HERA:
Electron-Proton-Collider
with Double Polarization?

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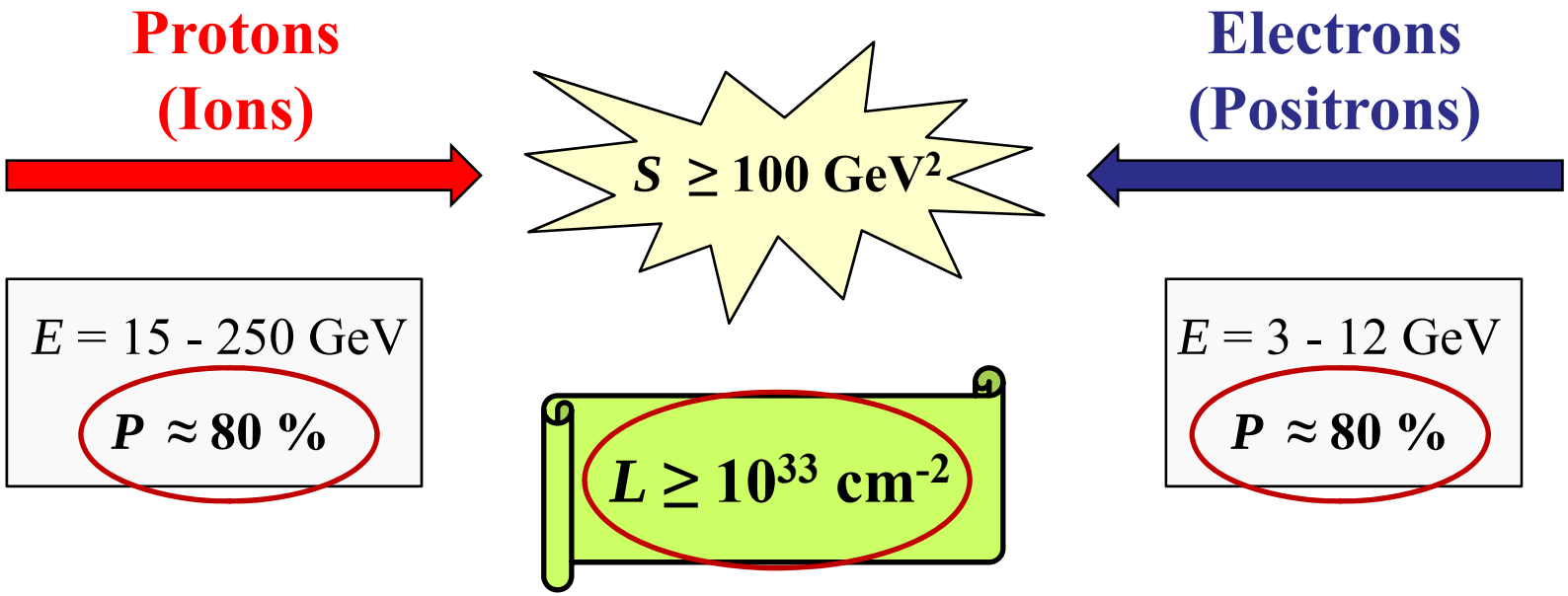
What shall we do with HERA?
„Experimental“ Particle Physics at DESY?

Presentation of an idea – not a concept!

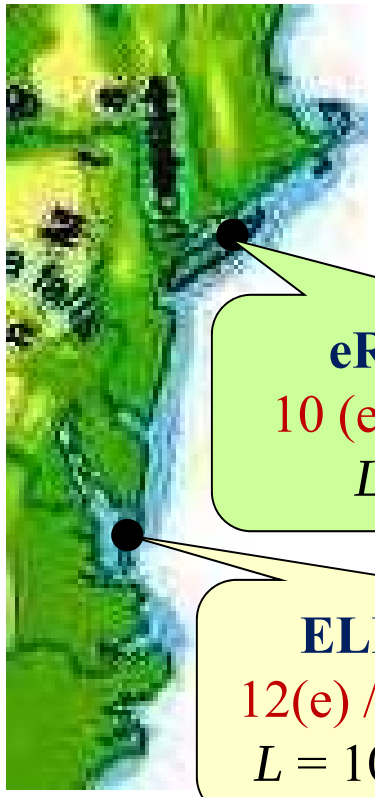
Electron-Ion-Collider

Experimenters Wish List:



ELIC, eRHIC, LeHC, ENC

EIC-Projects:



HERA@DESY:
???

LeHC@CERN
20-140 GeV / 7 TeV
$L \approx 10^{33}$ cm^{-2}

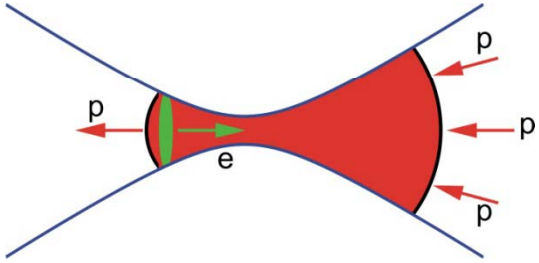
eRHIC@BNL
10 (e) / 250 (p) GeV
$L \approx 10^{33}$ cm^{-2}

ELIC@JLab
12(e) / 250 (p) GeV
$L = 10^{33}$-10^{35} cm^{-2}

ENC@GSI
3 (e) / 15 (p) GeV
$L < 10^{33}$ cm^{-2}

Challenges

Luminosity: $L = h \cdot f_{coll} \cdot \frac{n_p \cdot n_e}{2 \cdot \pi \cdot \left(r_e^2 + r_p^2\right)} \cdot F_{HGR}$



Limiting Parameters:

- Space Charge (Laslett) Tune Shift:

$$\Delta Q_{sc} = \frac{e}{8\pi^2 \varepsilon_0 m_p} \cdot \frac{1}{\beta_p^2 \cdot \gamma_p^3} \cdot \frac{L_p}{l_p} \cdot \frac{n_p}{\varepsilon_p} < 0.1$$

- Intrabeam-Scattering (IBS):

$$l_p > 10\text{cm}$$

- Beam-Beam Parameters:

Electrons: $\xi^e = \frac{r_{0,e}}{4\pi} \cdot \frac{n_p}{\gamma_e} \cdot \frac{\beta_e}{r_p^2} < 0.05$ Protons: $\xi^p = \frac{r_{0,p}}{4\pi} \cdot \frac{n_e}{\gamma_p} \cdot \frac{\beta_p}{r_e^2} < 0.01$

Polarization

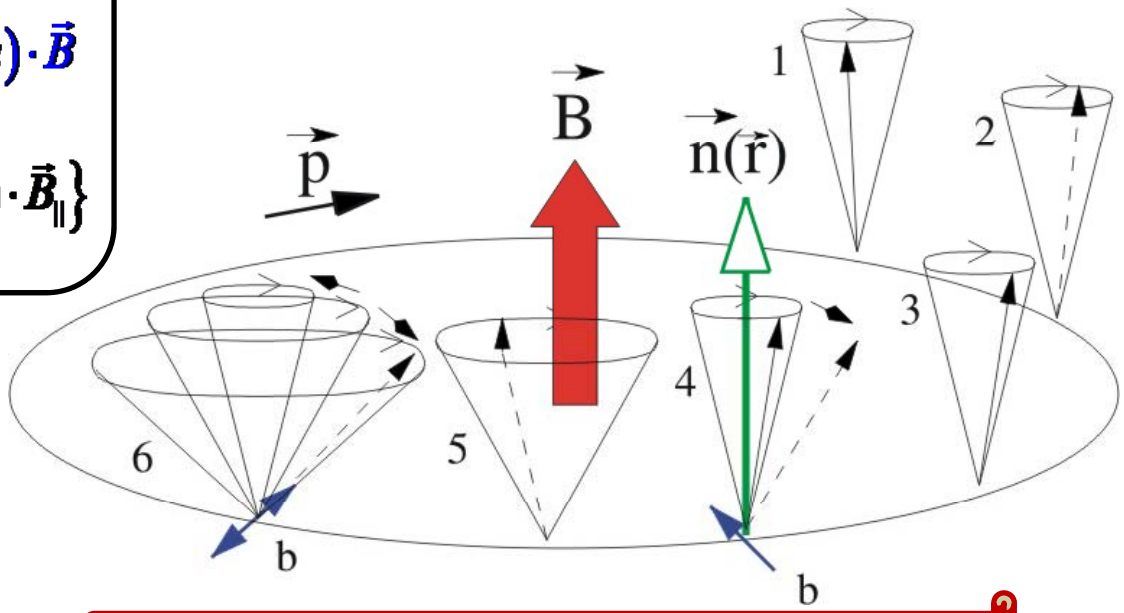
(BMT Equations)

$$\frac{d\vec{S}}{dt} = \vec{\Omega} \times \vec{S} \qquad \vec{\Omega}^{*} = -\frac{e}{m_0}(1+a)\cdot\vec{B}$$

$$\vec{\Omega}_{BMT} = -\frac{e}{m_0\gamma}\left\{(1+a\gamma)\cdot\vec{B}_{\perp} + (1+a)\cdot\vec{B}_{\parallel}\right\}$$

Spin Tune:

$$Q_{Sp} = \gamma a, \quad a = \frac{g-2}{2}$$

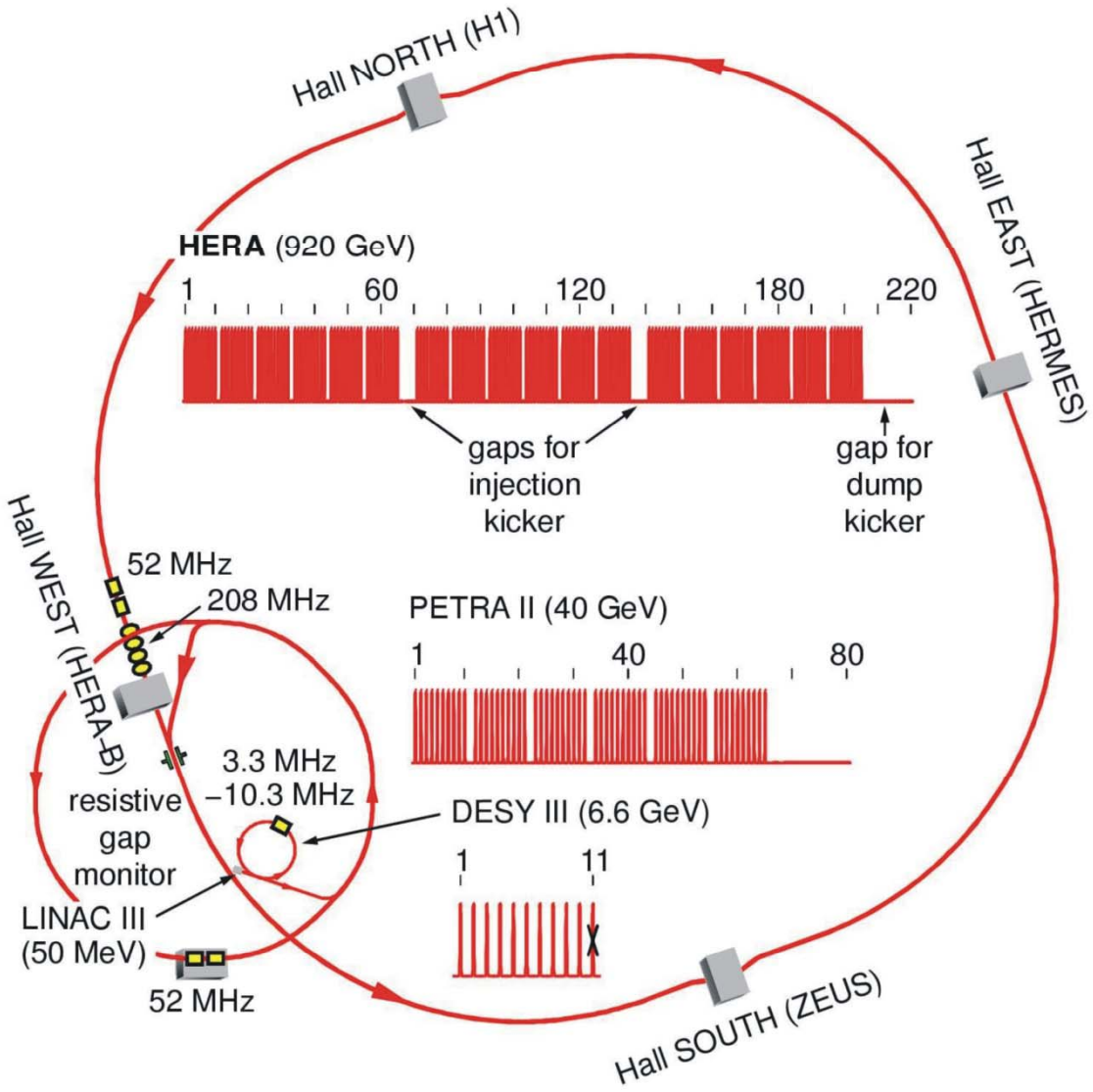


$$\Delta Q_{Sp} = 1 \leftrightarrow \Delta E_{e/p} = 440/523\,MeV$$

Imperfection Resonance: $\gamma \cdot a = n, \qquad n \in Z$

Intrinsic Resonance: $\gamma \cdot a = n \cdot P \pm Q_z, \quad n \in Z$

Former HERA Operation



Luminosity:

$n_{e,p} = 3.6 \cdot 10^{10}$ (e), $1 \cdot 10^{11}$ (p)

$h_{col} = 174$ (total $5 \cdot 220$)

$\sigma_{x,z} = 1.1 \cdot 10^{-4}$ m, $3 \cdot 10^{-5}$ m

$f_0 = 47.3$ kHz

$l_b = 20$ cm, $F_{HGR} = 0.95$

$E_{e,p} = 27.5 / 920$ GeV

→ $L = 7 \cdot 10^{31}$ cm^{-2}

Polarization:

$P_e > 60\%$ longitudinal

$P_p =$ ☹

A way to higher Luminosity?

- **Filling of every 52 MHz p-bucket (5·L)**
- **Reduction of beam sizes at IP:**

  → smaller ε using **eCool**

  → reduction of β (**final focusing**)

  } **(5·L)**

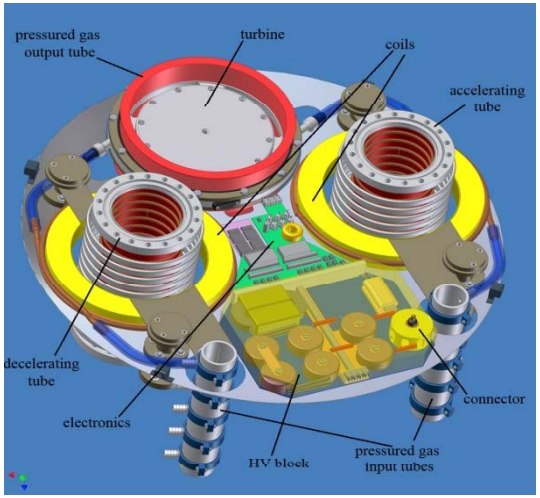
- **Higher e-current (more RF power) (5·L)**

  (ultimate limit given by single bunch instabilities)

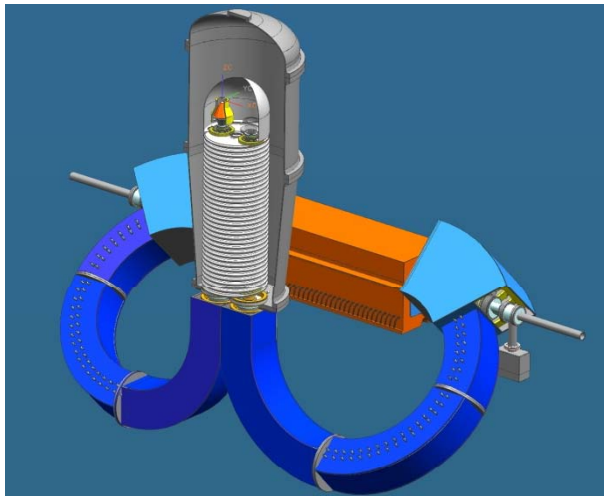
But: Take care of beam-beam parameter ξ_e!

eCool in DESY III @ 6.6 GeV

High voltage module
60kV, integrated solenoids,
powered by gas-turbine



0.03 – 2MV, 0 - 3A (34 modules)
HV-column: B = 0.05 T
toroids + cooling: B = 0.2 T

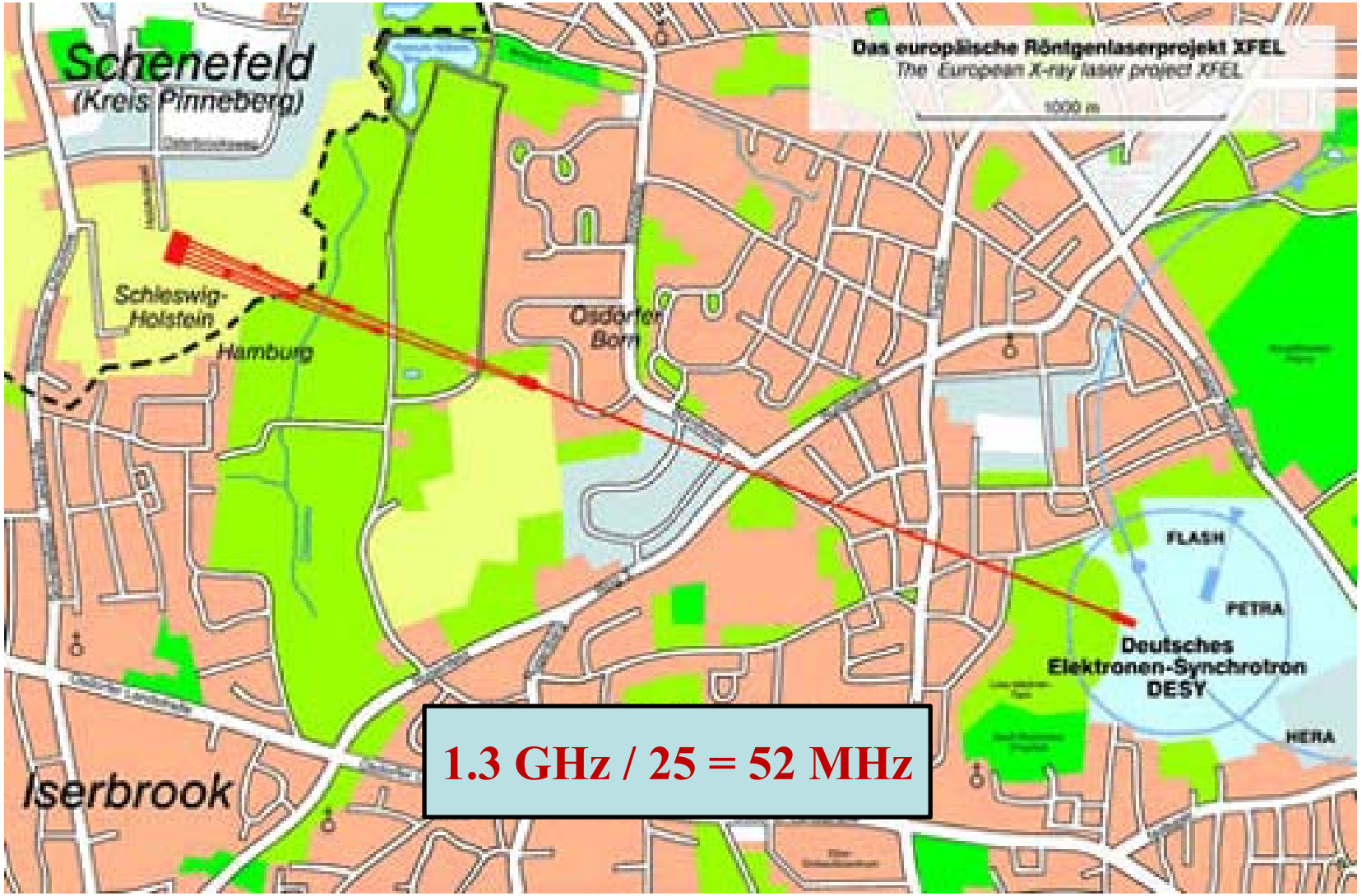


2MV COSY cooler under development as prototype for HESR eCool
(FZ-Jülich and Budker Institute / Novosibirsk)

First demonstration and measurements of high energy magnetised cooling !
Scalable? 2MV → 3.6MV (60 modules)?

3.6 MeV required!

Pre-Acceleration of Protons



Coherent Electron Cooling

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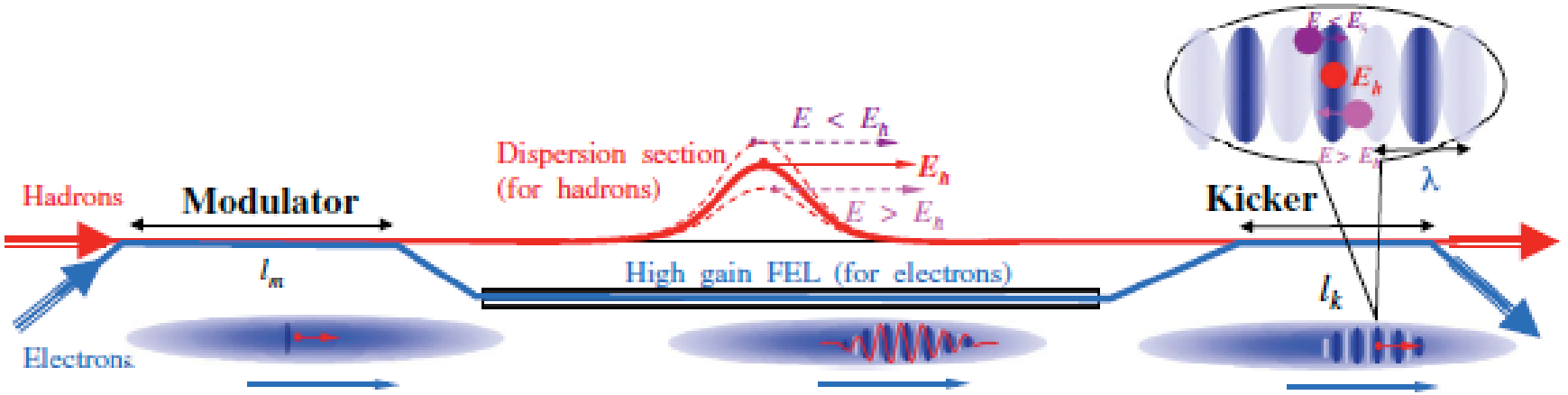

Reduction of:

- proton bunch length
- proton emittance

Accumulation of polarized protons in HERA?!

Polarized Protons

Depolarizing Resonances in DESY III:

- 12 imperfection resonances (every 523 MeV)

  → at least solenoid partial snake is required

- 2 strong intrinsic resonances (1.58 GeV and 6.48 GeV)

  → tune jump quadrupoles for fast crossing required

Depolarizing Resonances in HERA:

- **Lower beam energy < 250 GeV?** (spread of inv. spin field)
- **2 (4) full Siberian snakes required**

  → avoid snake resonances and co distortions!

(RHIC: 60% @ 100 GeV routinely, 42% @ 250 GeV)

Conclusions

HERA III: p-e-collider with double polarization:

- **DESY III with partial snake and ecool?**
- **XFEL-LINAC may be used as injector?**
- **Coherent ecool in HERA?**
- **Up to 4 full snakes in HERA?**
- **Reduced beam sizes at IP's in HERA**
- **Polarimeters required**

$L \approx 10^{33}$ cm^{-2}, lim. by ξ_e