JÜLICH
FORSCHUNGSZENTRUM

The Quest for Polarized Antiprotons

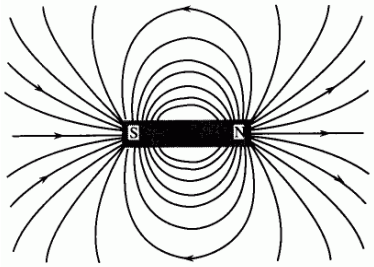
Spin Physics, Medieval Warfare, and Medical Applications

May 03, 2010 Frank Rathmann

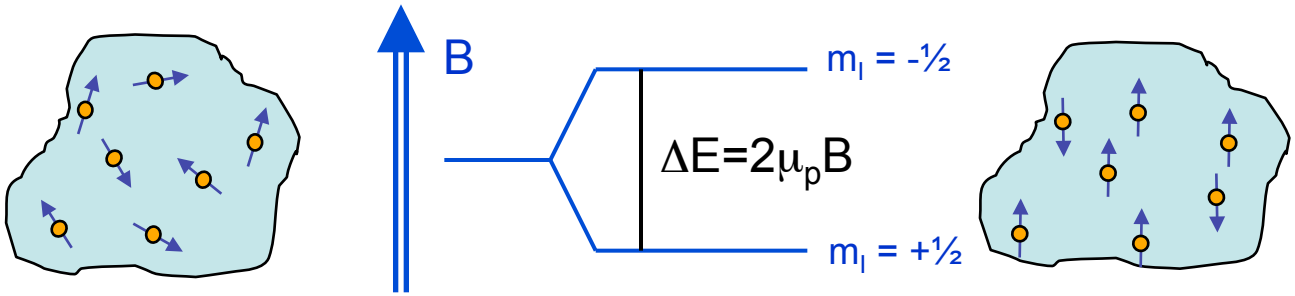
4th Georgian – German School and Workshop in Basic Science
Tbilisi, Georgia

What do we mean by „polarized“?

Most particles posses a magnetic moment,
→ they behave like little magnets

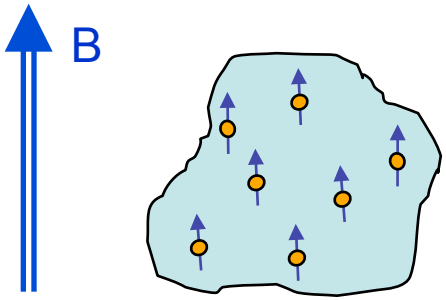


Unpolarized ensemble of particles (e.g. protons)



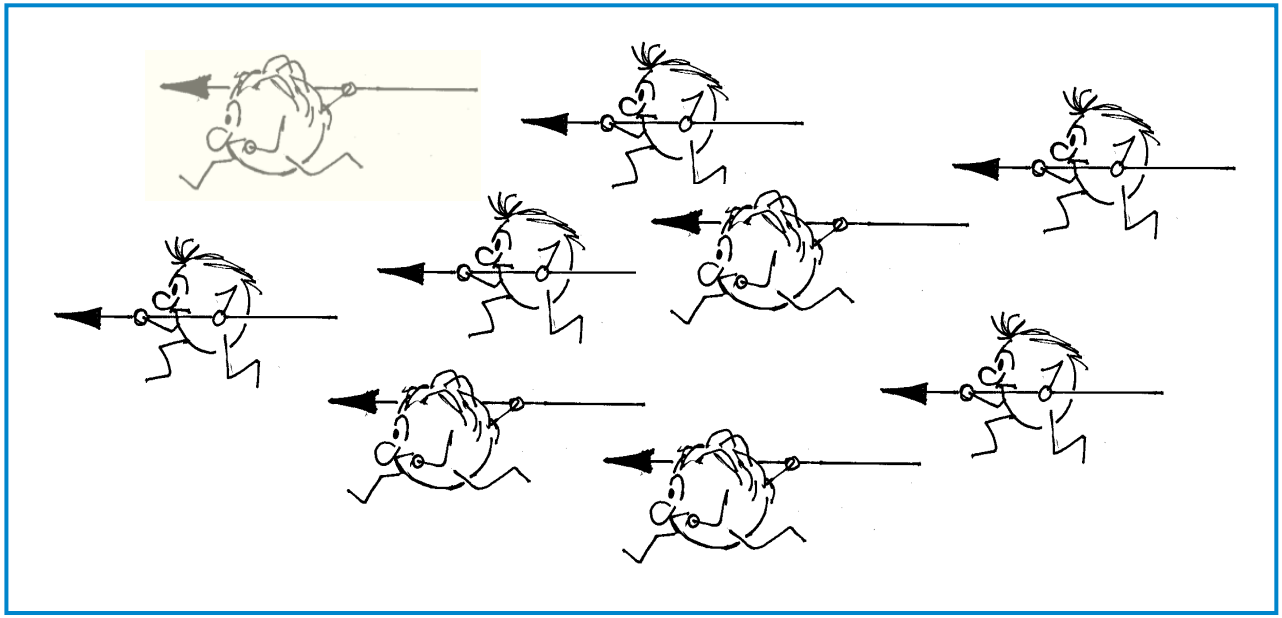
$$P = \frac{N_\uparrow - N_\downarrow}{N_\uparrow + N_\uparrow} \approx \frac{\mu_p \cdot B}{k_B \cdot T} \approx 5 \cdot 10^{-6}$$

Polarized ensemble of particles



$$P = \frac{N_\uparrow - N_\downarrow}{N_\uparrow + N_\uparrow} = \frac{7-0}{7+0} = 1$$

Picture polarized particles (stored in a ring or in a target)



Outline

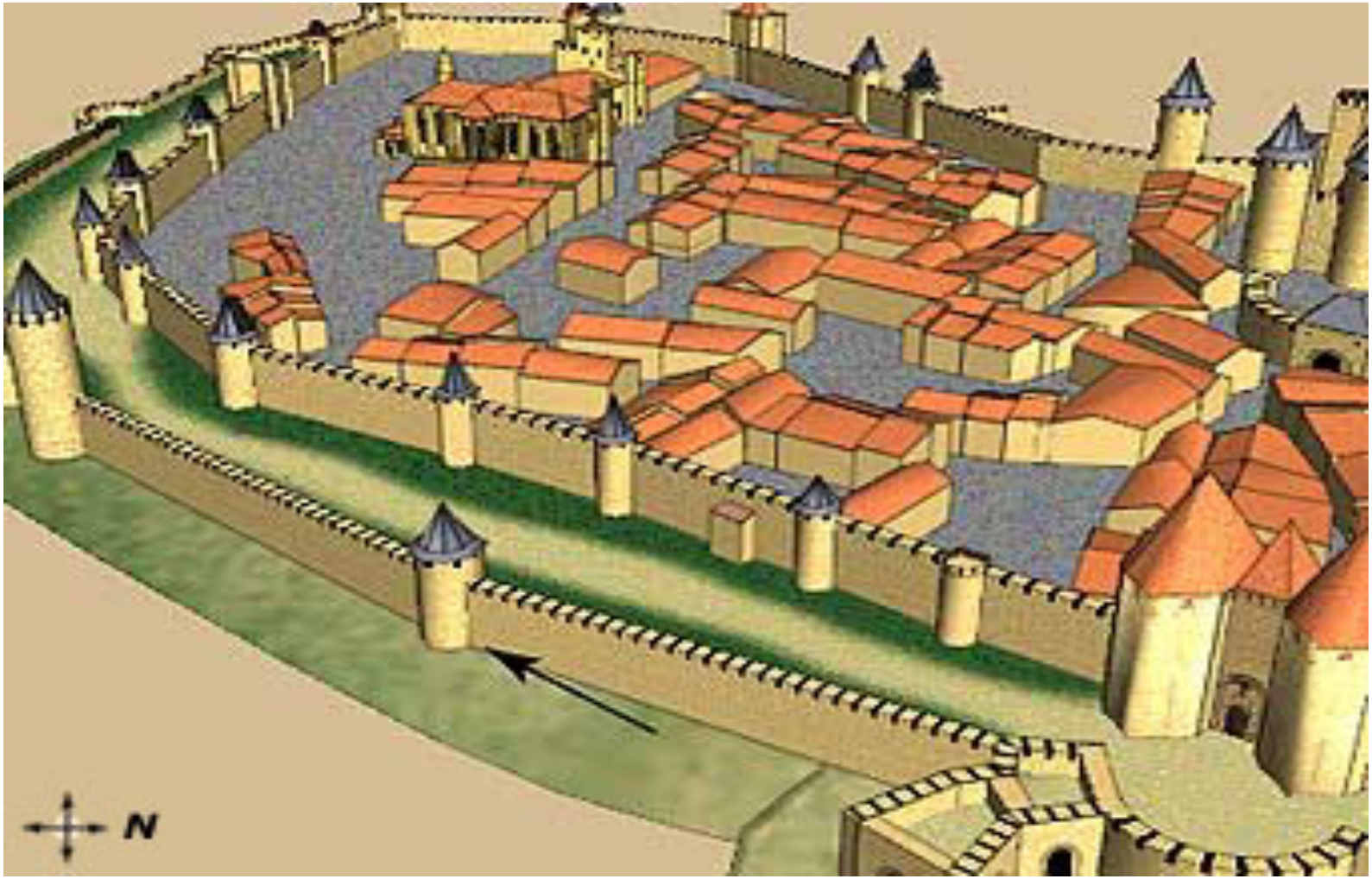
- Basics
- **Medieval Warfare**
  - **Storage Rings and Internal Targets**
- Quest for Polarized Antiprotons
- Medical Application of Polarized Targets

Medieval Warfare, Storage Rings, and Internal Targets

South of France, between Toulouse and the Mediterranean

Carcassonne

Fortress built by Philippe III (the Strong) (1270-1285)



Medieval Warfare

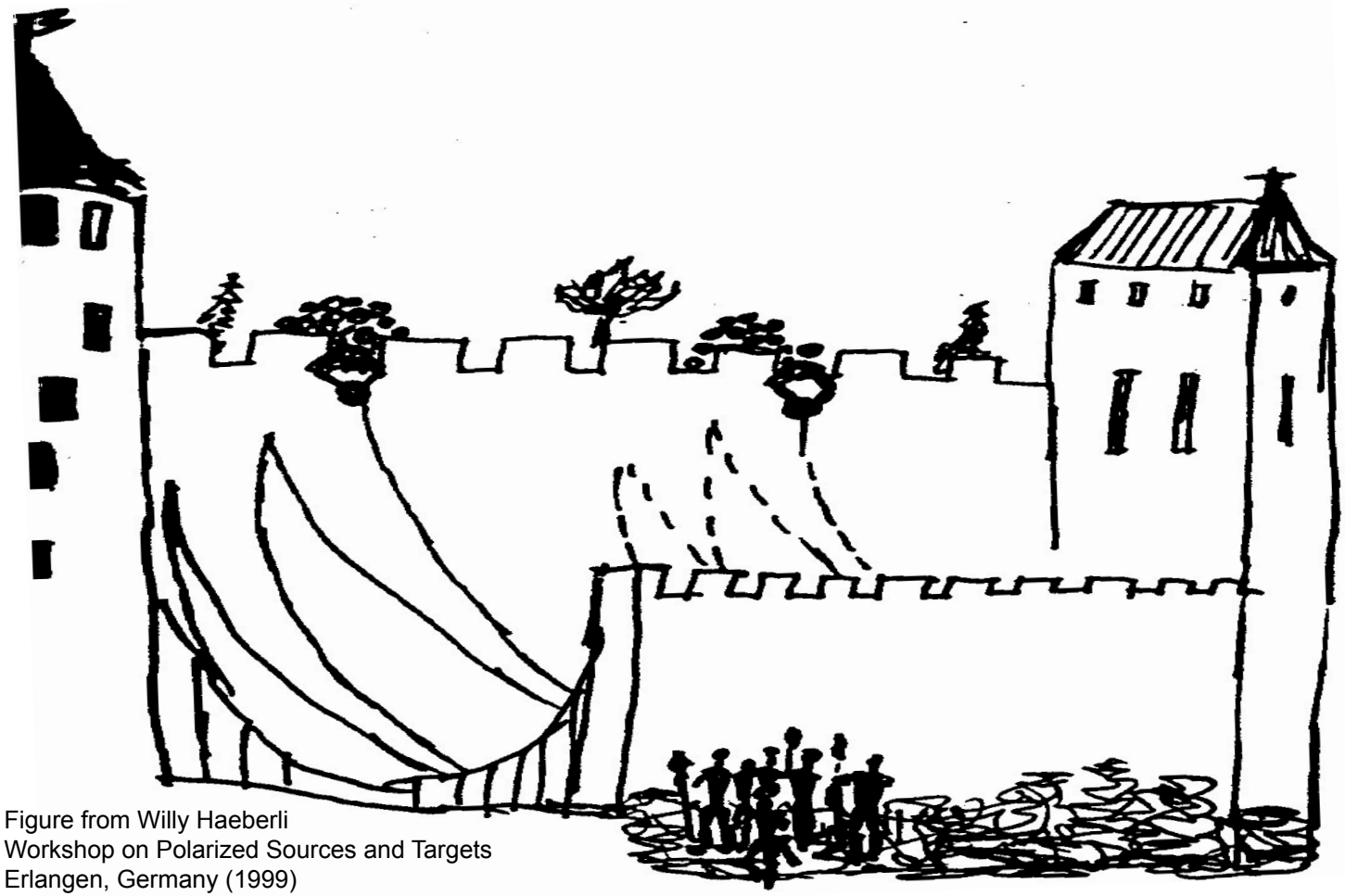
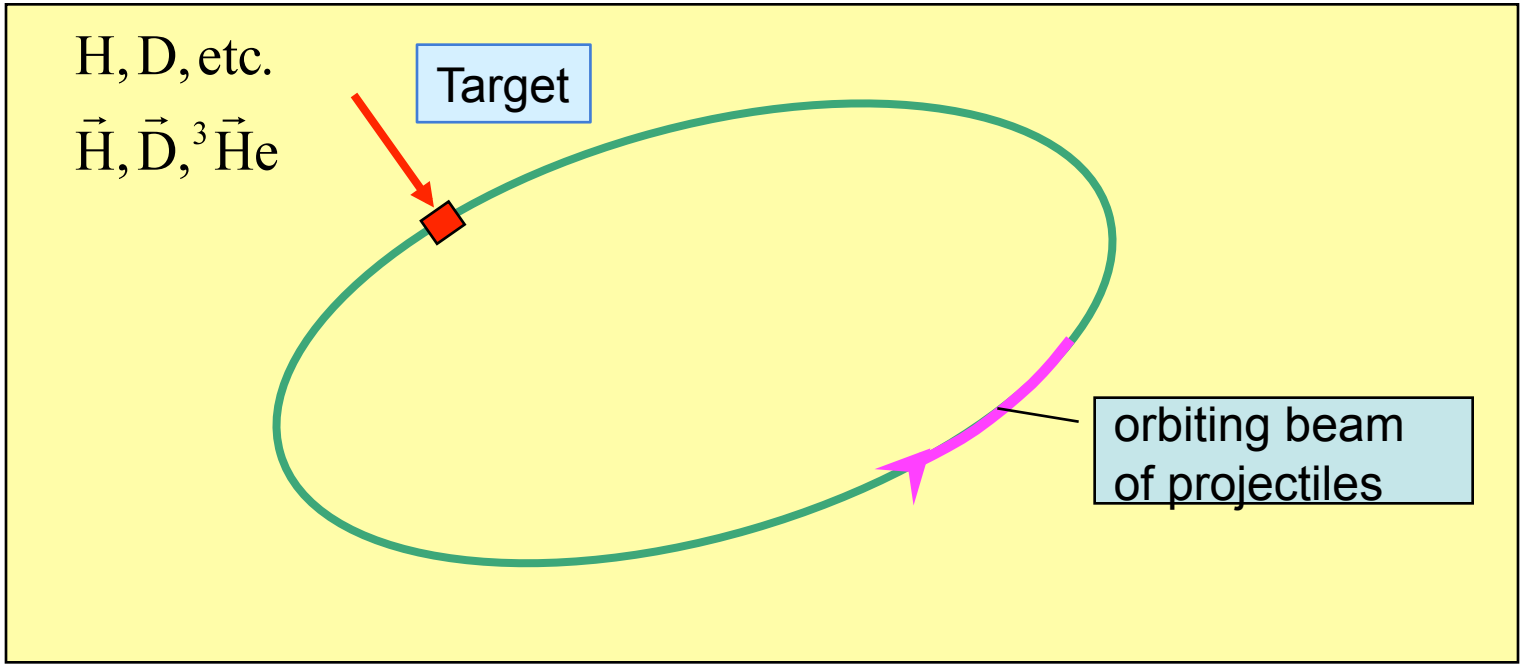


Figure from Willy Haeberli
Workshop on Polarized Sources and Targets
Erlangen, Germany (1999)

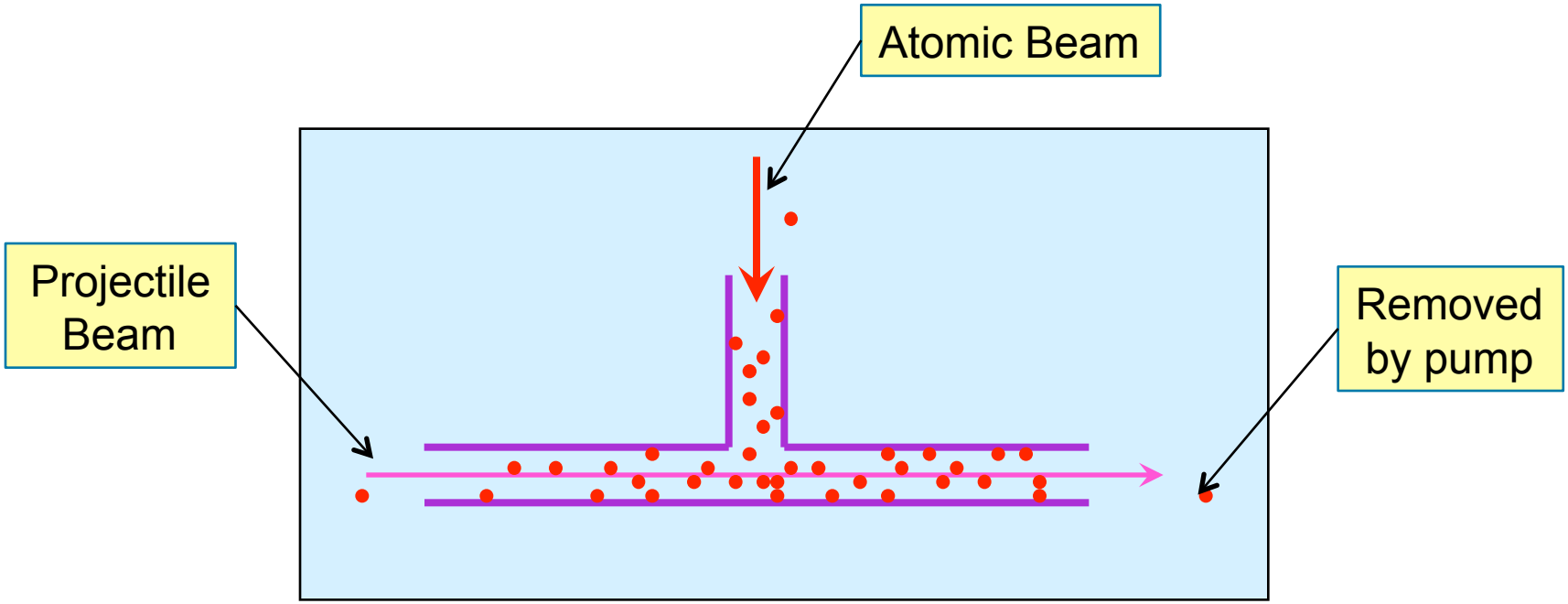
Multiple use of a projectile oscillating in a potential well.

Internal Target in a Storage Ring



Storage Ring: Re-usable Projectiles
Application of the Carcassonne principle (type I)

Polarized Storage Cell Target



After each wall collisions, atoms can intercept beam again.

Storage cell Target: Re-usable target atoms
Carcassonne principle (type II)

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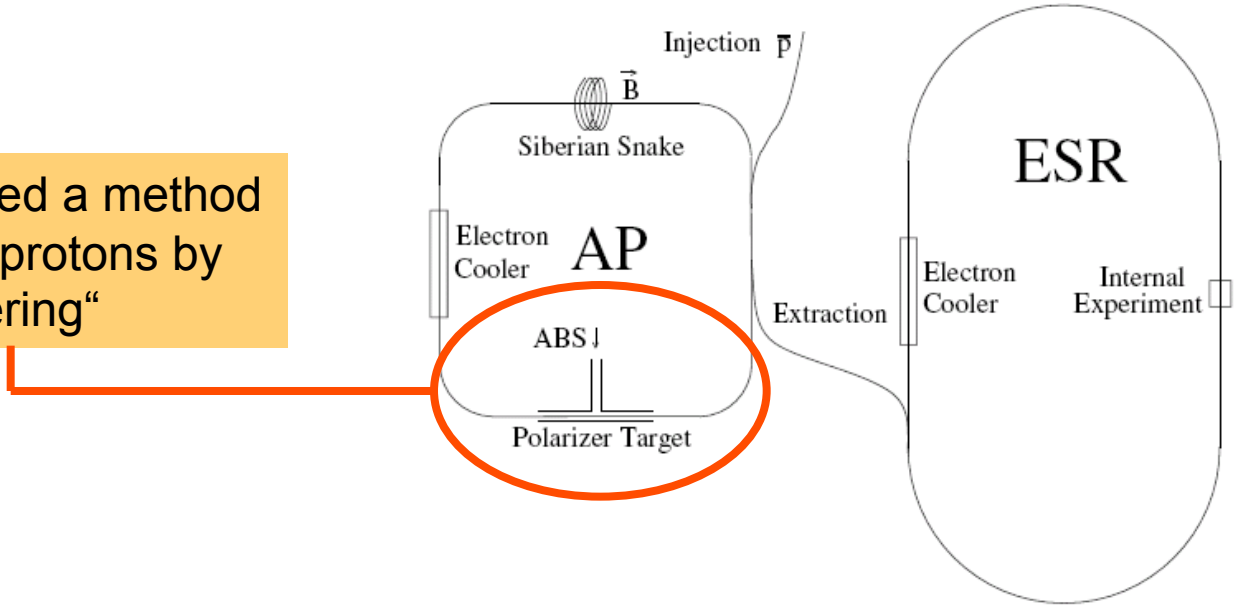
The basic concept

PRL 94, 014801 (2005) PHYSICAL REVIEW LETTERS week ending 14 JANUARY 2005

A Method to Polarize Stored Antiprotons to a High Degree

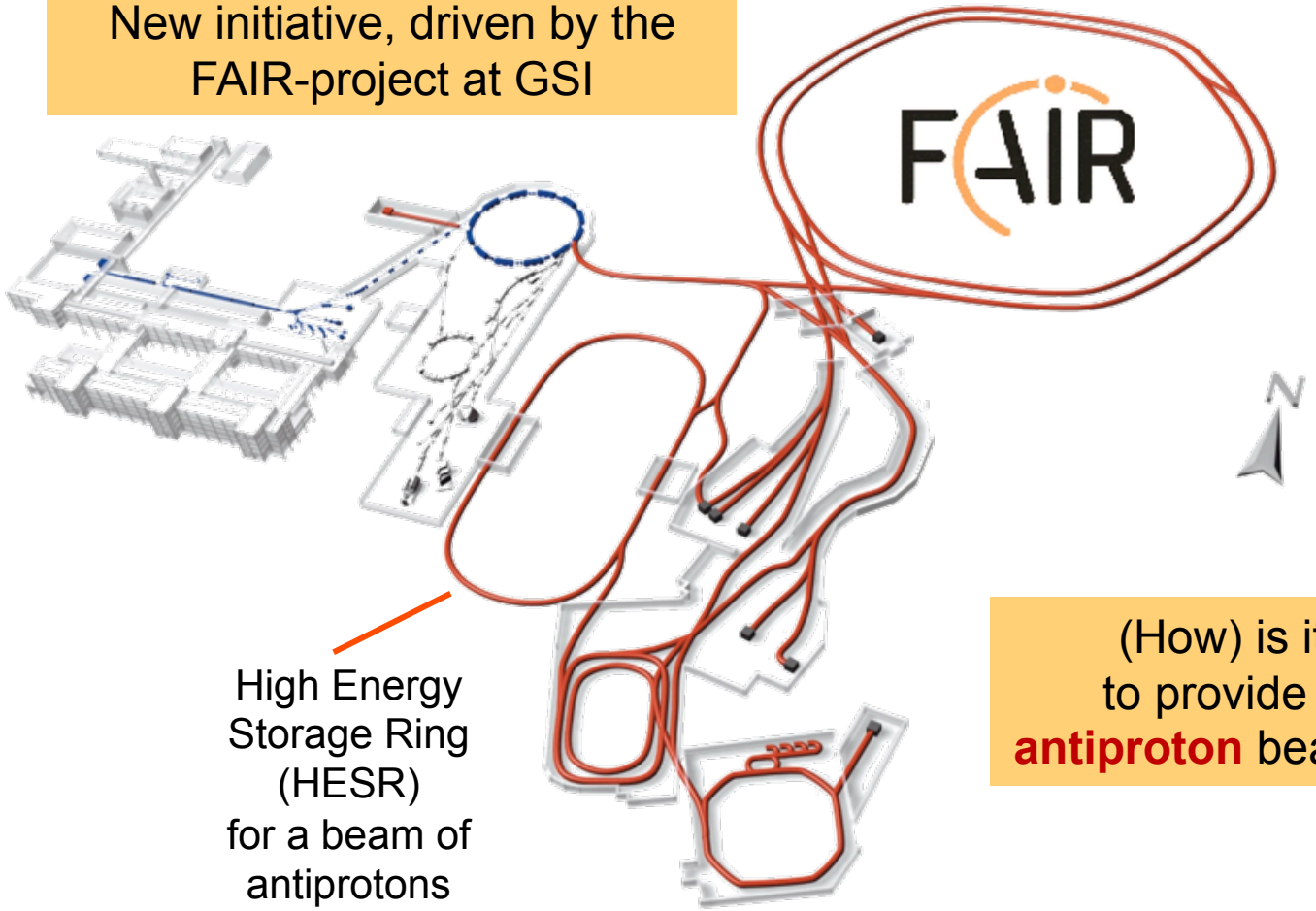
F. Rathmann,[1,*] P. Lenisa,[2] E. Steffens,[3] M. Contalbrigo,[2] P. F. Dalpiaz,[2] A. Kacharava,[3] A. Lehrach,[1] B. Lorentz,[1] R. Maier,[1] D. Prasuhn,[1] and H. Ströher[1]

We have proposed a method to polarize antiprotons by „spin-filtering“



FAIR

New initiative, driven by the FAIR-project at GSI

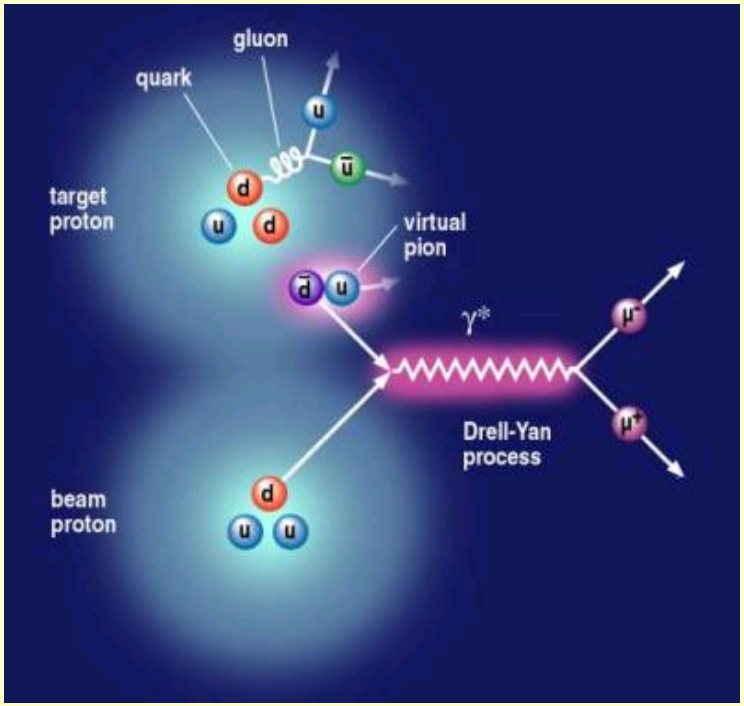


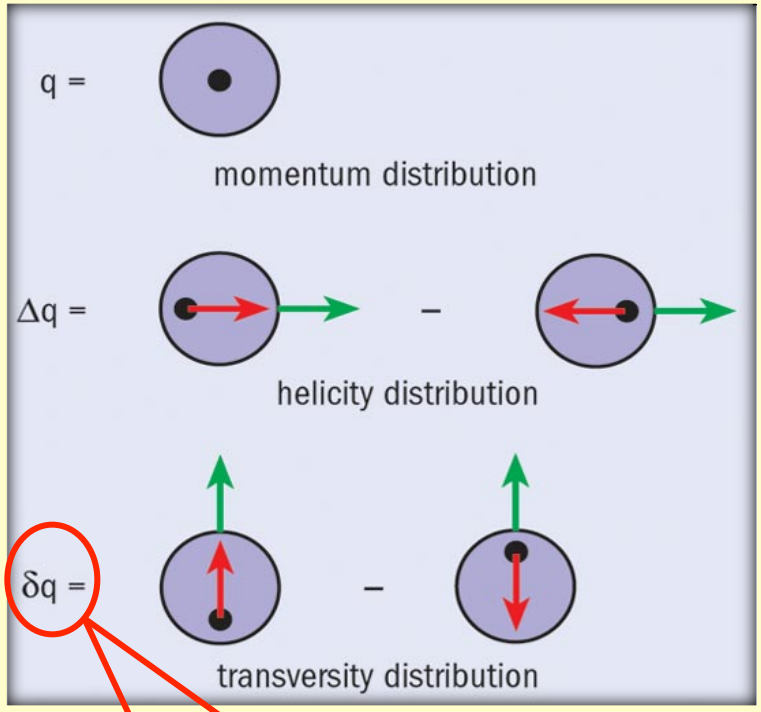
High Energy Storage Ring (HESR) for a beam of antiprotons

(How) is it possible to provide **polarized antiproton** beams in HESR?

Physics with polarized antiprotons

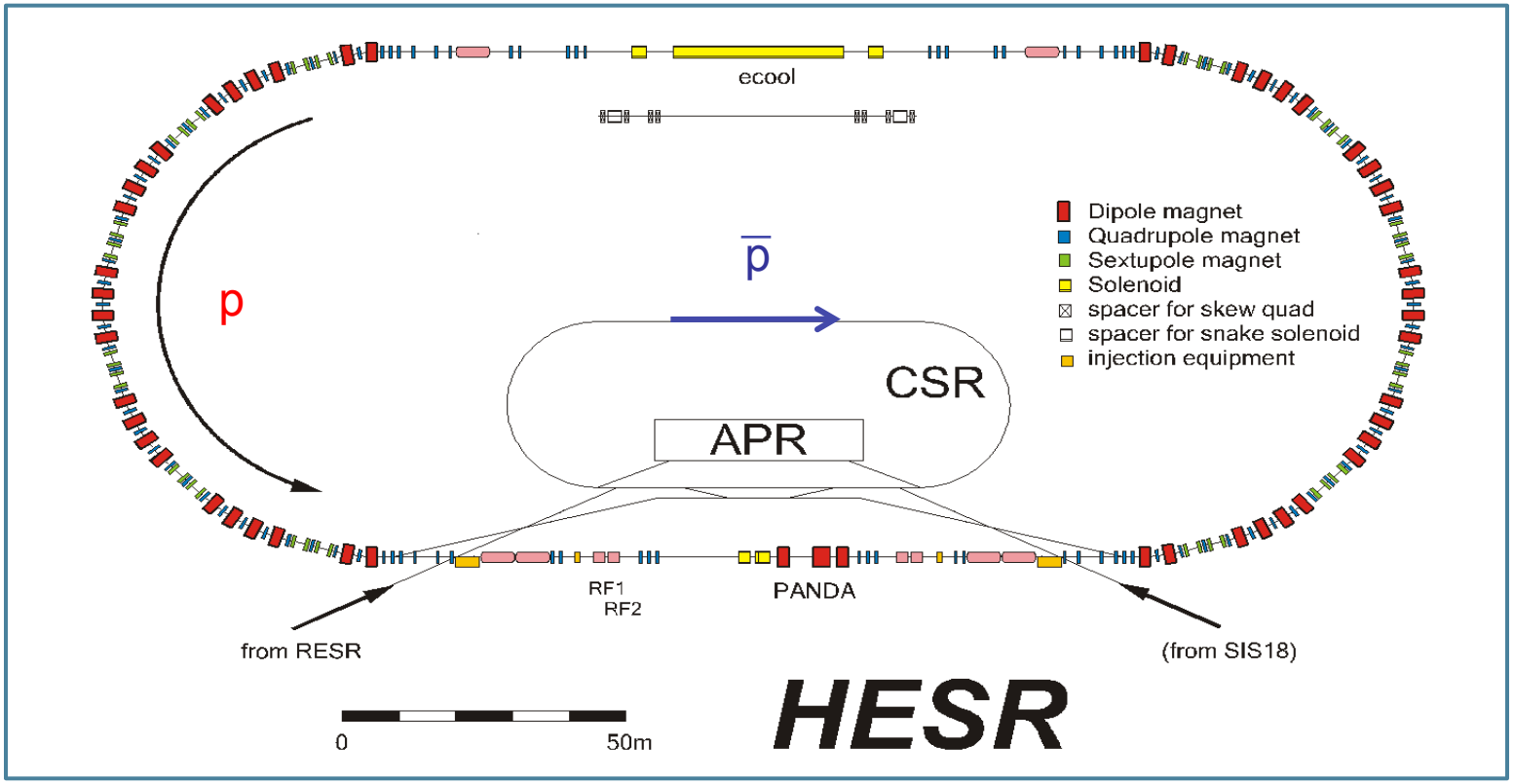
„Transversity“ in **polarized proton - polarized antiproton** Drell-Yan collisions:





$$A_{TT} \equiv \frac{d\sigma^{\uparrow\uparrow} - d\sigma^{\uparrow\downarrow}}{d\sigma^{\uparrow\uparrow} + d\sigma^{\uparrow\downarrow}} = \hat{a}_{TT} \frac{\sum_q e_q^2 h_1^q(x_1, M^2) \overline{h}_1^{\overline{q}}(x_2, M^2)}{\sum_q e_q^2 q(x_1, M^2) \overline{q}(x_2, M^2)}$$

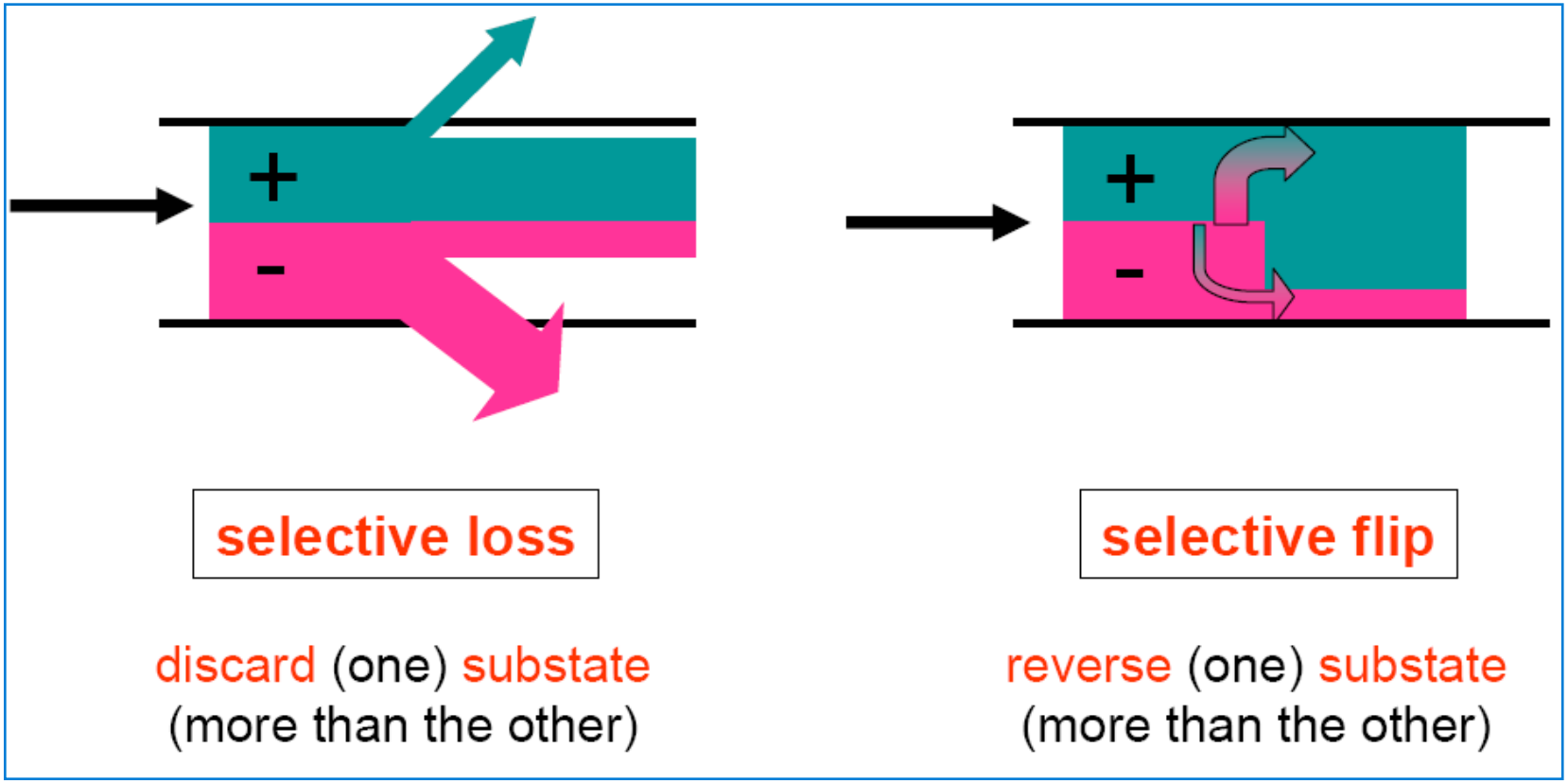
Hadron Physics „Dream Machine“ for FAIR



… an asymmetric (double-polarized)
proton (15 GeV/c) – antiproton (3.5 GeV/c) collider
using HESR, CSR and APR

Production of polarization in a stored beam

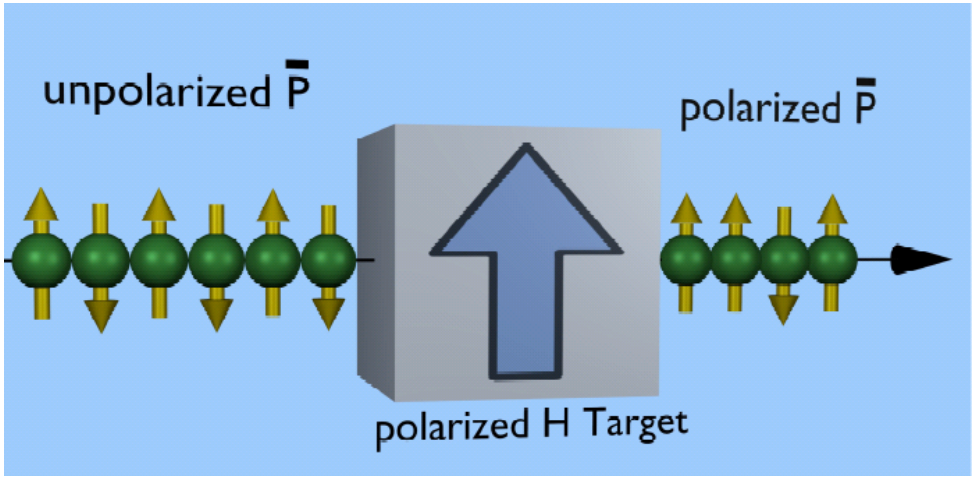
For an ensemble of spin ½ particles with projections **+** (↑) and **–** (↓)

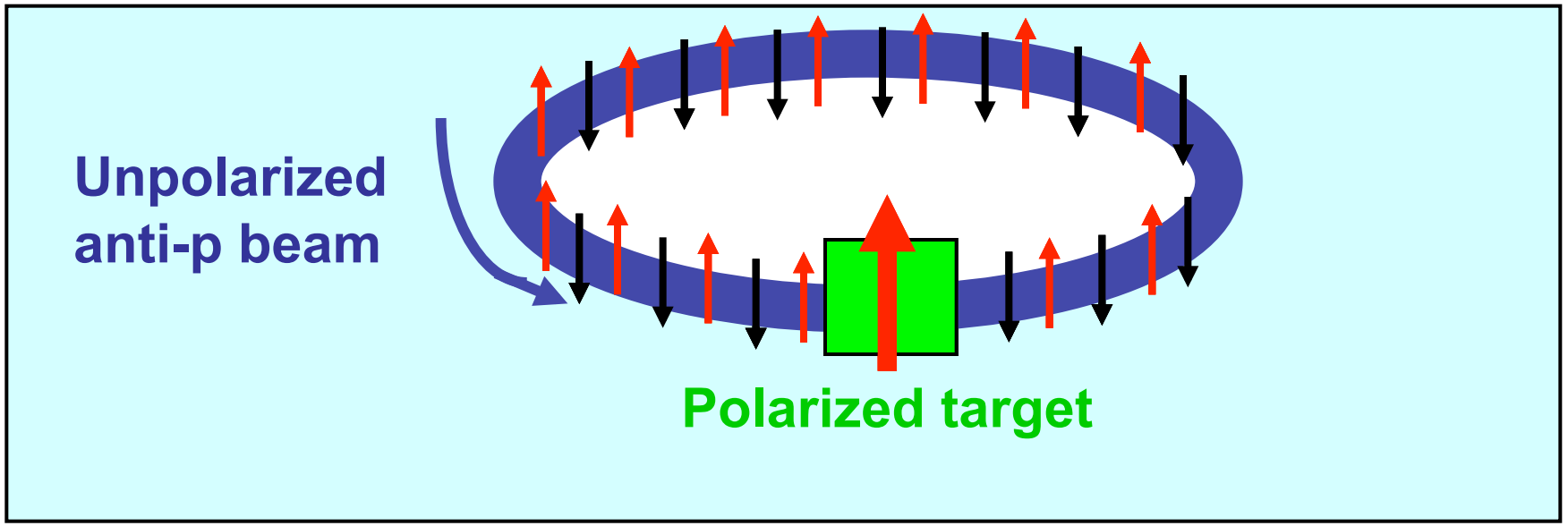


→Selective flip preferred (no loss in intensity) !

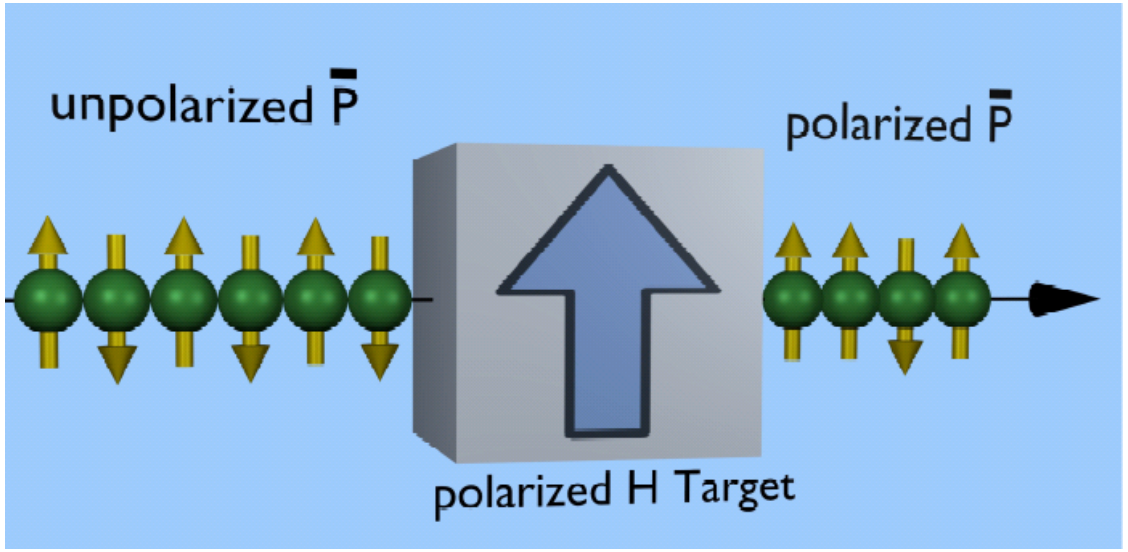
Polarization build-up

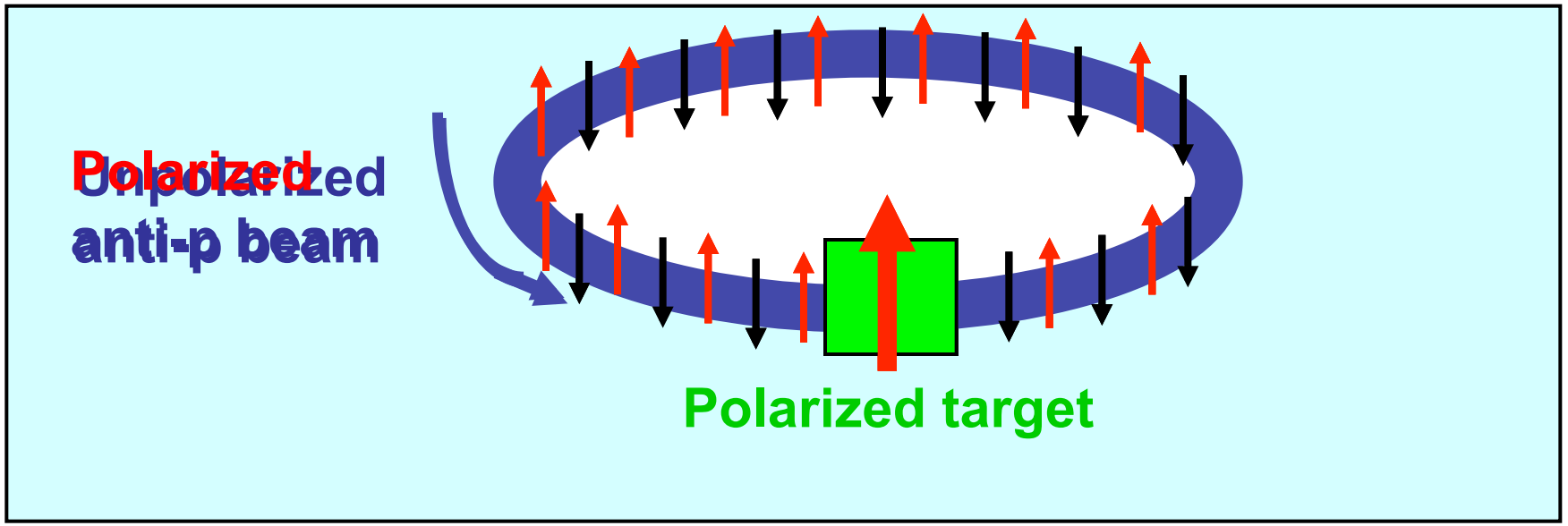
repeated passage through a polarized target in a storage ring:





Polarization Buildup

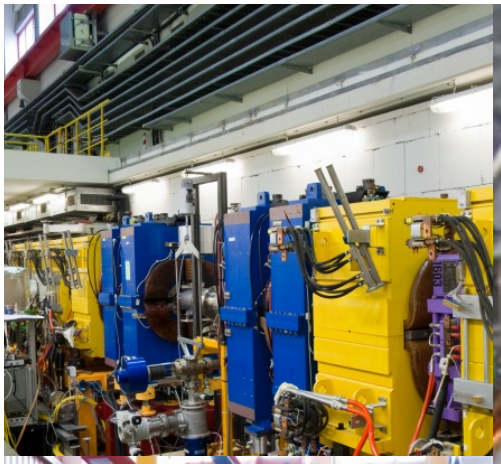


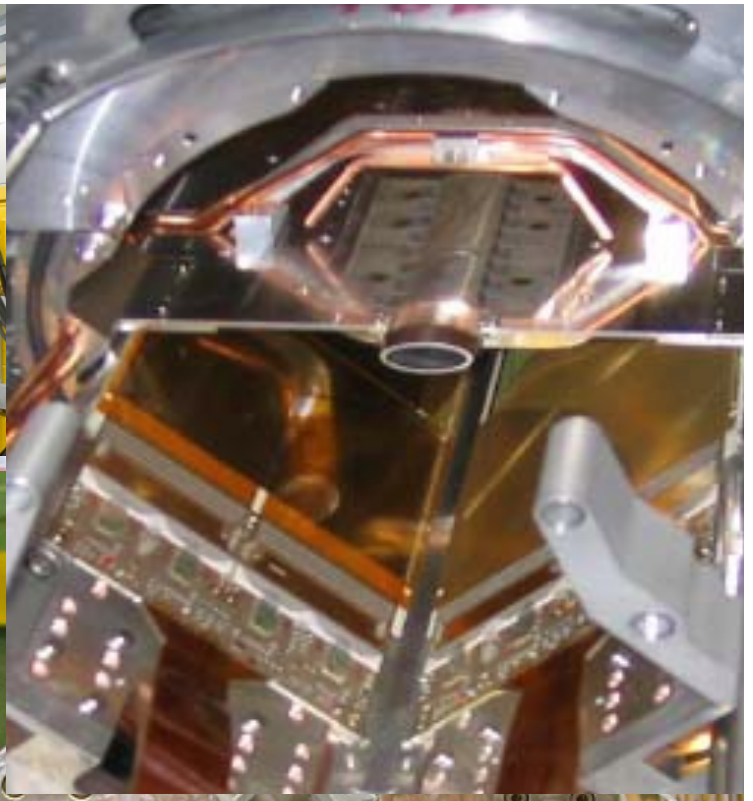


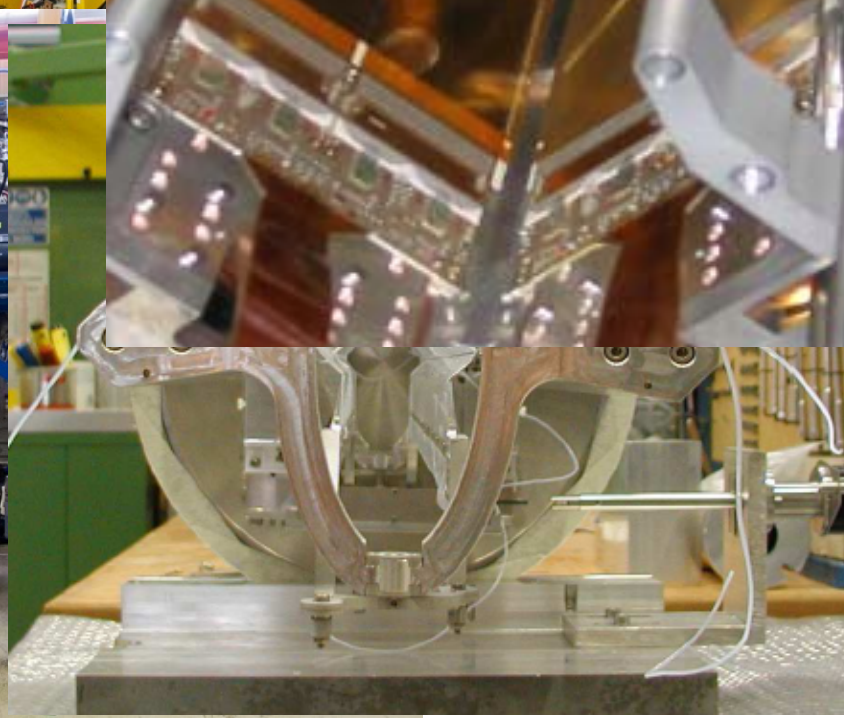
Spin-filtering studies at COSY

Experimental setup:

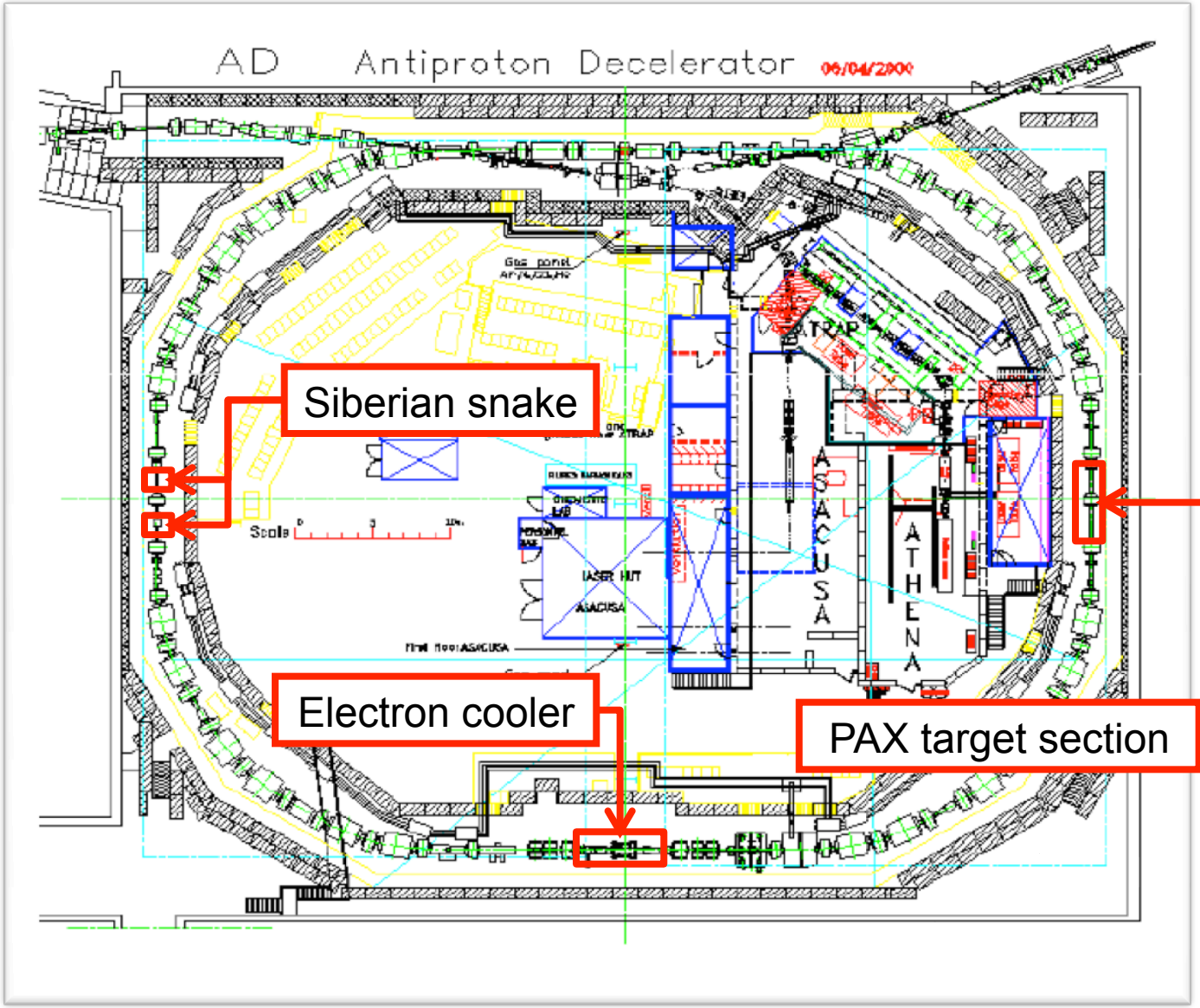
- low-ß section
- Atomic Beam Source
- Breit-Rabi polarimeter
- Openable storage cell
- Si tracking telescopes







PAX at the AD (the only place worldwide)



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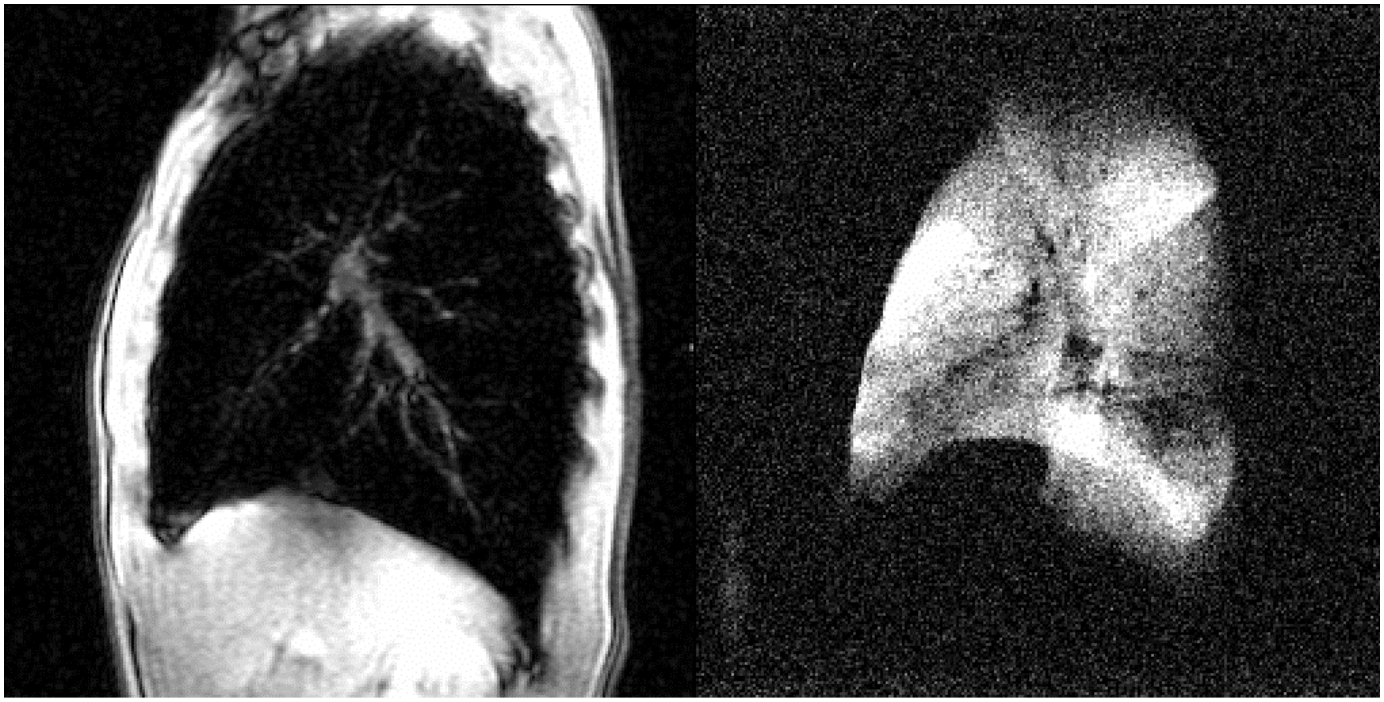
Polarized ^{3}He for NMR's of the human lung (Werner Heil)

Spin-Off of Polarized Gas Target Technology

Human Lung with 0.7 bar × liter of polarized ^{3}He



Proton - MRI (^{1}H)
DKFZ, HD Nov. 1995;

Helium - MRI (^{3}He)
Lancet 1996

$P_H \sim m \cdot B/kT$
$\sim 5 \cdot 10^{-6}$

$P_{He} \sim 1$

$\rho_H/\rho_{He} \sim 2500$

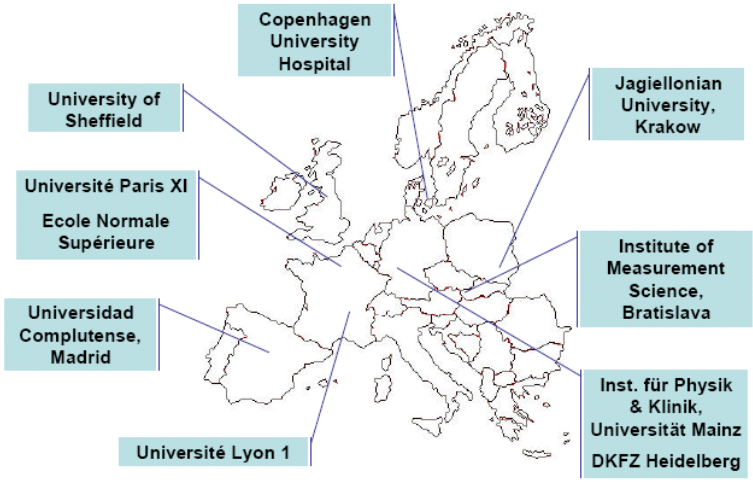
signal $P \cdot \mu \cdot \rho$
$S/S_H > 10$

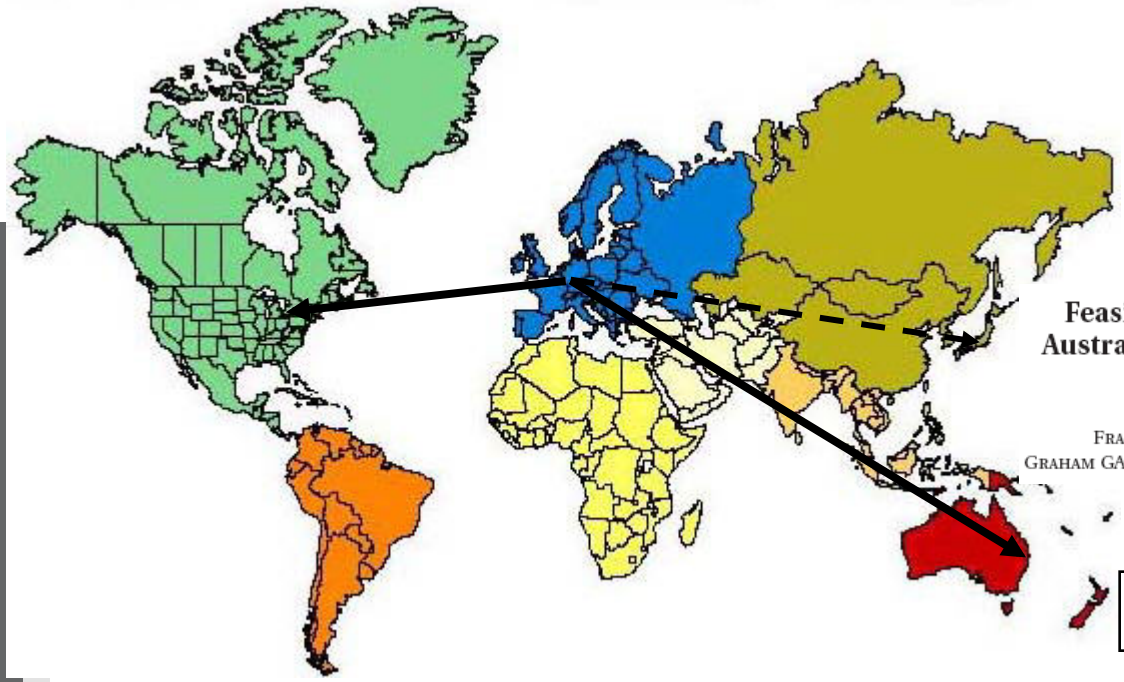
amount of gas:
1 bar · liter

Gas delivery to partners

Research & Training Network (RTN)
Marie Curie Actions
FP 6 (2007-2011)

PHeLINet
Polarized Helium Lung Imaging Network





Respirology (2008) 13, 599–602

Feasibility of functional magnetic resonance lung imaging in Australia with long distance transport of hyperpolarized helium from Germany

FRANCIS THIEN,[1] MARLIES FRIESE,[2] GARY COWIN,[2] DONALD MAILLET,[2] DEMING WANG,[2] GRAHAM GALLOWAY,[2] IAN BRERETON,[2] PHILIP J. ROBINSON,[3] WERNER HEIL[4] AND BRUCE THOMPSON[1]

≈ 100 shipments / year @ 500 bar·litres

Hyperpolarized ^{3}He administration

- volume-control:
  $\Delta V/V = 3\%$
- gas administration at predefined times during inspiration
- on-line polarimetry
- use of gas mixtures
  ($\vec{^3He}$,$\vec{^{129}Xe}$) , ($\vec{^3He}$,SF_6)
- gas recovery !!!
  (shortage of ^{3}He)

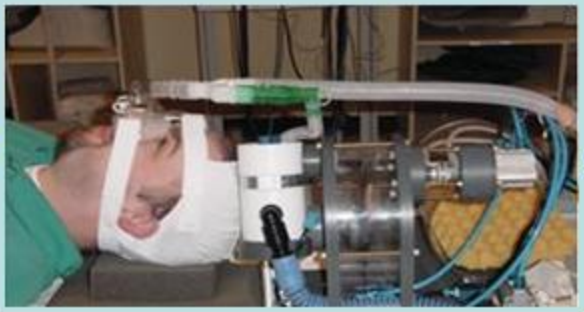
Techniques and practices for HP gas production and delivery

Central ^{3}He gas production facility

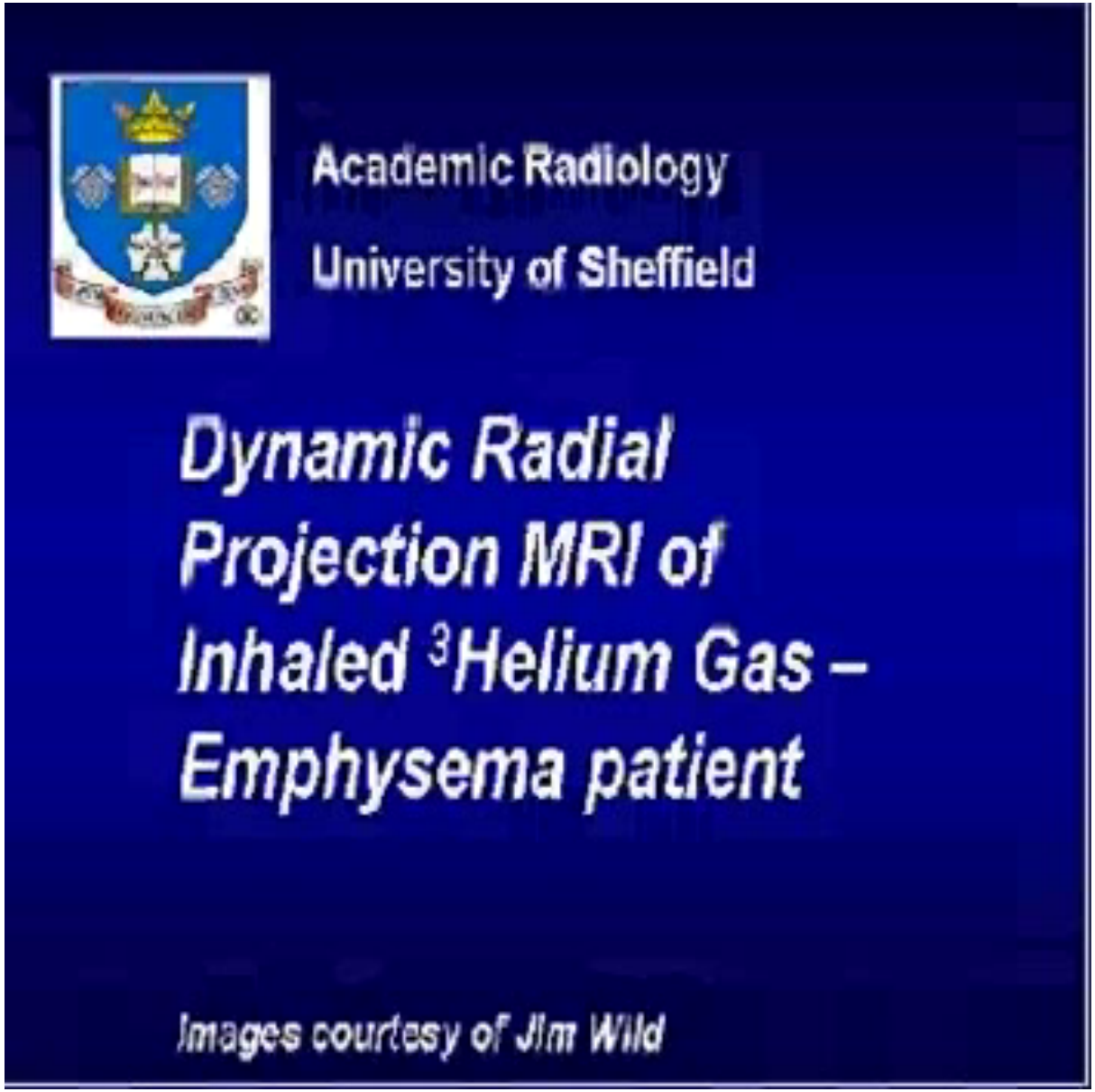
3He storage, transport, and polarimetry

^{3}He recovery

^{3}He administration



Functional NMR using ^{3}He



Georg Christoph Lichtenberg (1742-1799)

“Man muß etwas Neues machen, um etwas Neues zu sehen.”

**“You have to make (create) something new,
if you want to see something new”**

Polarized Antiprotons receive ERC Grant


European Research Council
Executive Agency

erc

a nice Xmas present

Brussels, 21/12/2009
ERC.C1 D(2009) / 602641

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Sent by electronic mail only

Programme "Ideas" - Call identifier: ERC-2009-AdG
Proposal No 246980 - POLPBAR

1584 ERC AdvG Proposals submitted

- 236 selected (15% success rate)
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