Polarized protons at HERA: the accelerator issues

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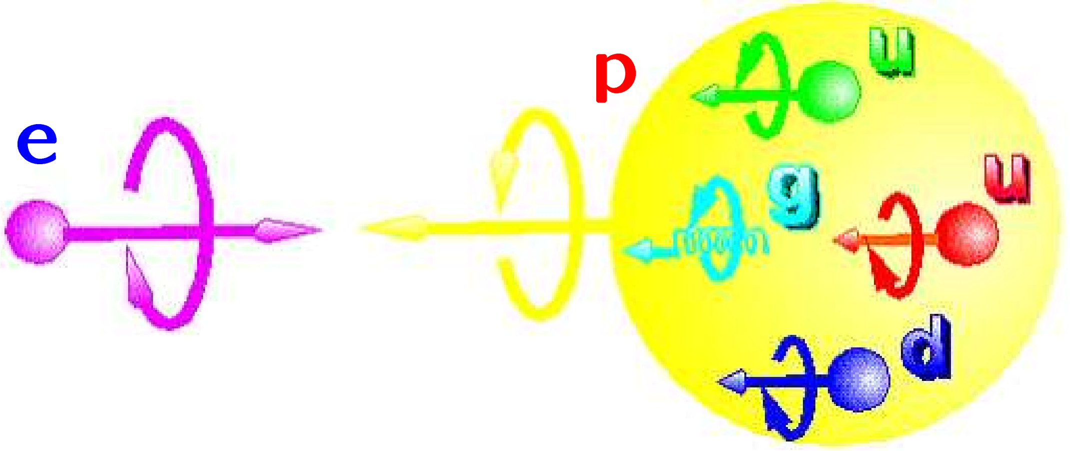
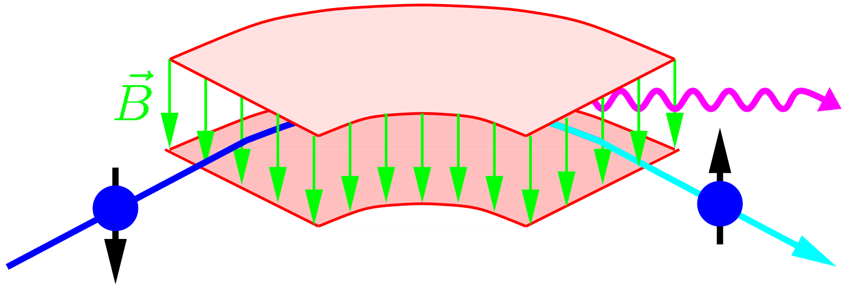
DESY, Hamburg

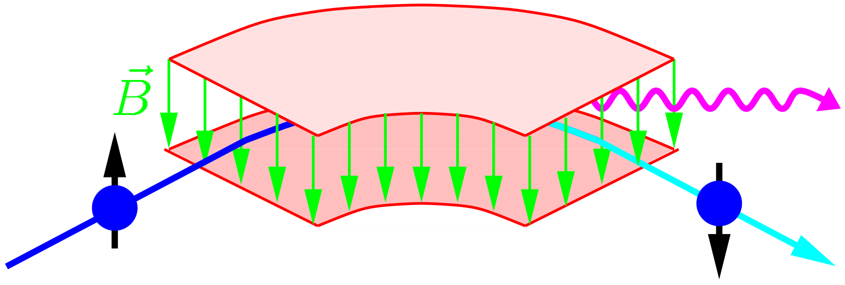


Logo of DESY 97-200

Selfpolarization of electrons

Every 10^{10}–th photon flips the spin of the electron.





in HERA every 38,5 minutes

in HERA every 16,2 hours

Idealized ring: Equilibrium polarization ≈ 92,38%.

HERA : routine running 60% polarization.

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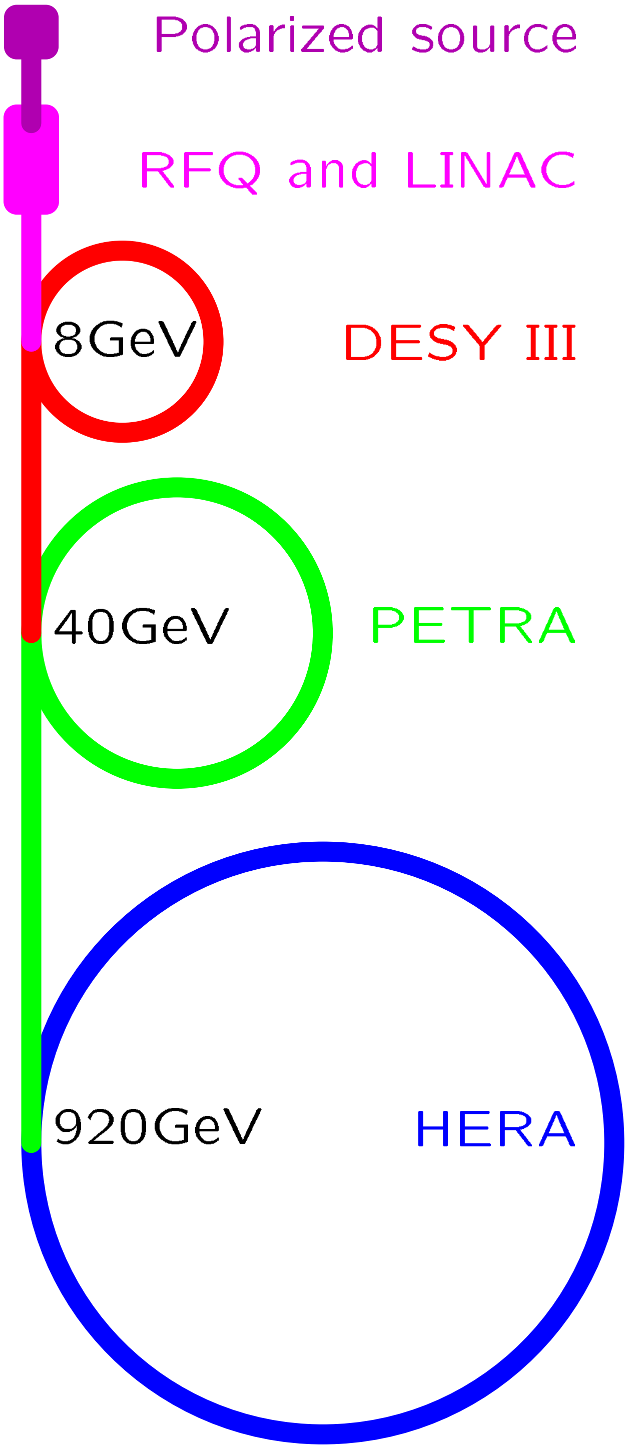
Polarized protons at DESY



Polarized source

RFQ and LINAC

8GeV

DESY III

40GeV

PETRA

920GeV

HERA

Challenges:

- Polarized 20mA H^- source
- Acceleration
- Storage at 920 GeV
- Polarimetry

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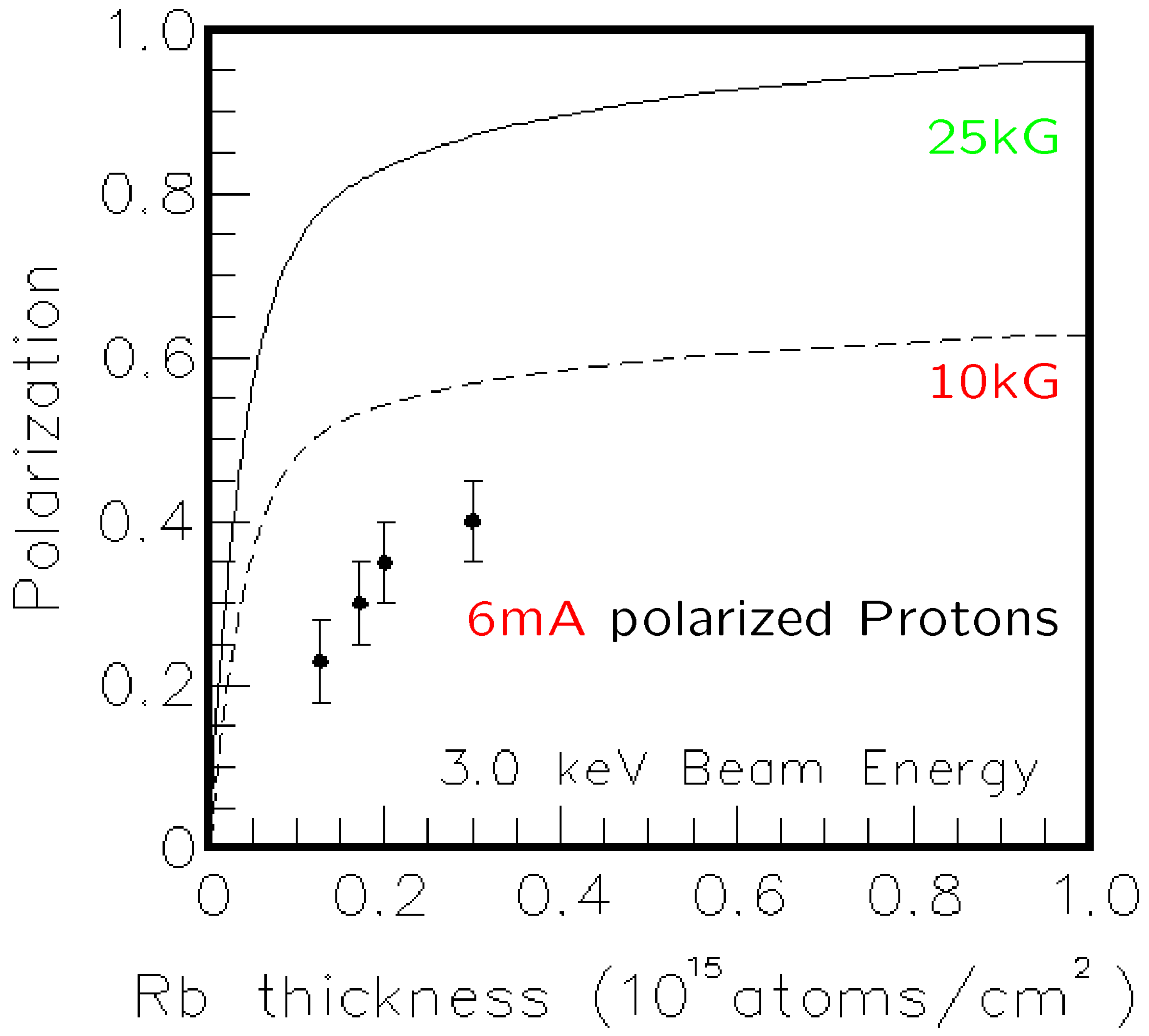
Polarized H^- source



Potential for higher polarization and for higher current.

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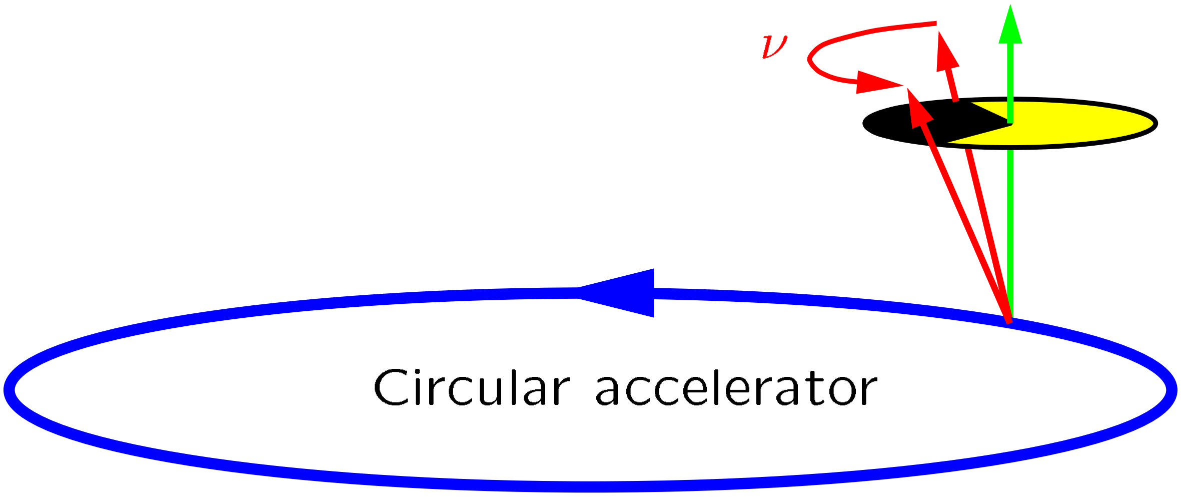
Spintune and spinkick

$$\frac{d\vec{p}}{dt} = (\frac{-q}{m\gamma})\{ \qquad \vec{B}_\perp \qquad \} \times \vec{p}$$

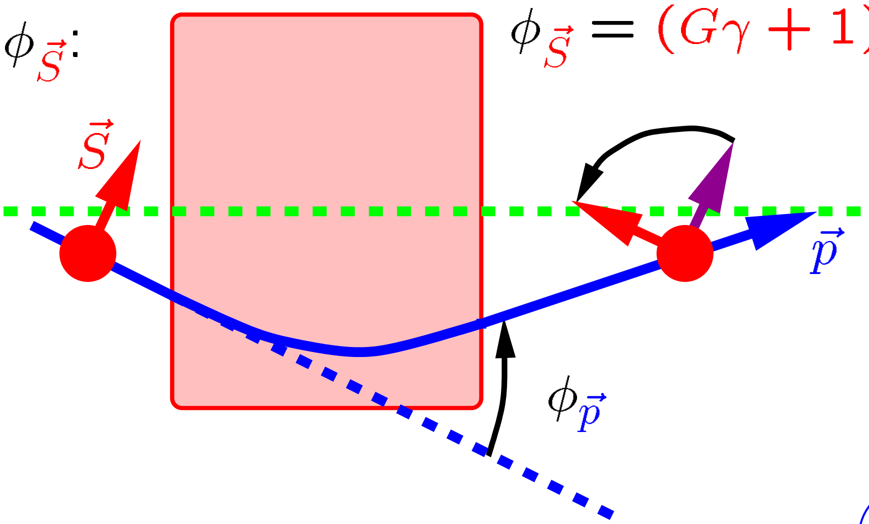
$$\frac{d\vec{S}}{dt} = (\frac{-q}{m\gamma})\{(G\gamma + 1)\vec{B}_\perp + (1+G)\vec{B}_\| \} \times \vec{S}$$


ν
Circular accelerator

Spintune ν: Number or spin rotations per turn, 1758 at 920GeV.

Spinkick $\phi_{\vec{S}}$:

$$\phi_{\vec{S}} = (G\gamma + 1)\phi_{\vec{p}}$$


$\vec{S}$
$\vec{p}$
$\phi_{\vec{p}}$

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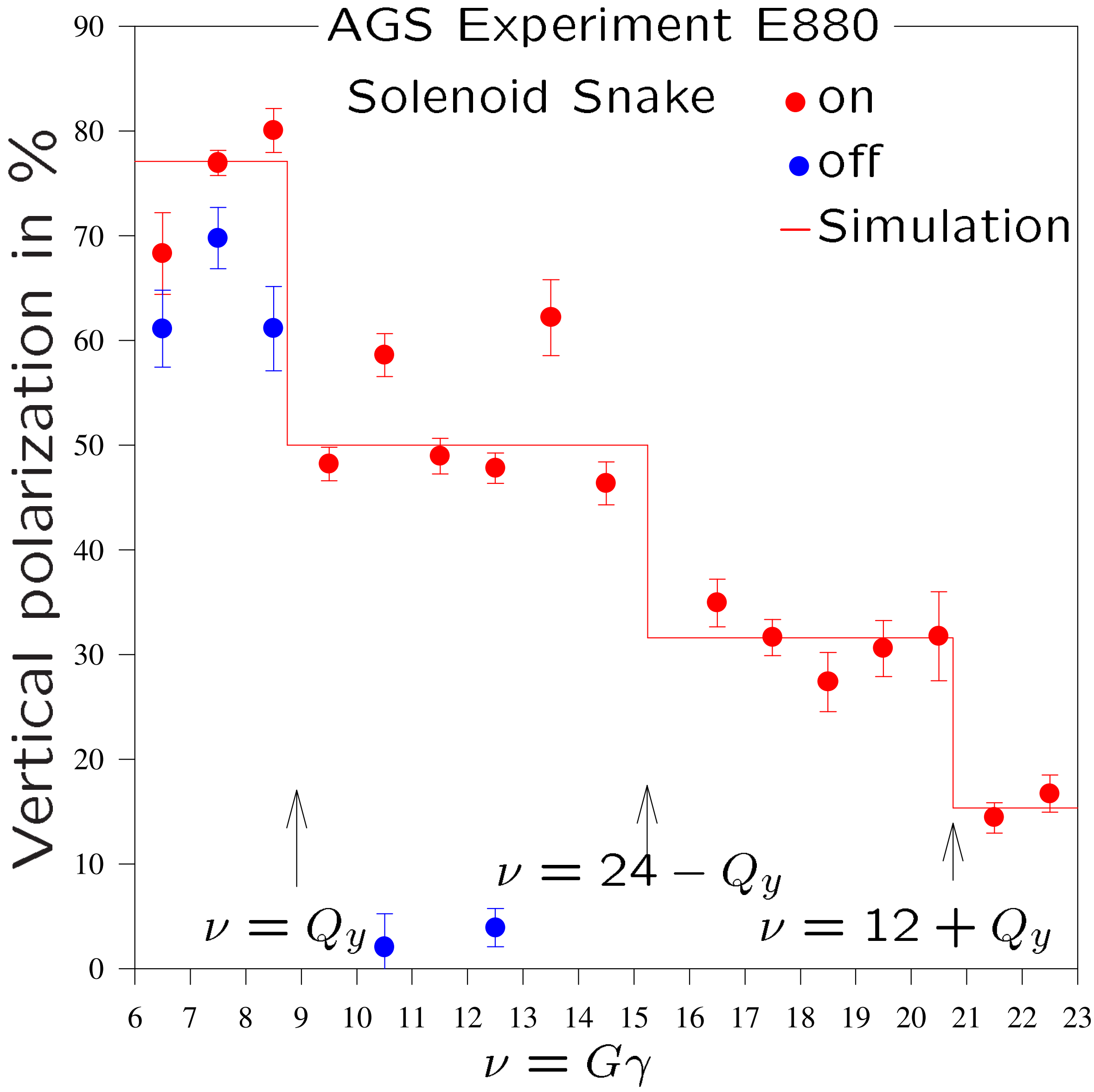
Imperfection Resonances

Integer spin tune: Spins have the same orientation every turn - disturbances accumulate.

Remedy: Controlled spin disturbance (Snake)



courtesy T. Roser

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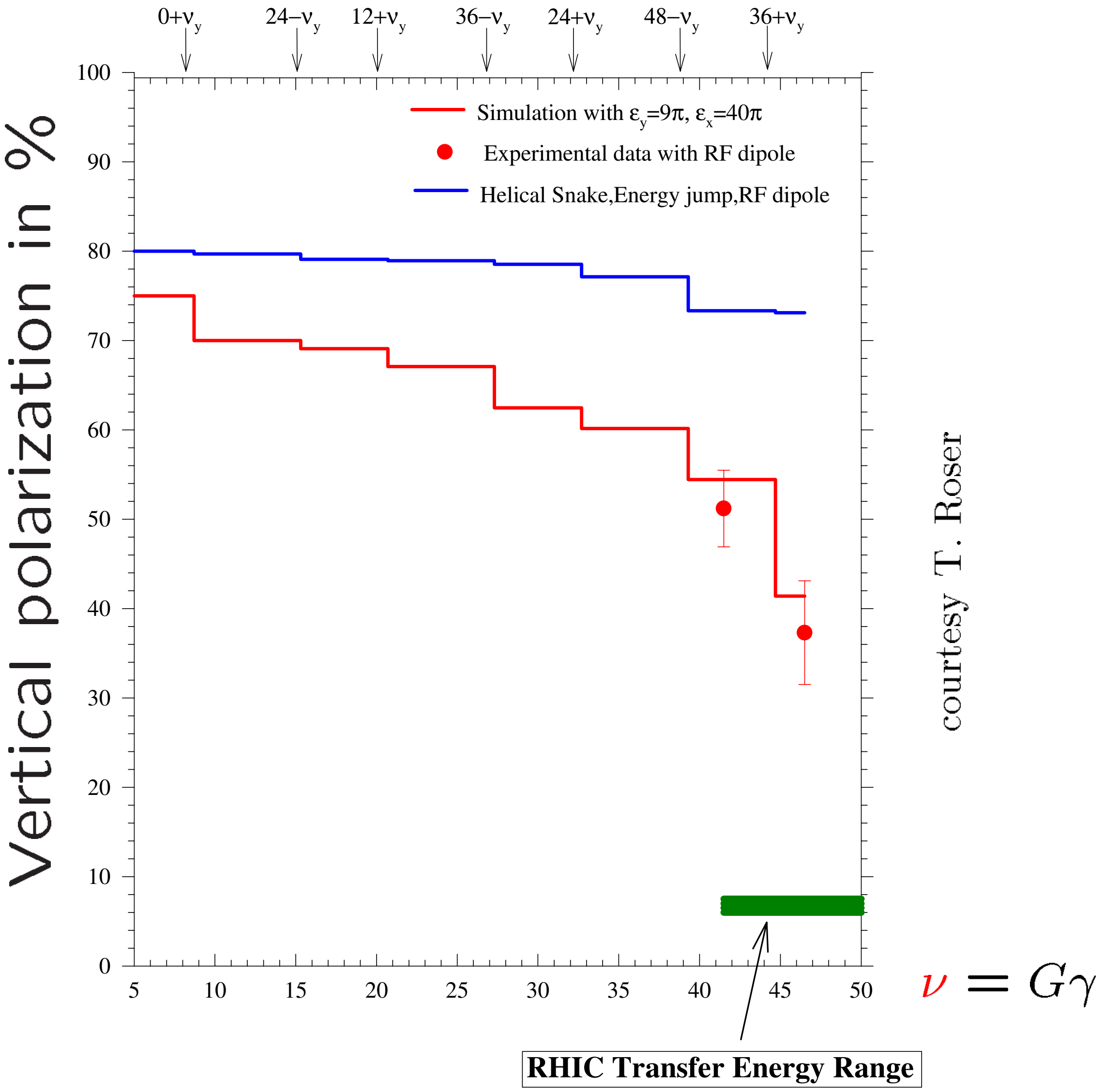
Crossing resonances

Remedy for DESY III: Tune jump, Energy jump, and RF dipole excitation

AGS Experiment E880



Remedy for PETRA and HERA: Fixing the spin tune $\nu = \frac{1}{2}$ by Siberian Snakes.

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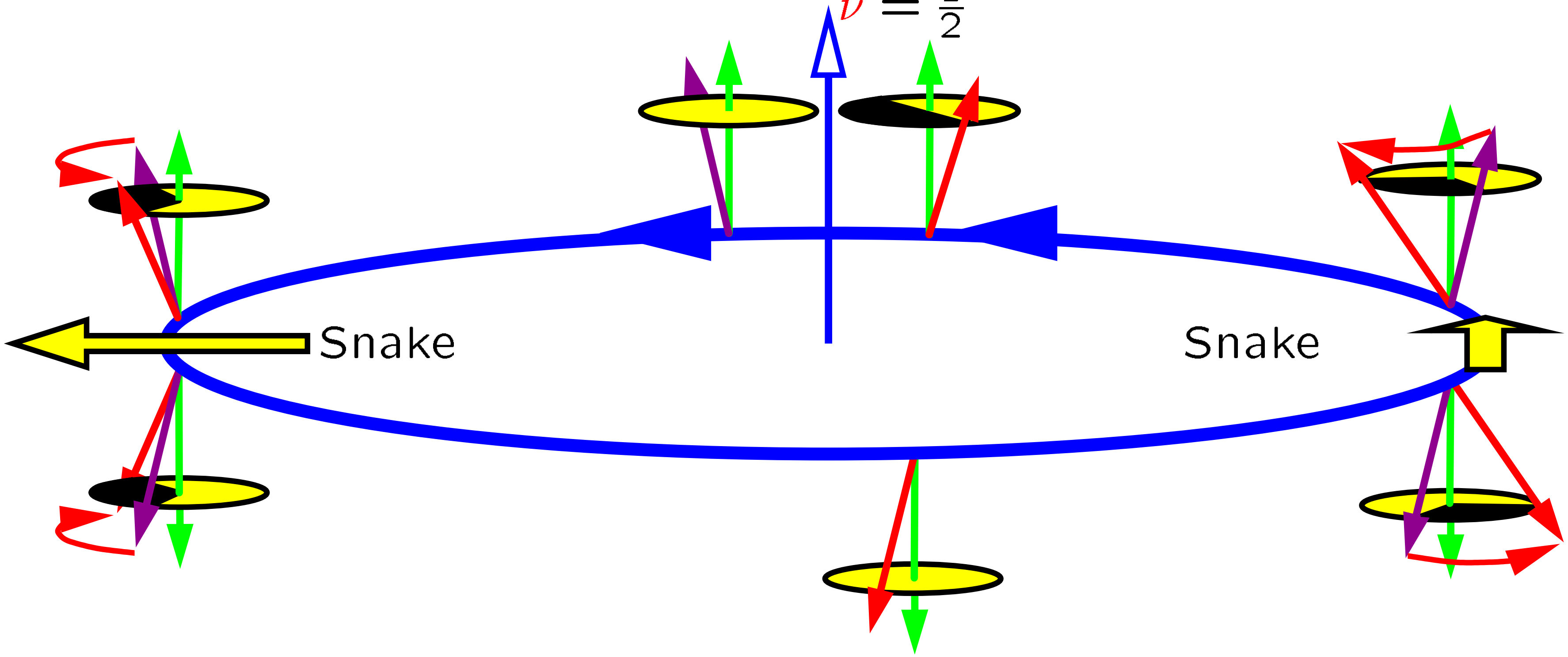
Siberian Snakes

Siberian Snakes rotate spins at all energies by $\frac{1}{2}$.


$\nu = \frac{1}{2}$
Snake
Snake

Freedom: Direction of rotation axis in the horizontal plane

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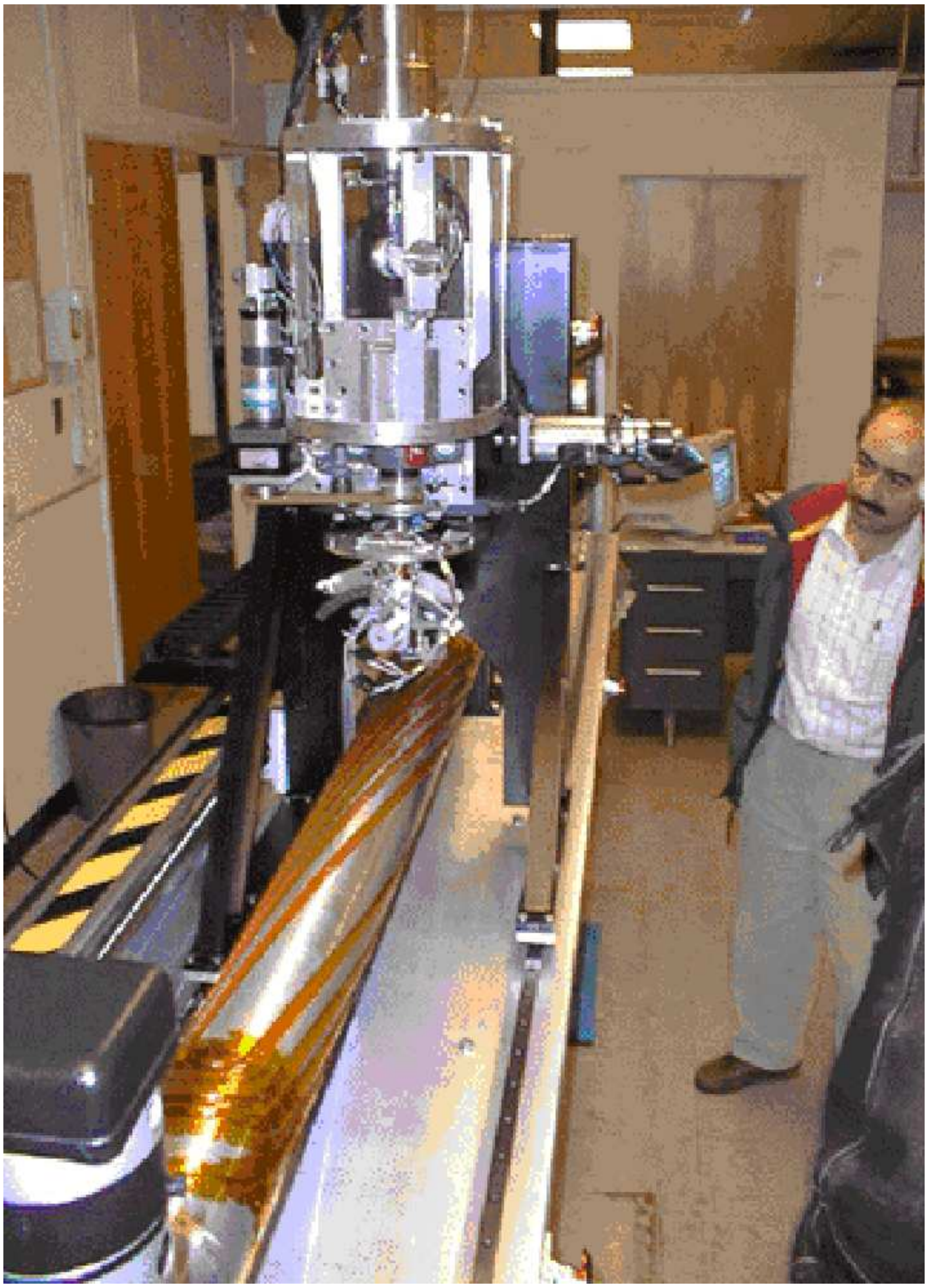
Helical Siberian Snakes

$$\frac{d\vec{p}}{dt} = \left(\frac{-q}{m\gamma}\right)\{\quad \vec{B}_\perp \quad\} \times \vec{p}$$

$$\frac{d\vec{S}}{dt} = \left(\frac{-q}{m\gamma}\right)\{(G\gamma+1)\vec{B}_\perp + (1+G)\vec{B}_\parallel\} \times \vec{S}$$



http://ad1.ags.bnl.gov/ rhicspin/images/Winder.jpg

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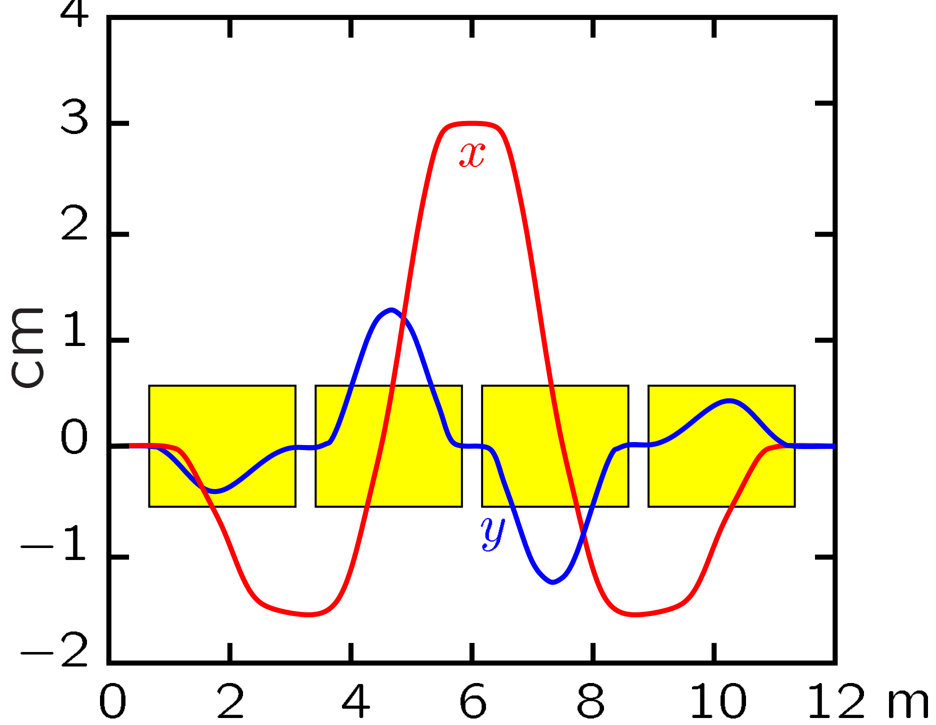
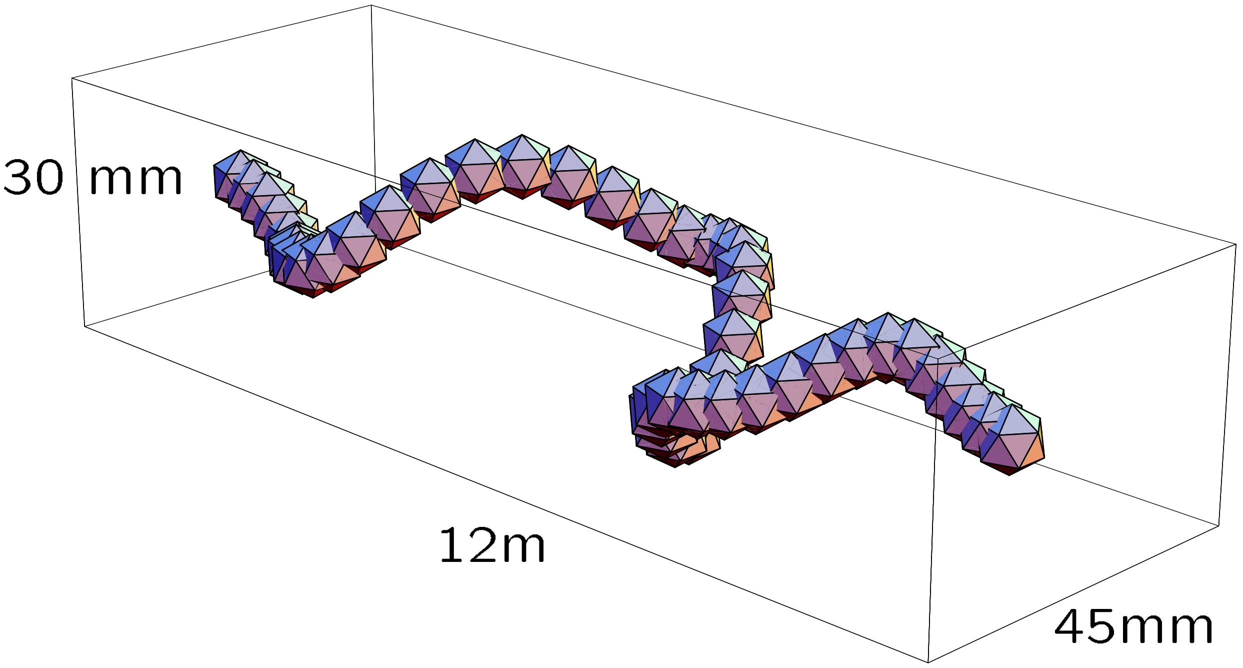
Orbit motion in RHIC type Siberian Snakes

At 25GeV




30 mm
12m
45mm

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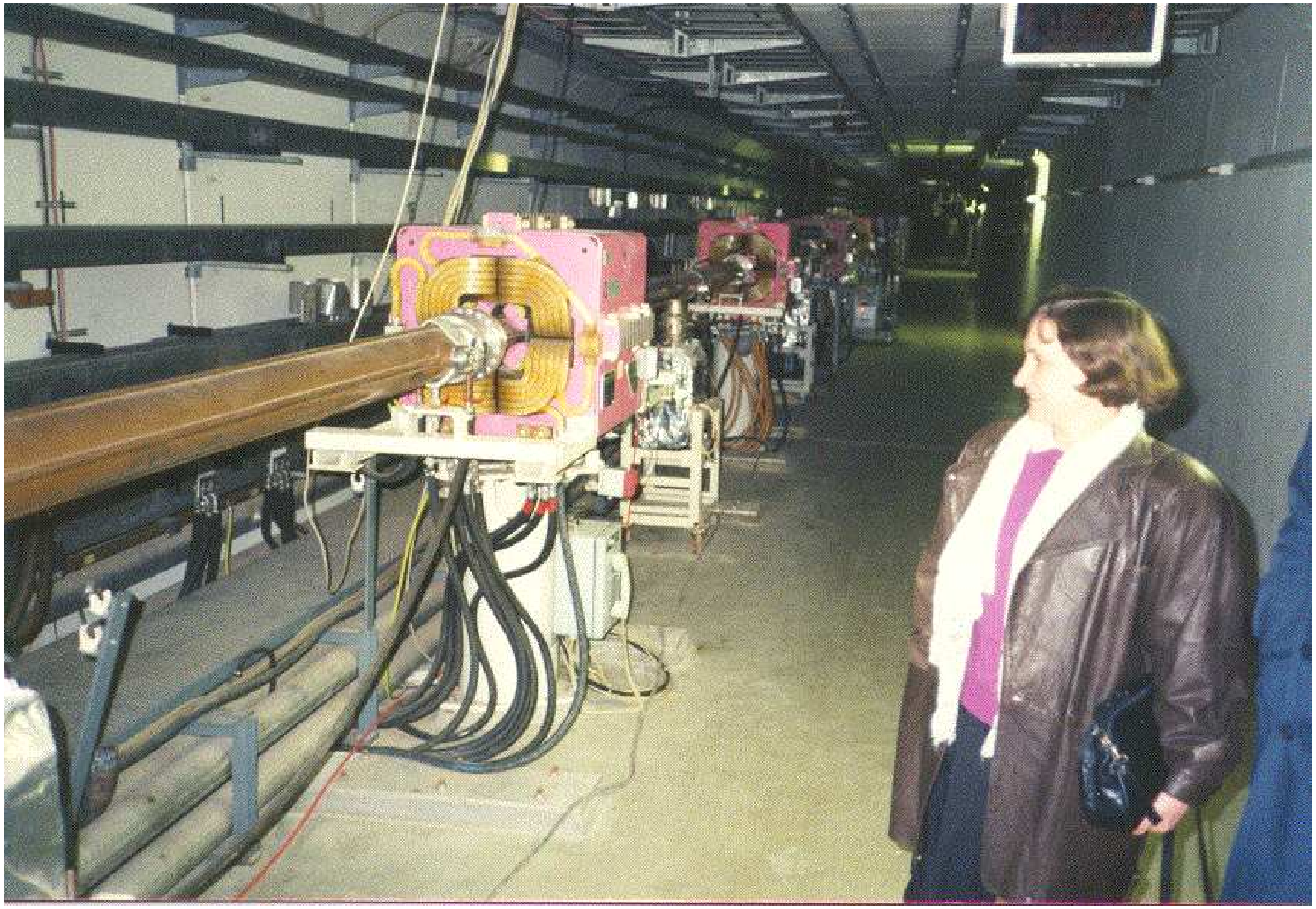
Space for Siberian Snakes in PETRA



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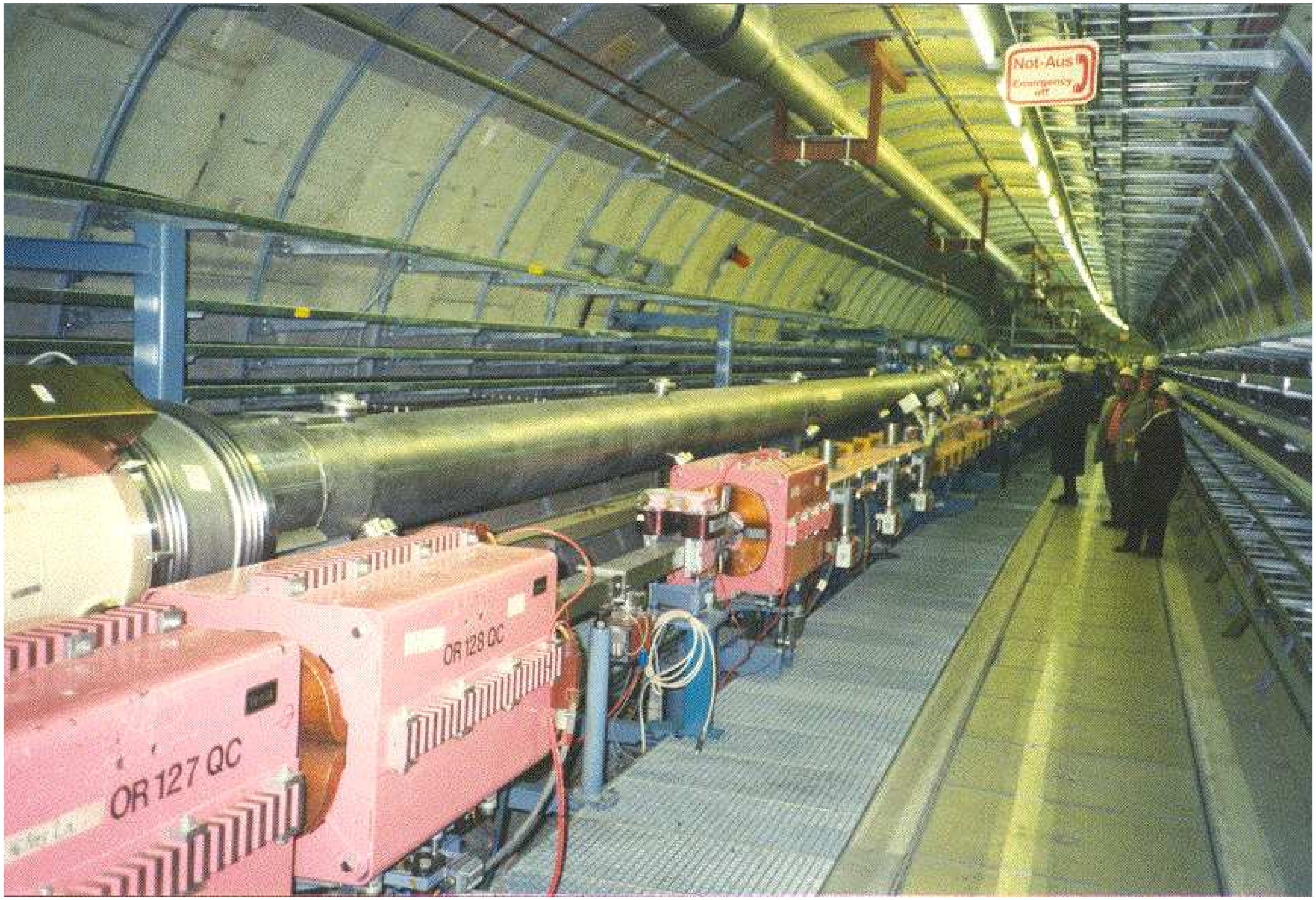
Space for Siberian Snakes in HERA


Not-Aus
Emergency off
OR 128 QC
OR 127 QC

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Difficulties for polarized protons in HERA

- No perfect symmetry
- Vertical bends (Remedy: Flattening Snakes)
- Not build for polarization
- Hardly space for more than 4 Siberian Snakes
- Very high energy (920GeV) and spin tune (ν=1758)

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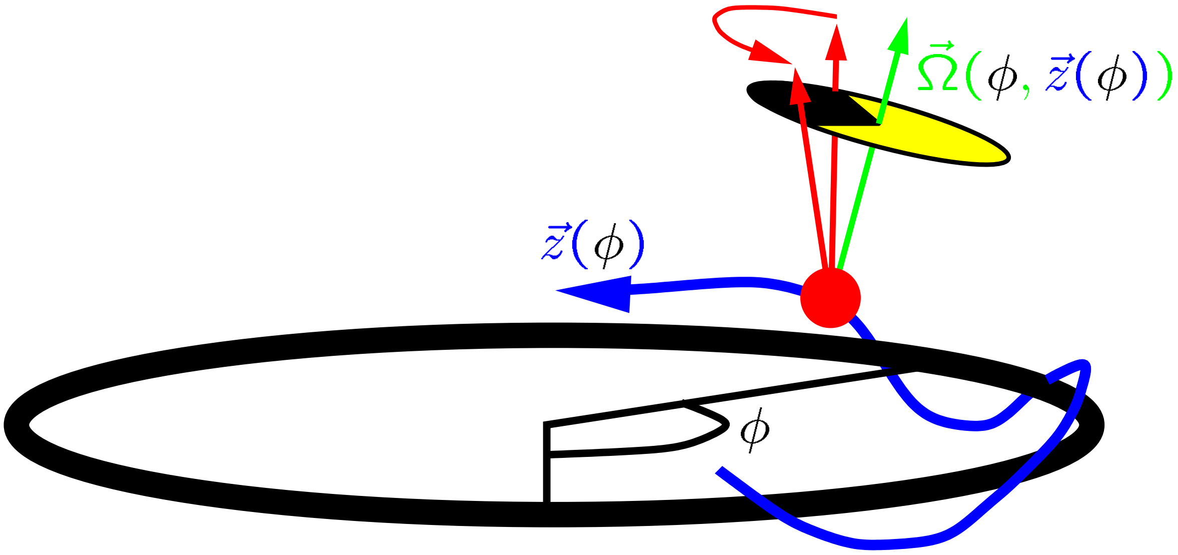
Isolated resonance model


$\vec{\Omega}(\phi,\vec{z}(\phi))$
$\vec{z}(\phi)$
ϕ

$$\vec{S}' = \vec{\Omega}(\phi,\vec{z}(\phi)) \times \vec{S}$$

Approximation: all but one dominant Fourier component of $\vec{\Omega}(\phi,\vec{z}(\phi))$ are neglected.

Is this theory still applicable at

HERA	920GeV

???

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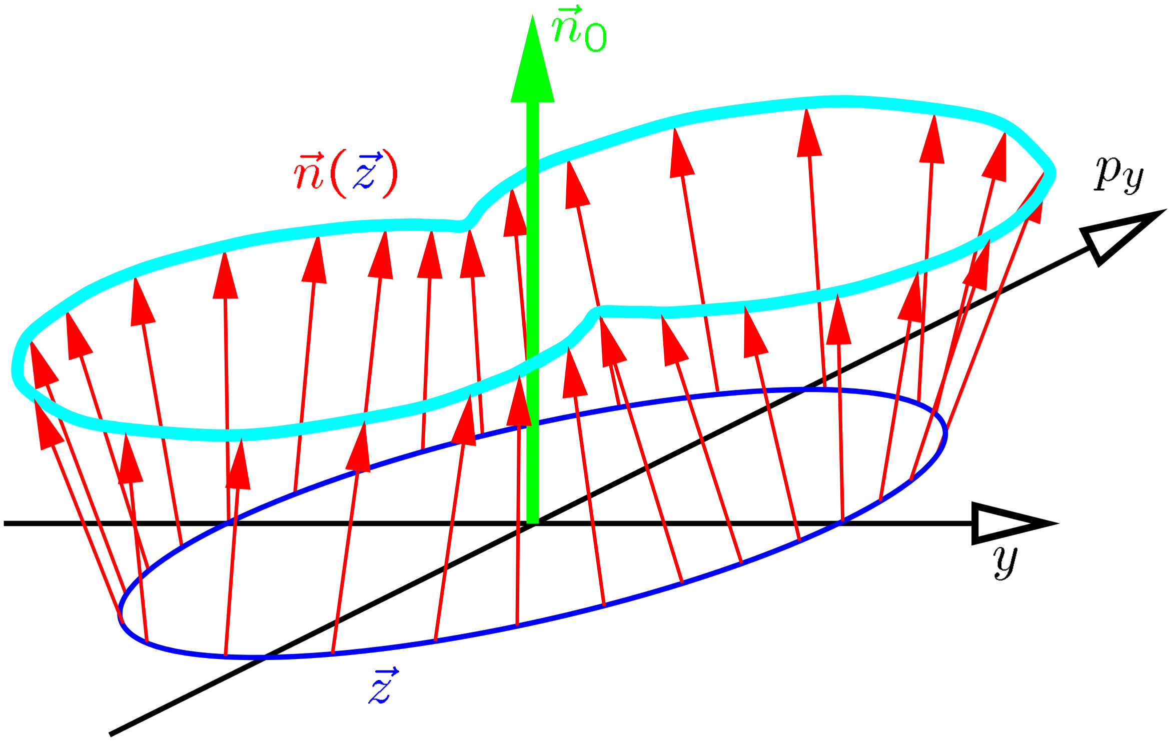
Significance of the $\vec{n}$–axis



Maximal polarization: $< \vec{n}(\vec{z}) >_{\text{phase space}}$

Divergence: $\sphericalangle\{\vec{n}(\vec{z}), \vec{n}_0\}_{\text{phase space}}$

At large divergence, the average polarization is small, even at 100% local polarization.

Linearized $\vec{n}(\vec{z})$ can easily be calculated.

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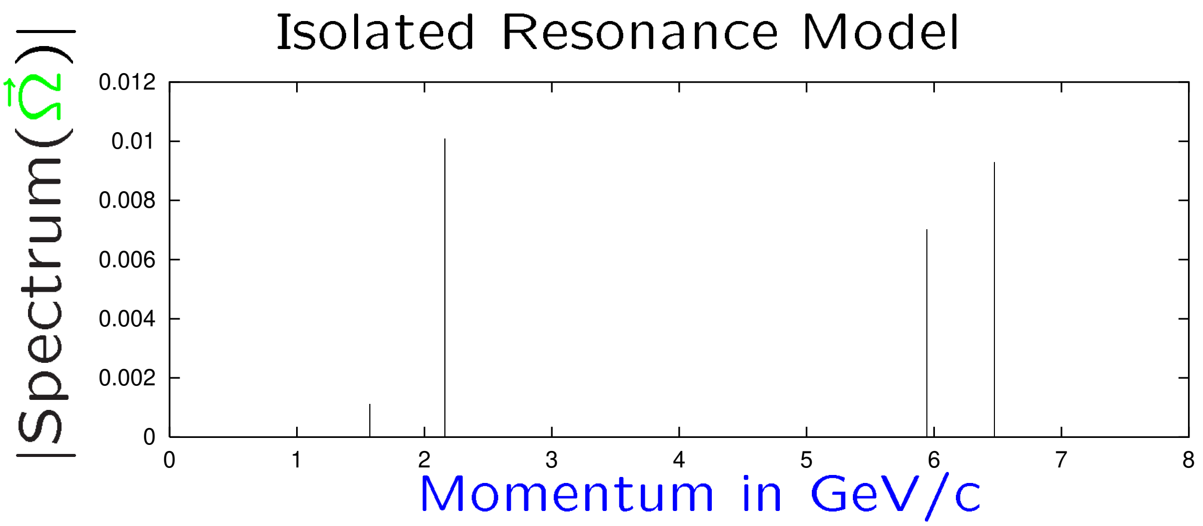
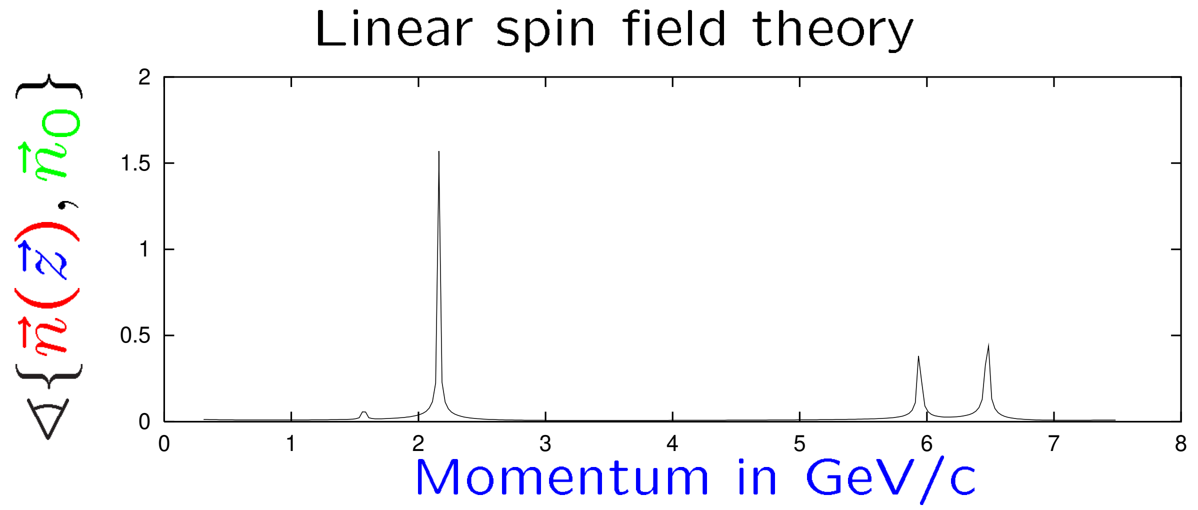
First order theory

A) DESY III


Isolated Resonance Model


Linear spin field theory

Low energy: First order theories agree.

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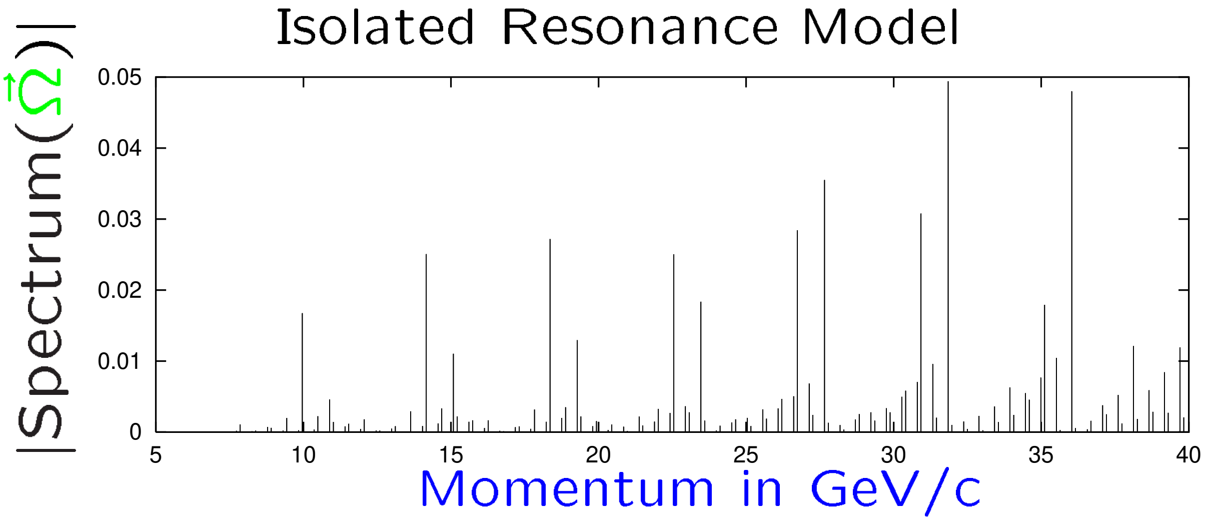
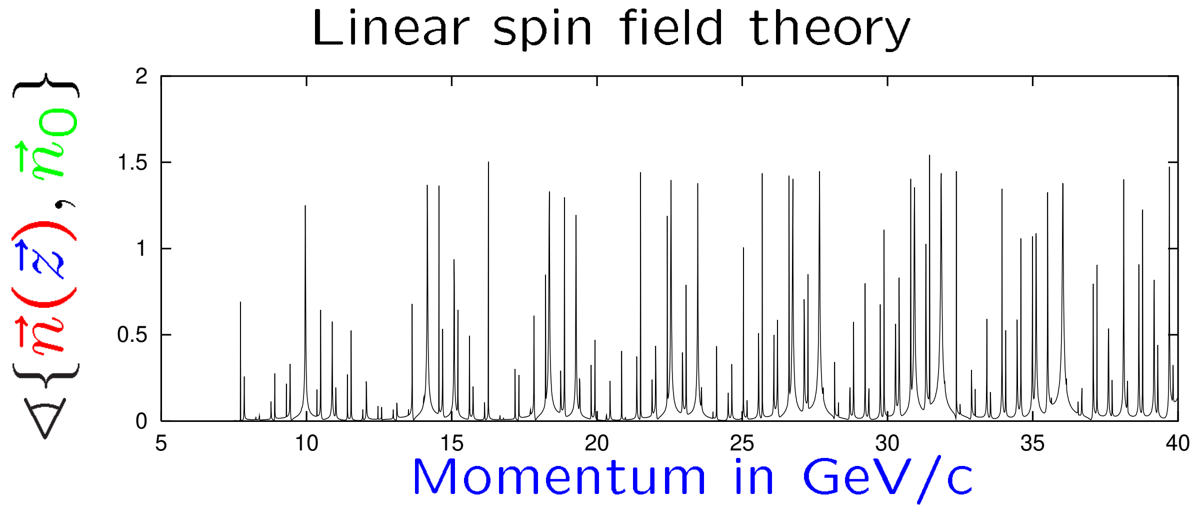
First order theory

B) PETRA





Medium energy: Resonances are
barely isolated

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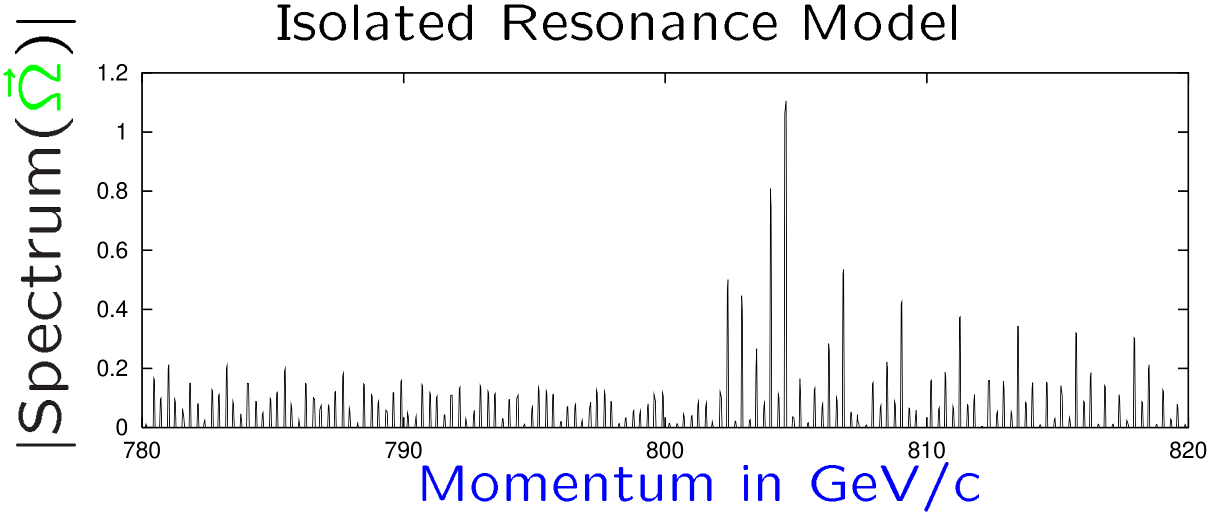
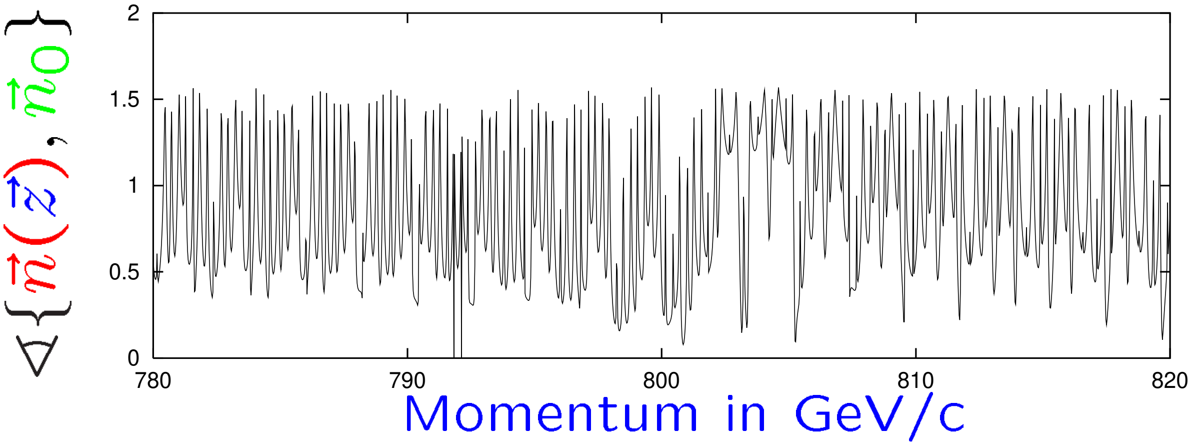
First order theory

C) HERA

Isolated Resonance Model



Linear spin field theory



High energy: Resonances are not isolated.

The Isolated Resonance Model looses applicability.

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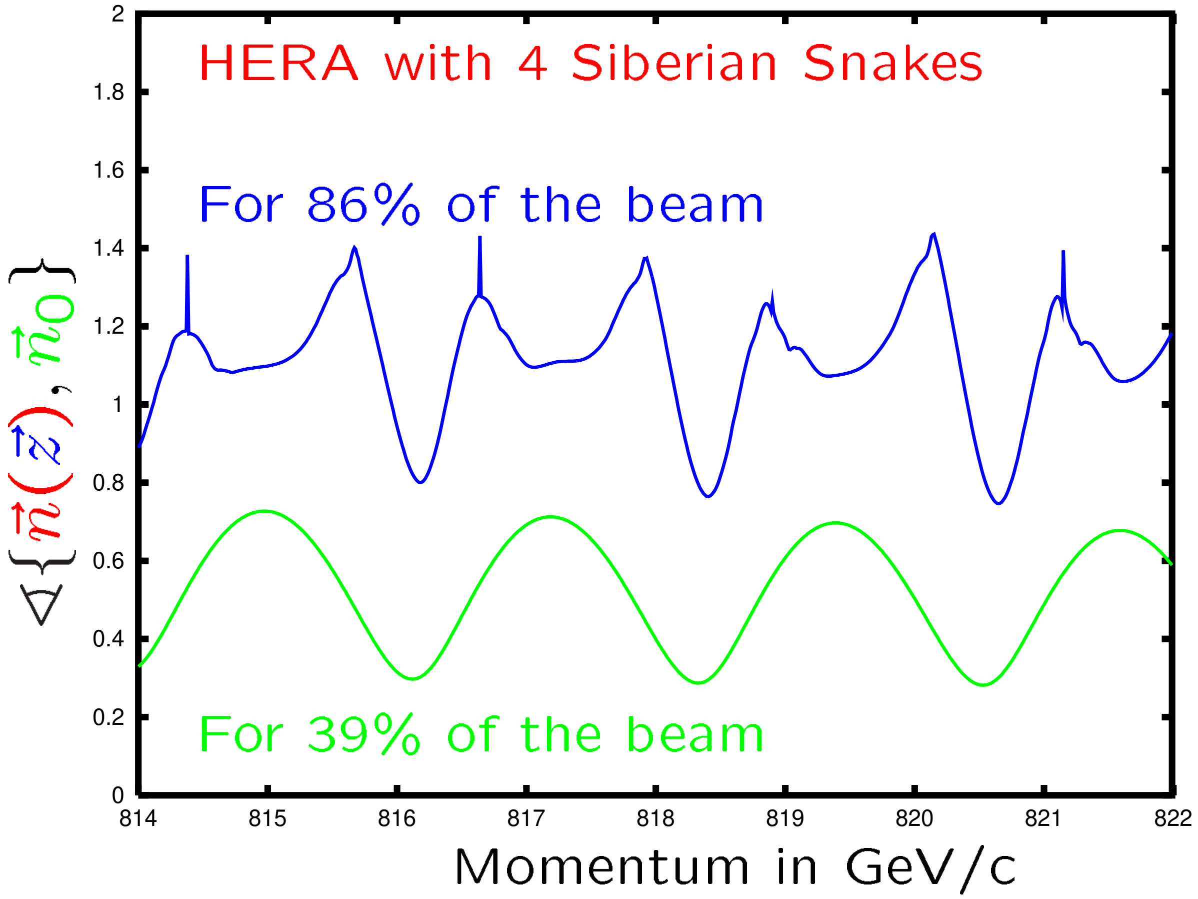
Higher order effects

- Overlapping resonances
- Amplitude dependent spin tune
- Nonlinear spin transport matrix $\vec{A}(\vec{z})$
- Deformation of the invariant spin field
- Higher order resonances



Siberian Snakes avoid first order resonances.
Higher order resonances become visible.

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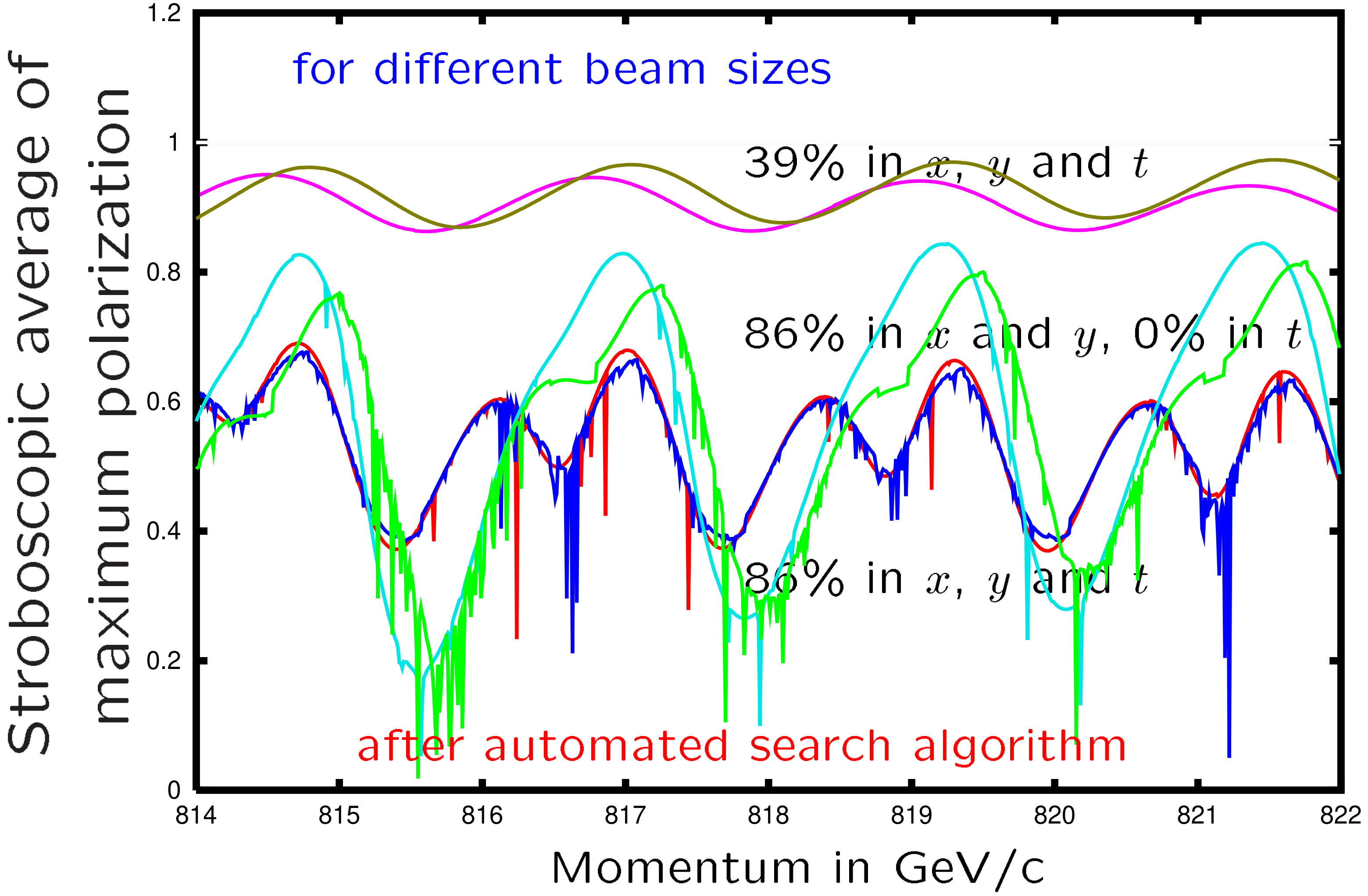
Maximum polarization



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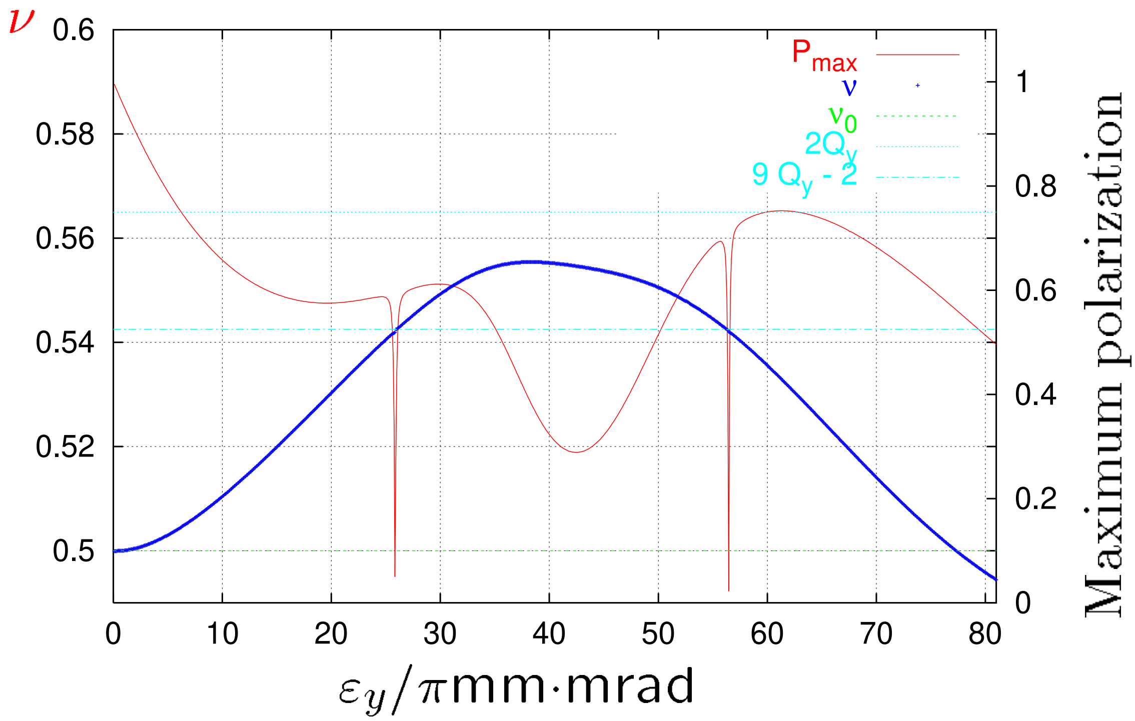
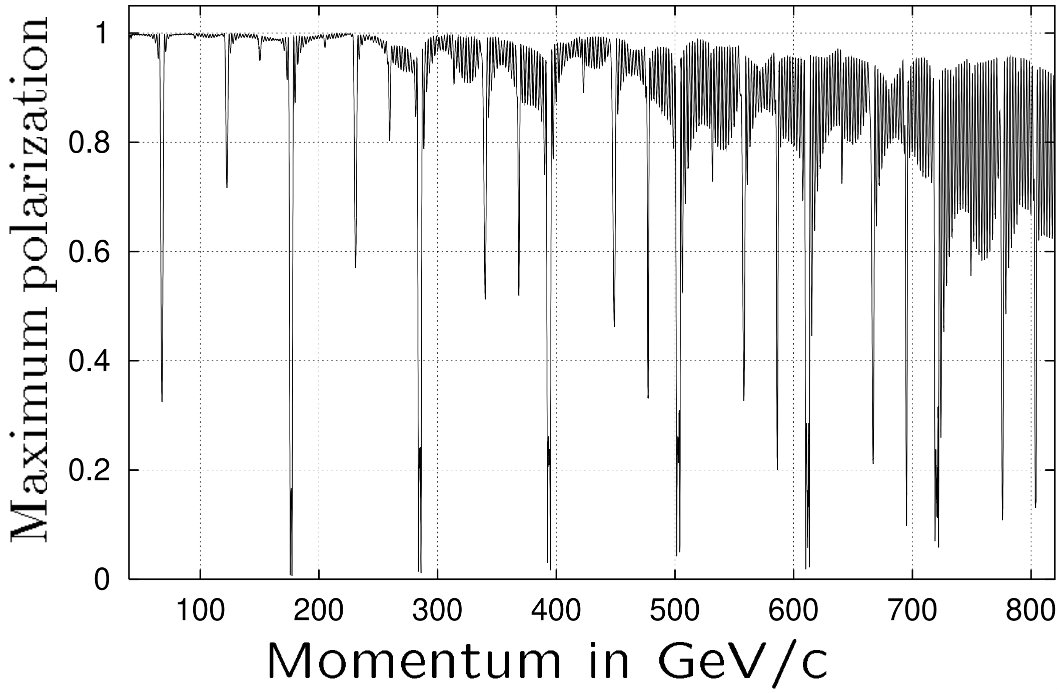
Amplitude dependend spin orbit resonances



Acceleration of $2\sigma_x/2\sigma_y/2\sigma_\tau$



courtesy M. Vogt

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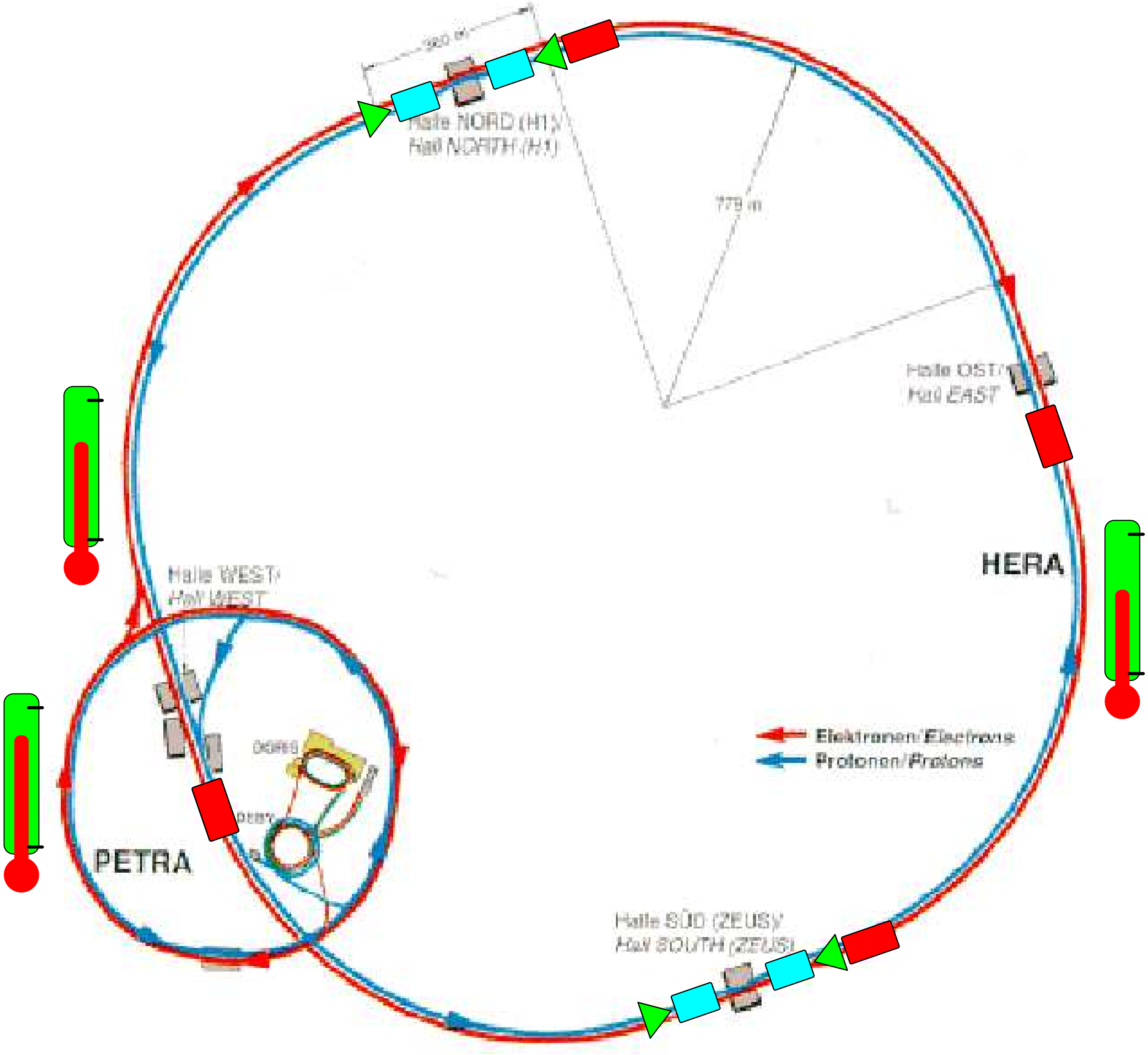
Required instalations in HERA


380 m
Halle NORD (H1)/
Hall NORTH (H1)
779 m
Halle OST/
Hall EAST
HERA
Halle WEST/
Hall WEST
DORIS
DESY
PETRA
Elektronen/Electrons
Protonen/Protons
Halle SÜD (ZEUS)/
Hall SOUTH (ZEUS)

- Polarimeters
- Flattening Snakes
- Spin rotators
- At least 4 Siberian Snakes

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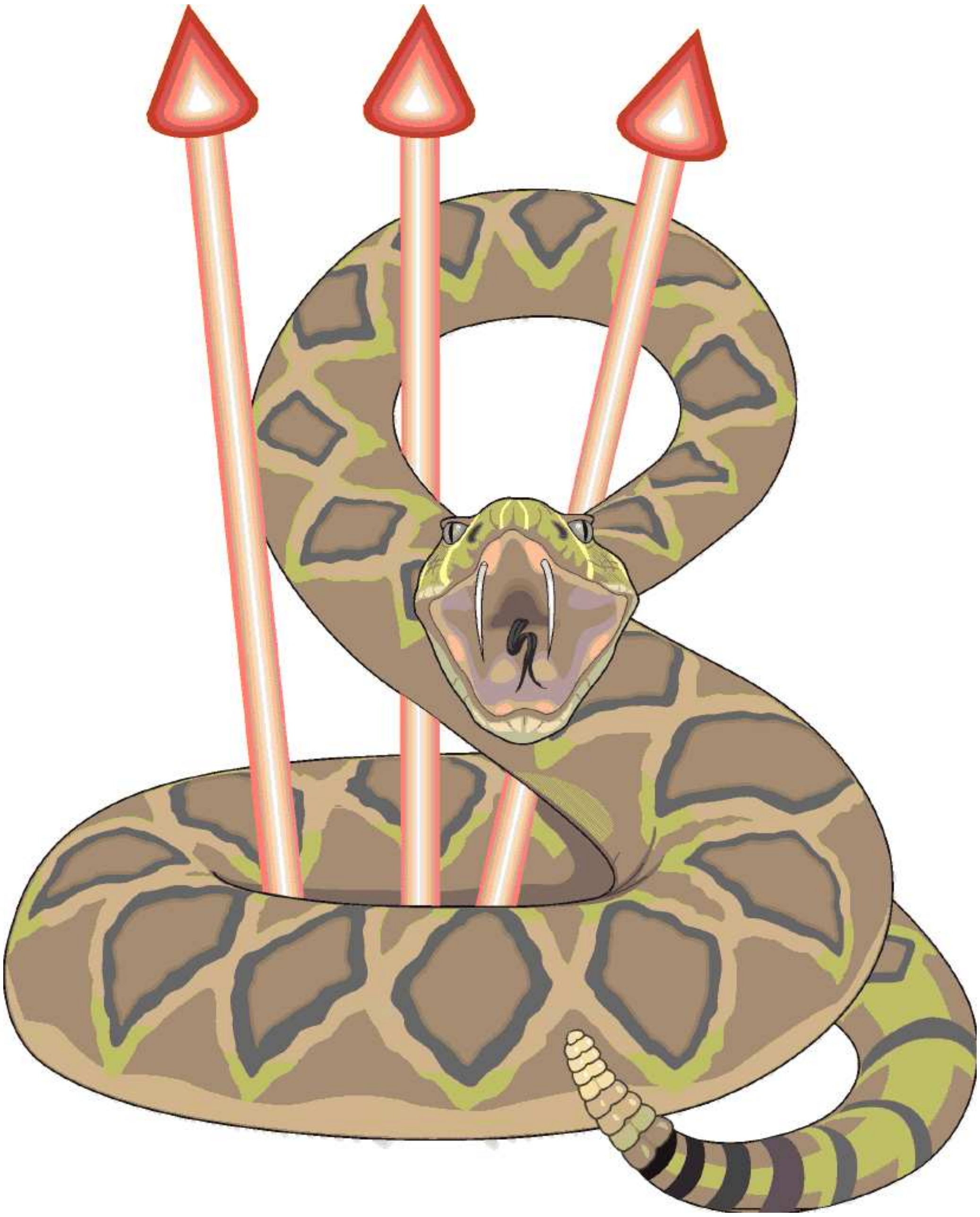
More information



http://www.desy.de/~hoff/proton_pol/

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