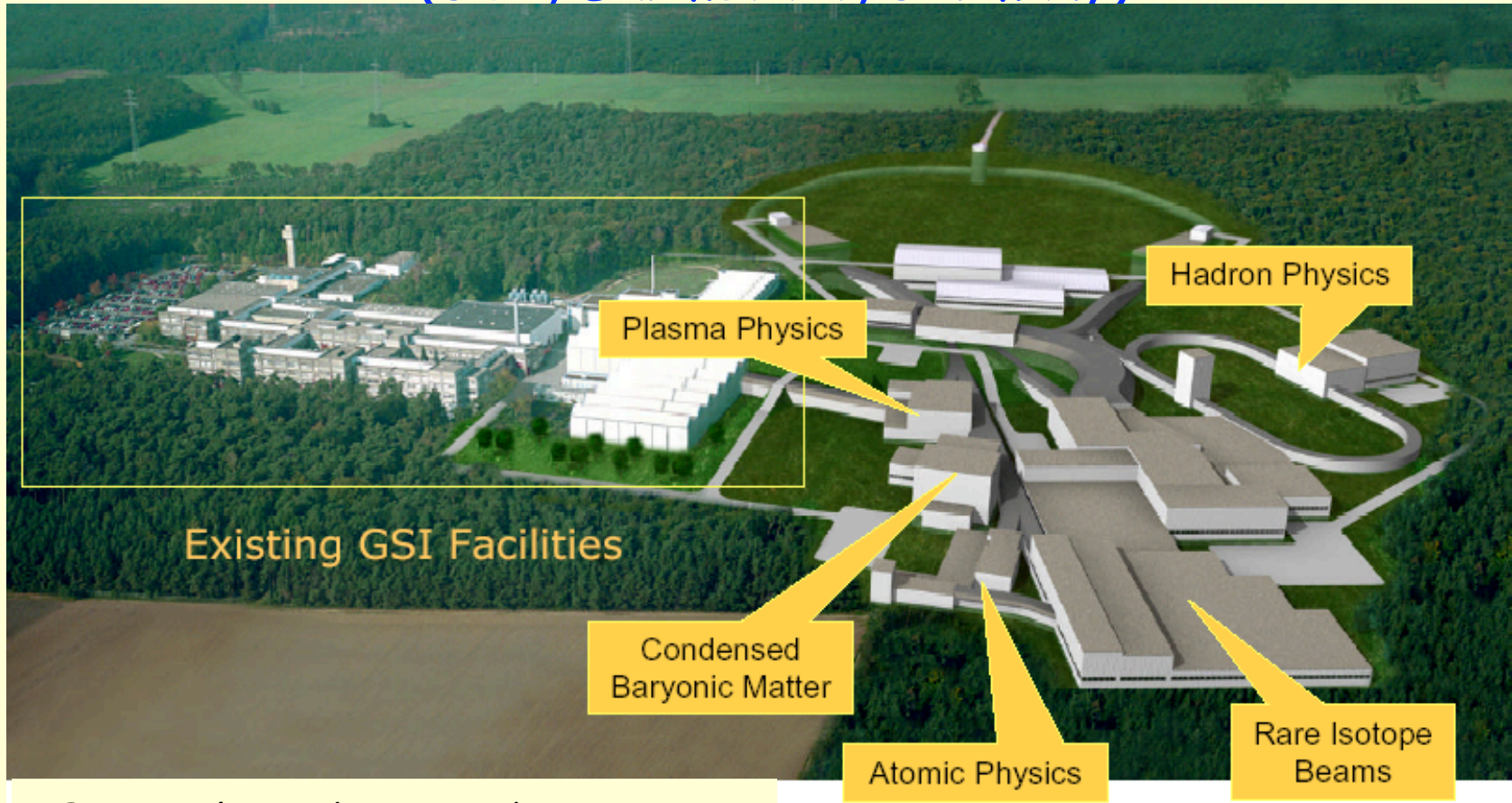
Technical Report submitted

14-16.03.05

QCD-PAC meeting at GSI

Polarized \bar{p} should enter FAIR core program

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



- Proton linac (injector)
- 2 synchrotrons (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

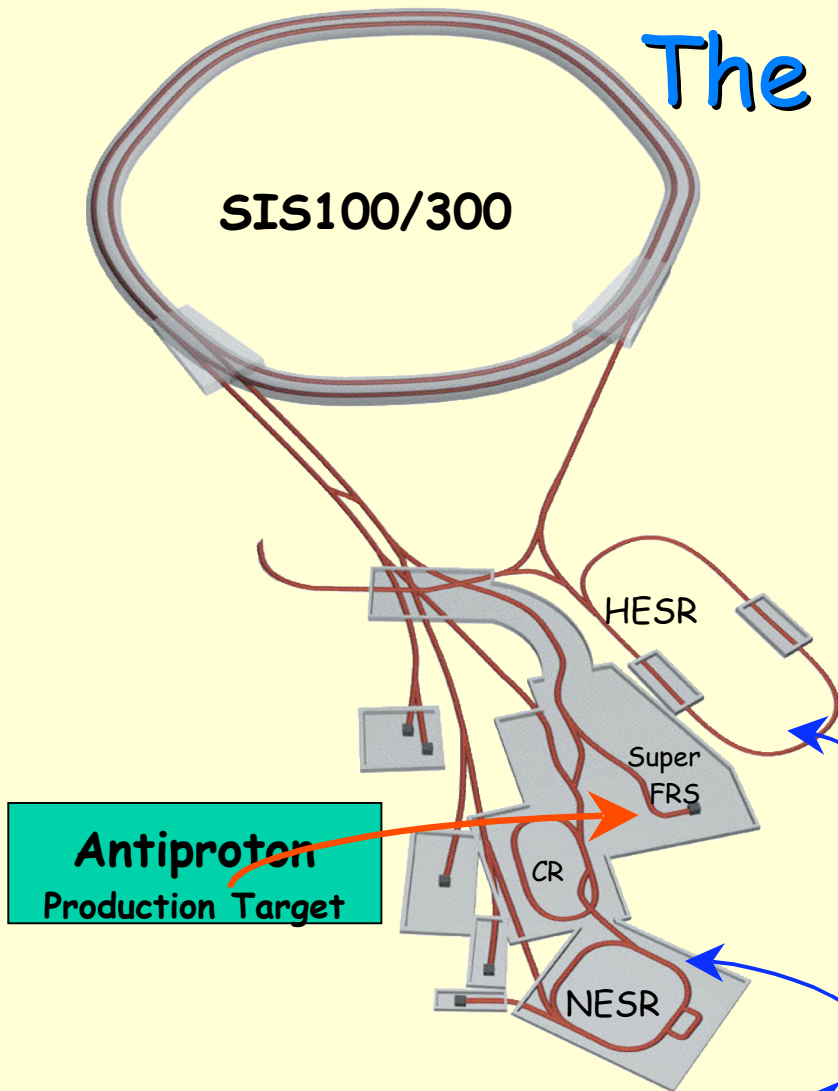
- FAIR will need a significant fraction of the available man-power and money in the years to come:

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 Antiproton Facility



HESR (High Energy Storage Ring)

- Length 442 m
- $B_{\perp} = 50 \text{ Tm}$
- $N = 5 \times 10^{10}$ antiprotons

High luminosity mode

- Luminosity = $2 \times 10^{32} \text{ cm}^{-2}\text{s}^{-1}$
- $\bar{p}/p \sim 10^{-4}$ (stochastic-cooling)

High resolution mode

- $\bar{p}/p \sim 10^{-5}$ (8 MV HE e-cooling)

Luminosity = $10^{31} \text{ cm}^{-2}\text{s}^{-1}$

Gas Target and Pellet Target:
cooling power determines thickness

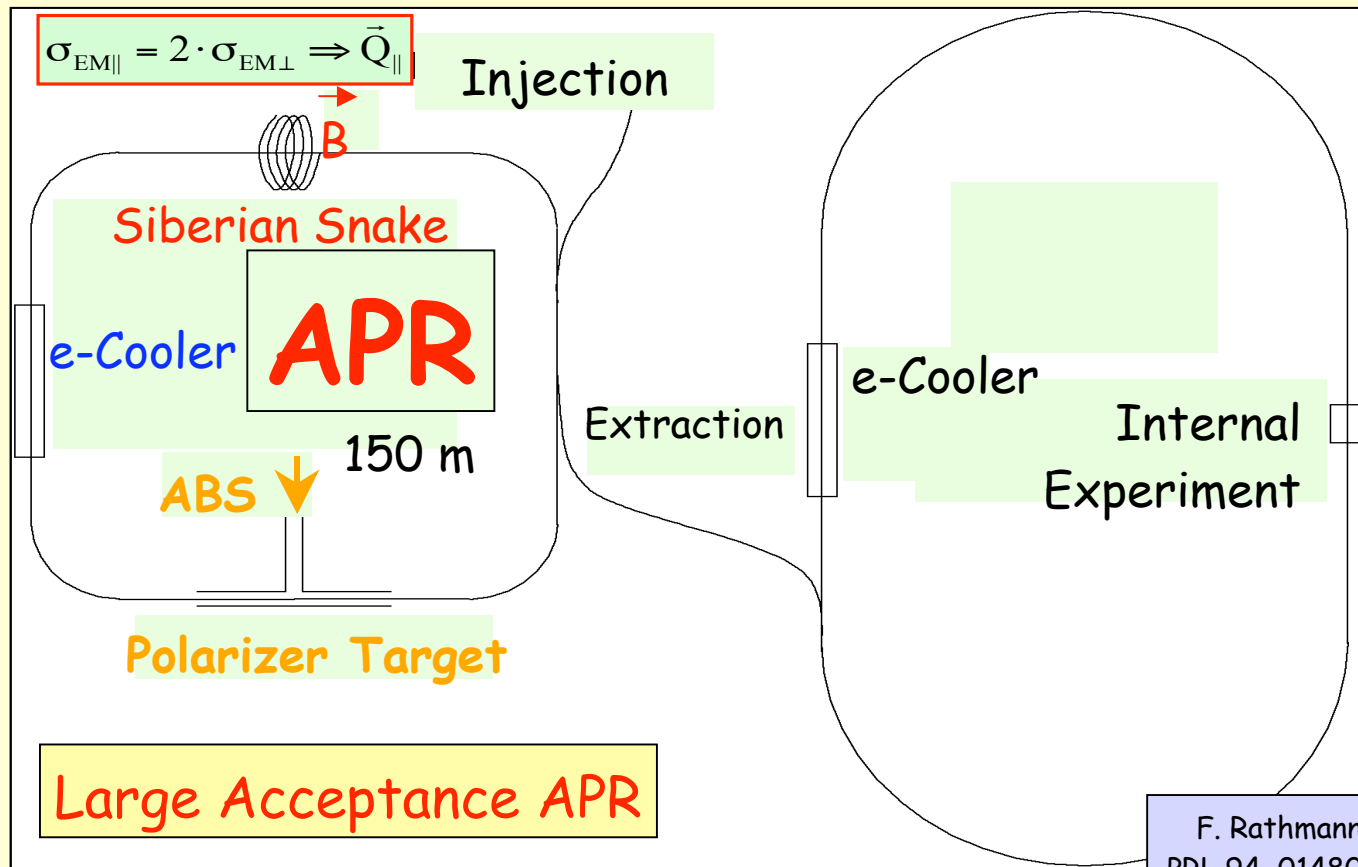
Beam Cooling:

e^- and/or stochastic

2MV prototype e-cooling at COSY

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

Antiproton Polarizer Ring (APR)



Small Beam Waist at Target

$$\sigma_z = 0.2 \text{ m}$$

High Flux ABS

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

→ Dense Target

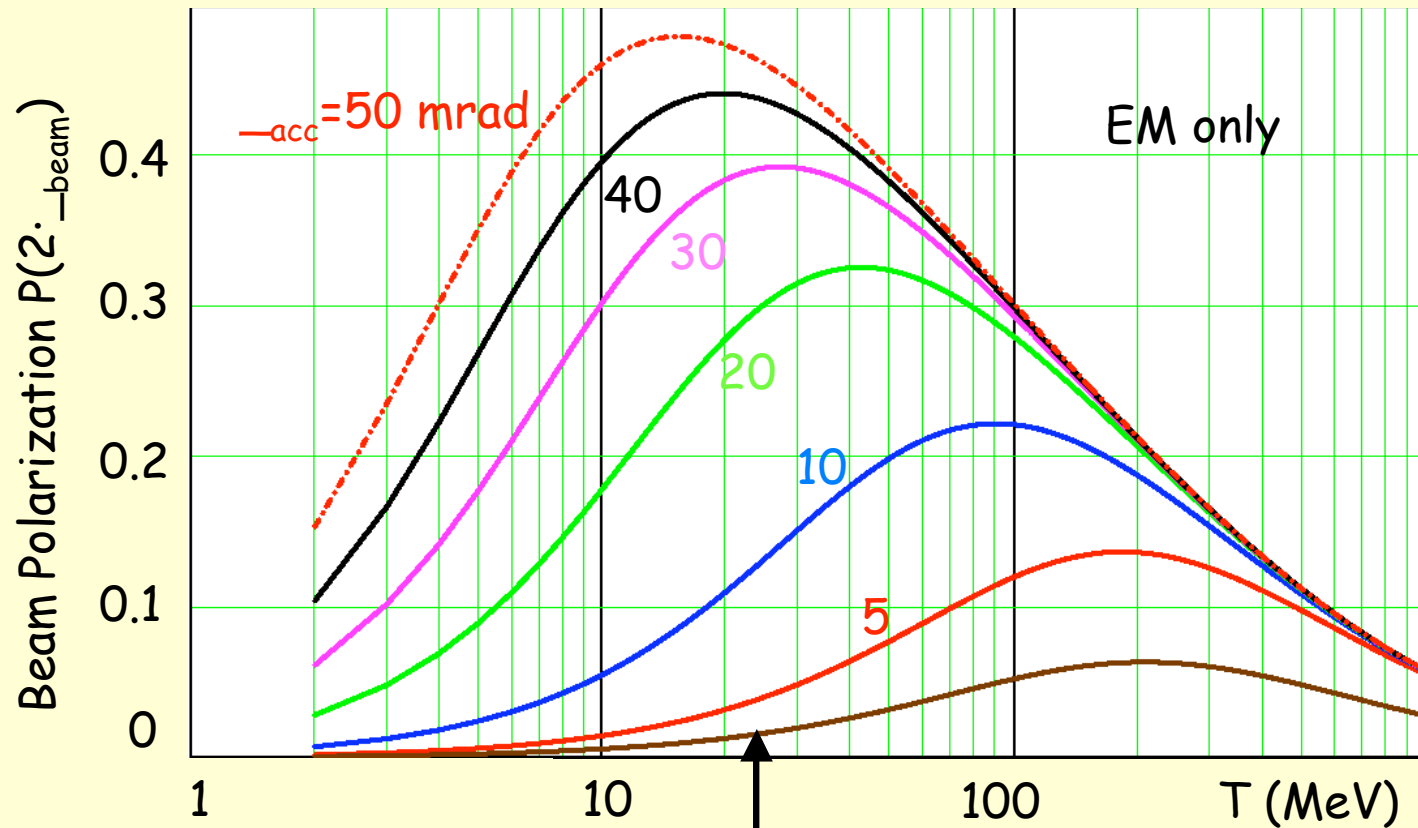
$T = 100 \text{ K}$, longitudinal Q (300

mT)

beam tube

$$d_b = \frac{d_{acc}}{2} \rightarrow d_{\dagger} = d_{\dagger}(\underline{d}_{acc}), l_b = 40 \text{ cm}$$

Beam Polarization (Electromagnetic Interaction)

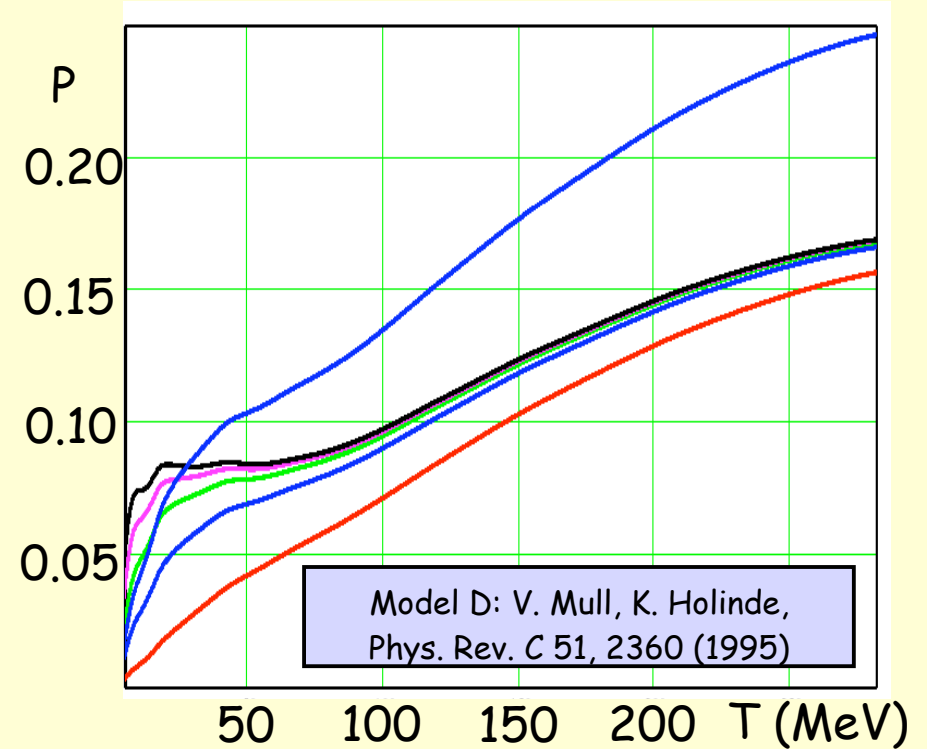
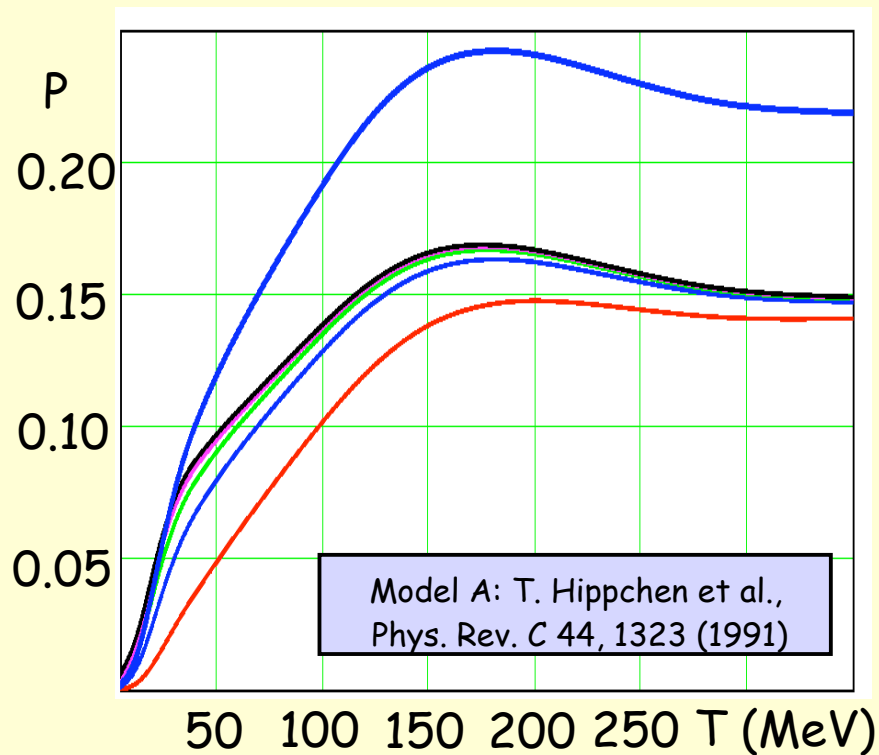


Filter Test: $T = 23$ MeV
 $\theta_{\text{acc}} = 4.4$ mrad

Buildup in HESR (800 MeV)

Beam Polarization

(Hadronic Interaction)



Experimental Tests required:

- Test of EM effect needs protons only (e.g. COSY)
- Final Design of APR: Filter test with p (e.g. CERN)

PAX Accelerator Setup

Antiproton Polarizer Ring (APR)

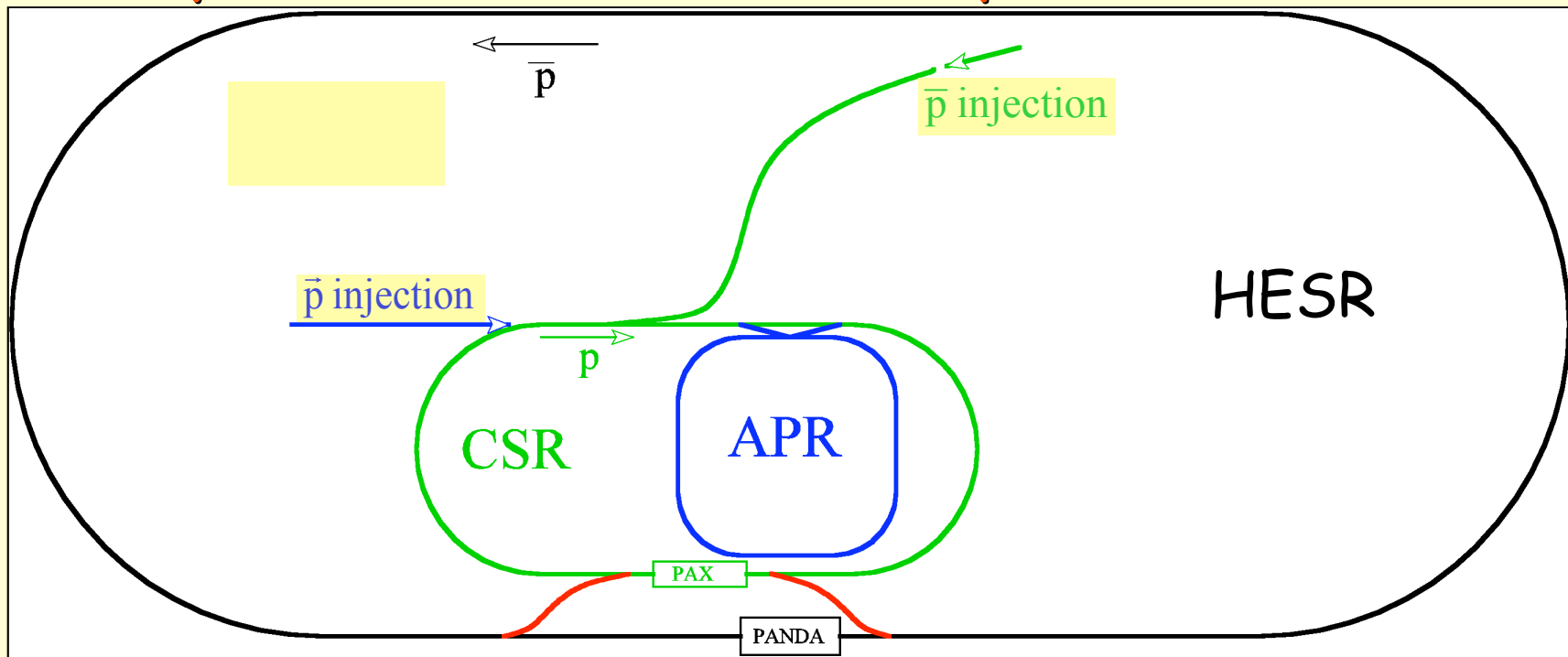
+

Cooler Storage Ring (CSR, COSY-like): 3.5 GeV/c

+

HESR: 15 GeV/c

→ Asymmetric Double-Polarized Antiproton-Proton Collider

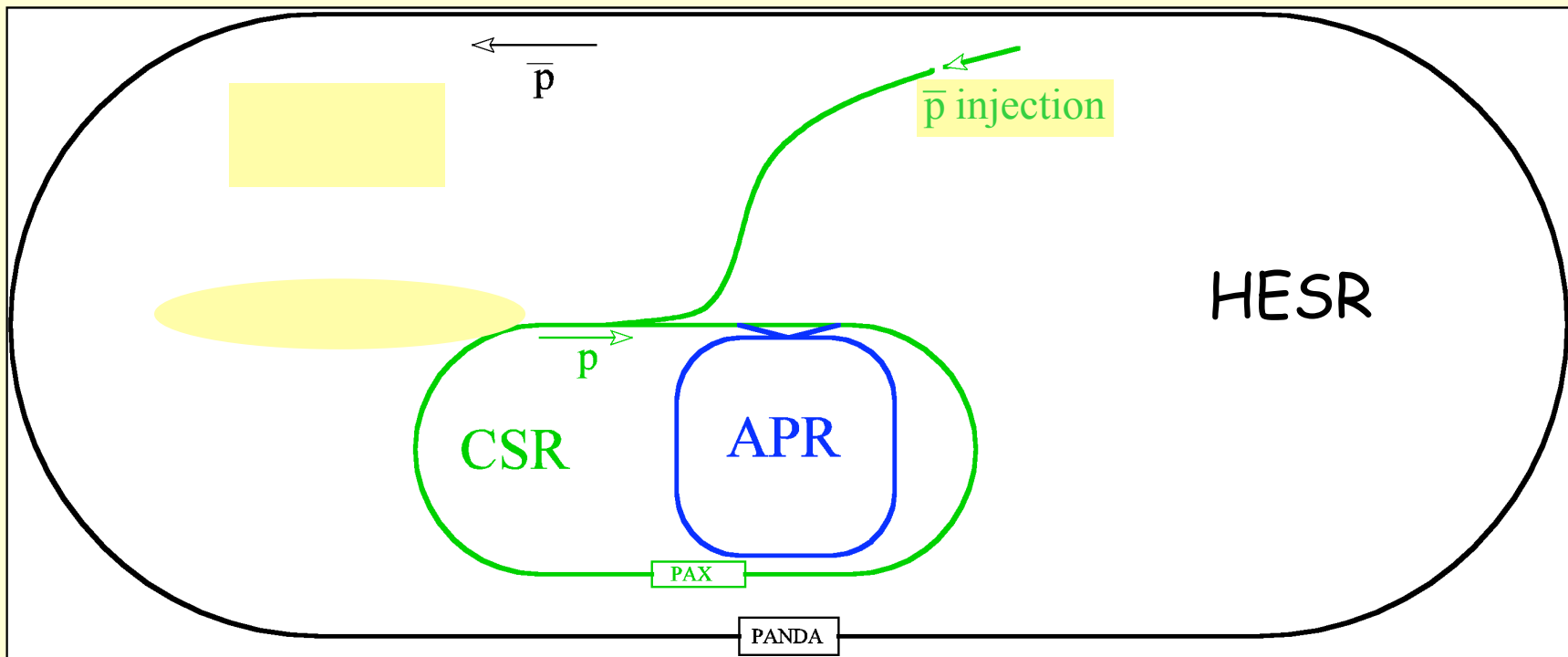


Phase I: PAX at CSR

Physics: Electromagnetic Form Factors
pp elastic scattering

Experiment: polarized/unpolarized p on polarized target

Independent of HESR experiments



Phase II: PAX at CSR

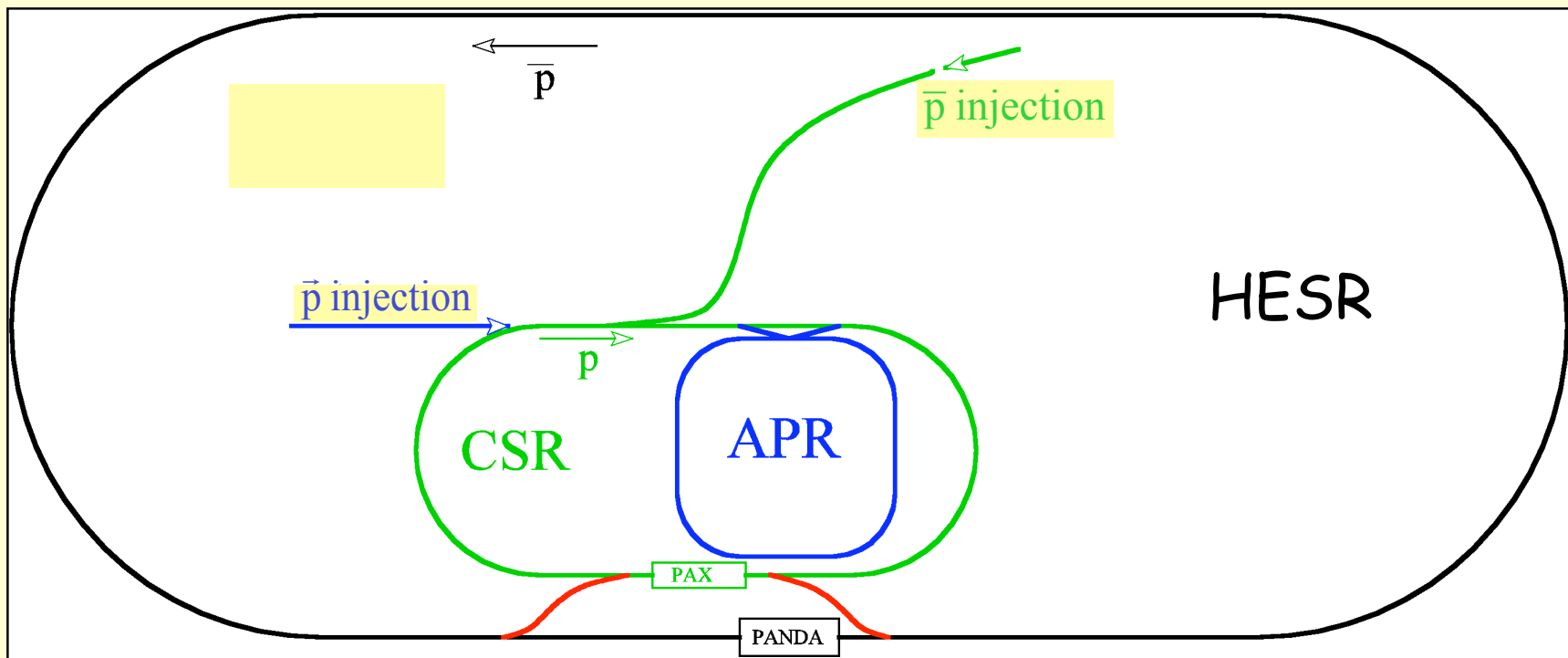
Physics: Transversity

EXPERIMENT: Asymmetric Collider:

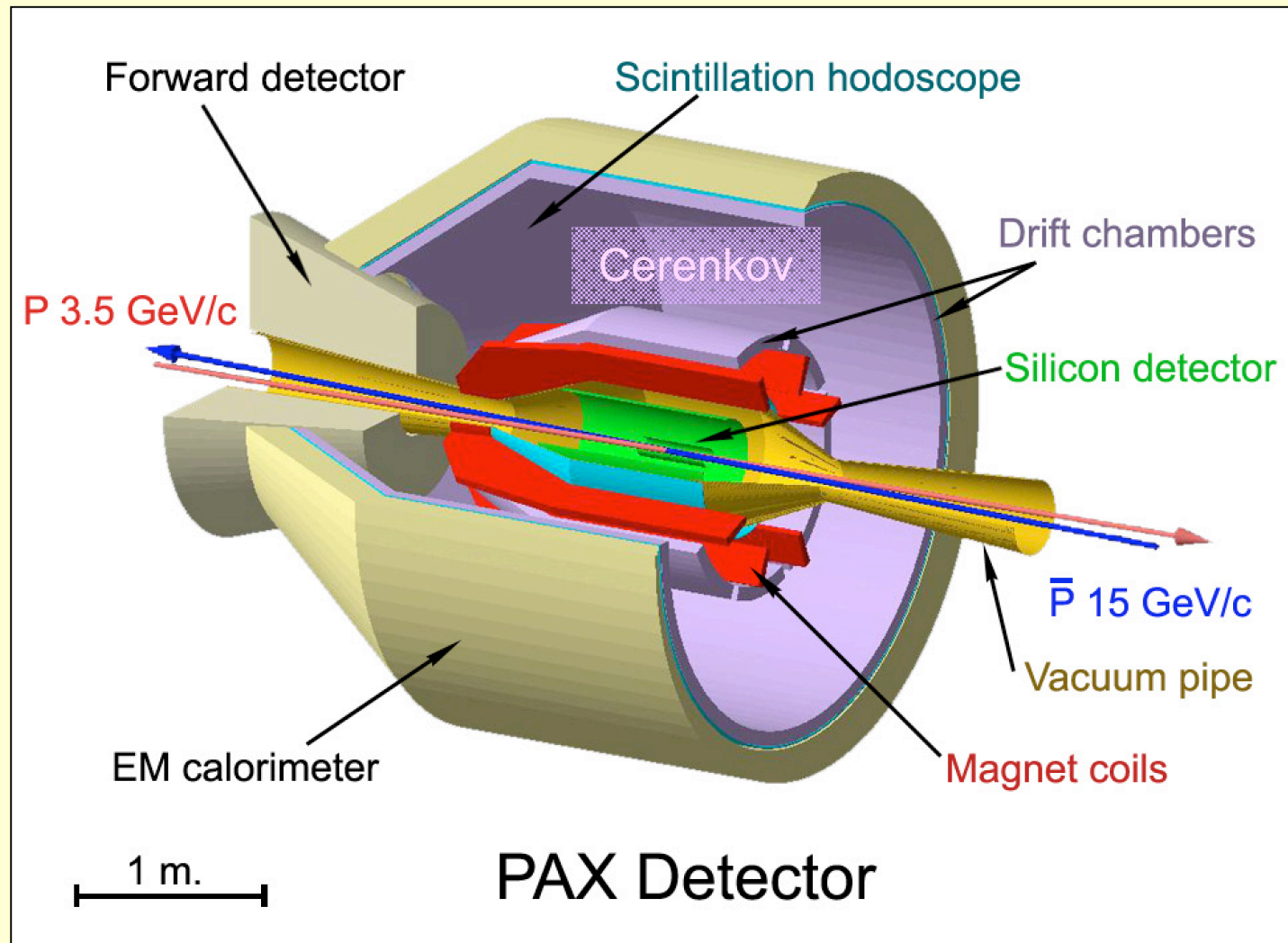
Polarized Antiprotons in HESR (15 GeV/c)

Polarized Protons in CSR (3.5 GeV/c)

Second IP with minor interference with PANDA



PAX Detector Concept



Designed for Collider, but compatible with fixed target

PAX Timeline

Phase 0: 2005-2012

- Physics: Measurement of spin-dependent πp interaction (COSY & CERN)
- Polarizer Ring Design and Construction

Phase I: 2013-2015

- APR+CSR @ GSI
- Physics: EMFF, πp elastic with fixed target

Phase II: 2015 - ...

- HESR+CSR: Asymmetric Collider
- Physics: h1

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