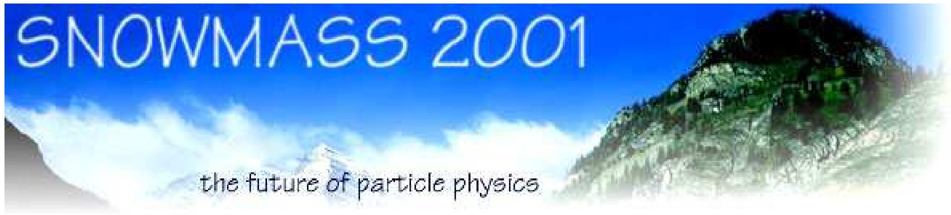

M5: Lepton Hadron Colliders

20 July 2001

Ilan Ben-Zvi (BNL) and Georg Hoffstaetter (DESY)

K.Balewski, D.Barber, R.Brinkmann, J.Butterworth, A.Chao,
W.Chou, S.Derbenev, A.DeRoeck, A.Desphande, K.Floettmann,
D.Hasell, E.Keil, M.Klein, B.King, G.Krafft,
W.Krasny, SY.Lee, S.Magill, J.Marriner, L.Merminga,
R.Millner, S.Nagaitsev, J.Norem, B.Parker, S.Peggs,
U.Ratzinger, T.Roser, J.Sheppard, C.Sinclair, A.Skrinsky,
M.Tigner, C.Tschalaer, F.Willeke,

Charge: Present status, Vision of the future, New ideas,
R&D issues, Beam physics limits, Technology limits

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Experimental Excitement from HERA

- **Proton structure & QCD**

→Rise of F2
Role of gluon
Jet physics
Precise aS
Electroweak physics

- **Low x physics**

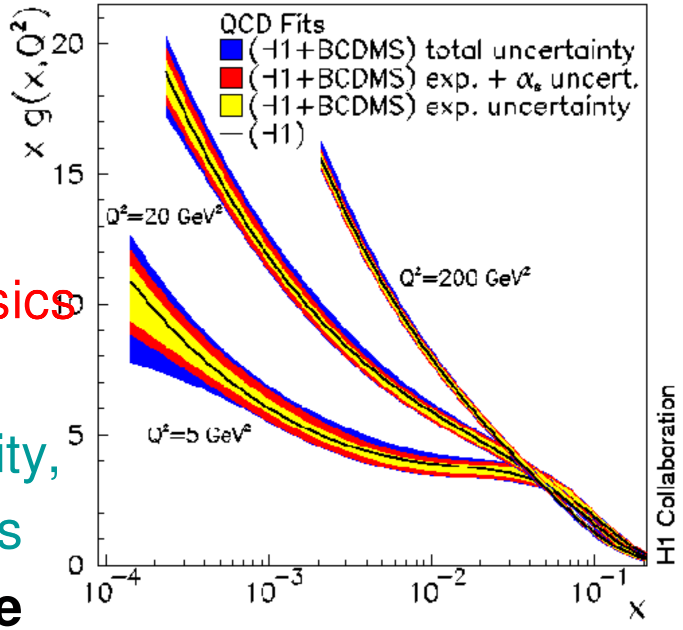
→High parton density,
Diffractive physics

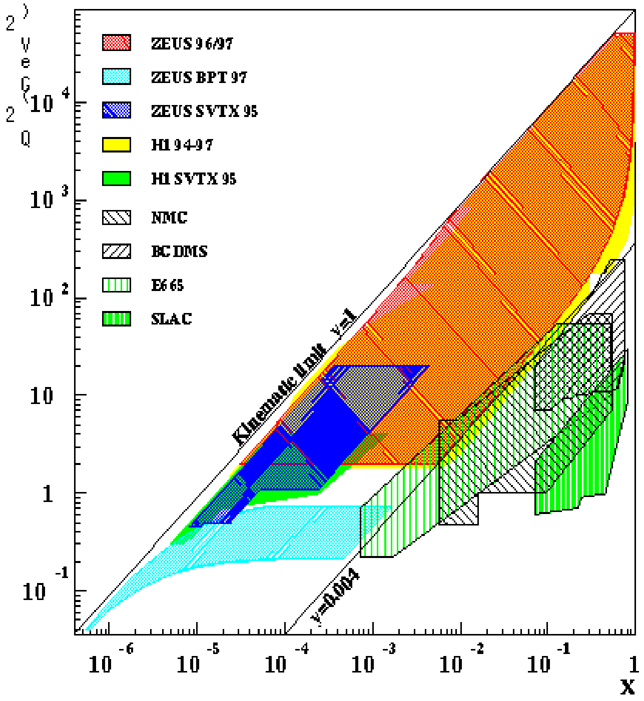
- **Photon structure**

→ Jet physics, Prompt photons

- **Physics beyond SM**

→ Lepto-quarks, Contact interactions,
excited leptons etc….





$$E_p \approx 820-920\,\mathrm{GeV}$$

$$E_e \approx 27.5\,\mathrm{GeV}$$

Talks by: A.Desphan, W.Krasny, M.Klein,
A.Deroeck, R.Millner, and Steve Magill

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Future Unpolarized DIS

- Interesting physics may lie beyond the kinematic reach of HERA

- Higher energy machines need to be designed…

→ Cost efficient method: use TESLA, HERA, LHC or VLHC

- High density partonic matter could be found in high energy e-A scattering

- Diffractive signals from eA physics at high energies might tell us something about the very low x region

→ Cost efficient method: use HERA or RHIC

→ Discovery of a new state of matter… Color Glass Condensate…?

→ Gluons in heavy ions

→ e/A is needed to understand the initial states of A/A in RHIC, LHC and VLHC

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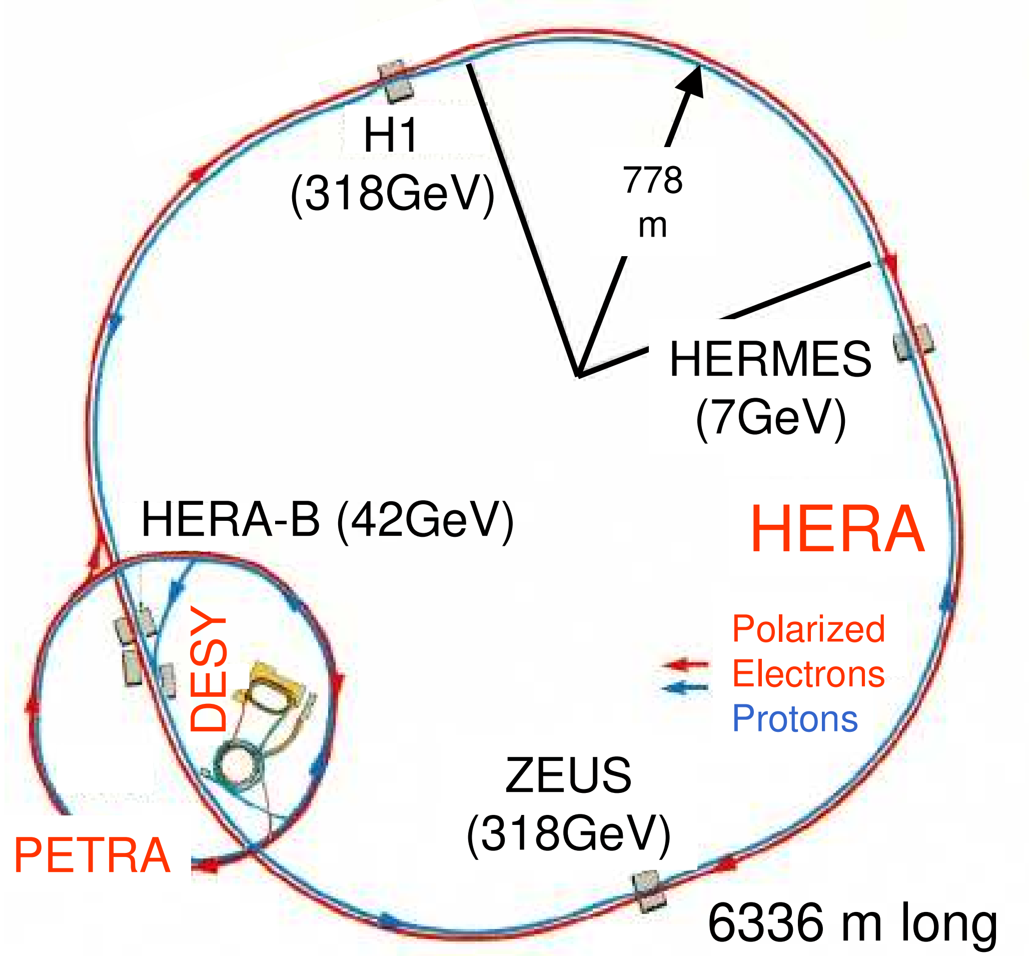
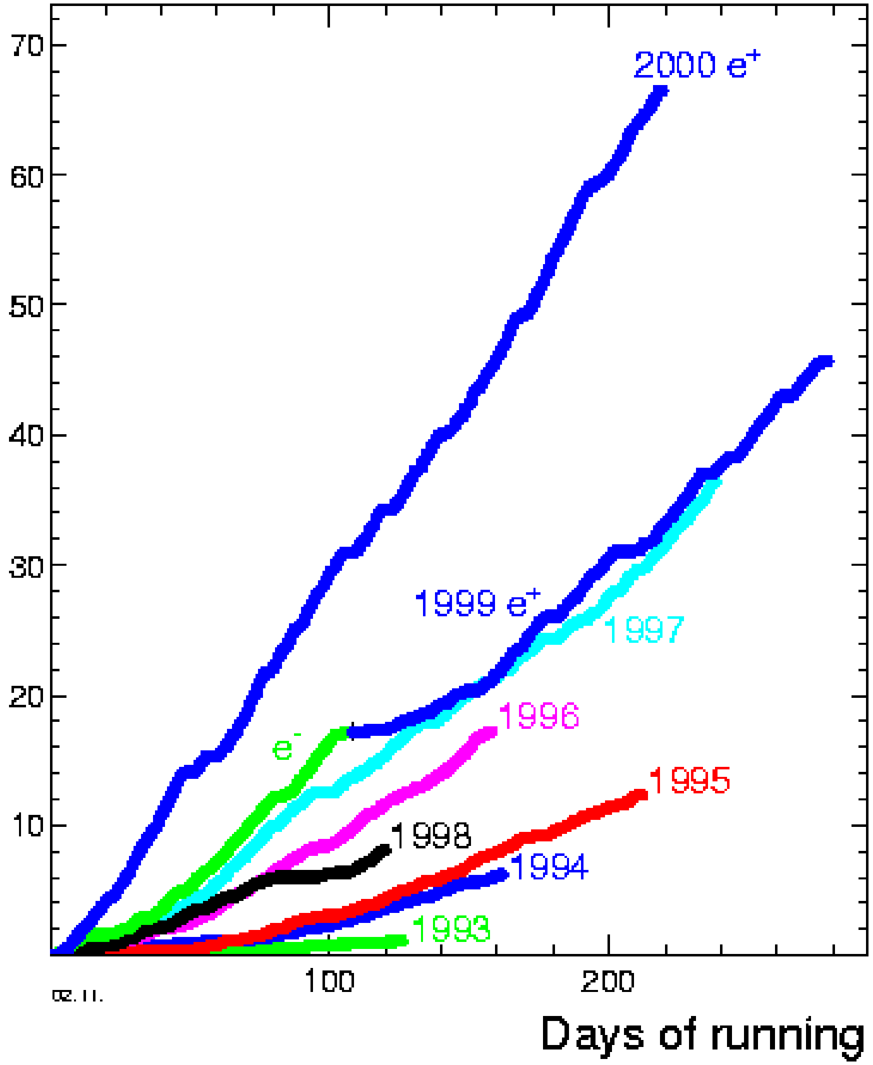
Current Performance of HERA

- Design luminosity surpassed
- Now an Upgrade is needed



H1
(318GeV)
778
m
HERMES
(7GeV)
HERA-B (42GeV)
HERA
DESY
Polarized
Electrons
Protons
ZEUS
(318GeV)
PETRA
6336 m long



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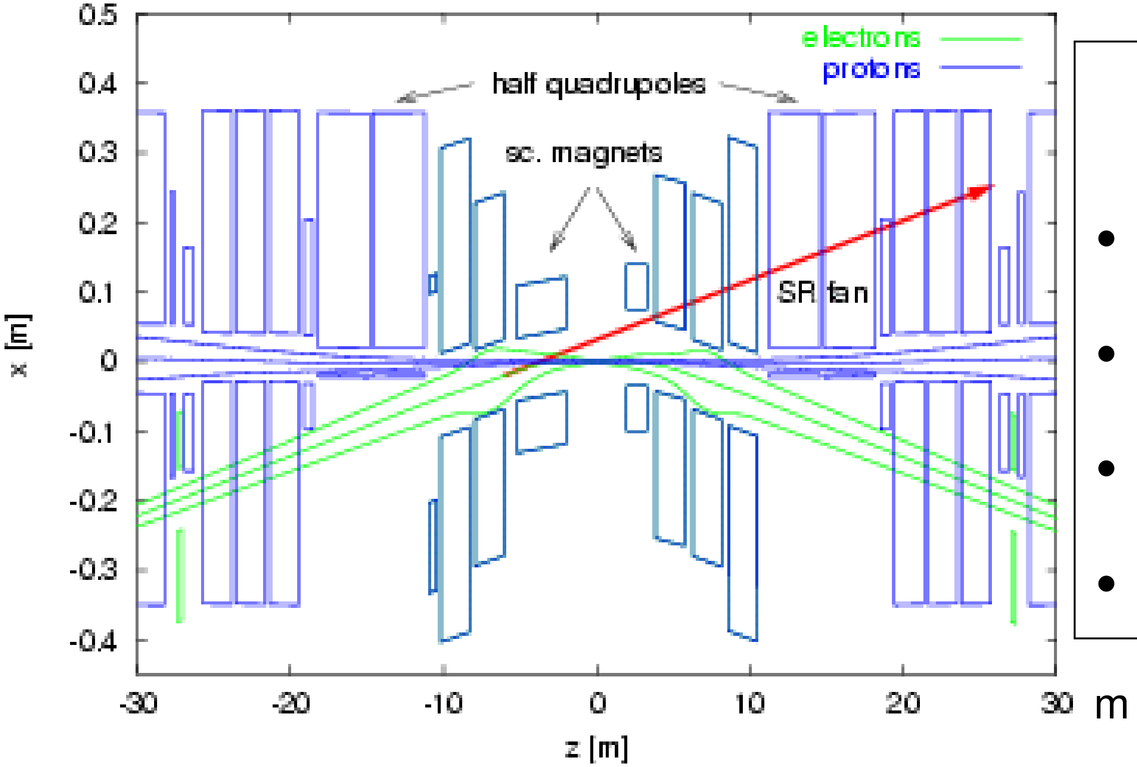
The HERA Luminosity Upgrade



New limitations:

- beam-beam tune shift
- hourglass effect for protons
- background due to radiation
- dynamic aperture of e-beam

- Increase of luminosity from $1.5 \cdot 10^{31}$ to $7 \cdot 10^{31}$
- Beam separation by super-conducting magnets in the detectors
- Focusing to ¼ of the old beam cross-section

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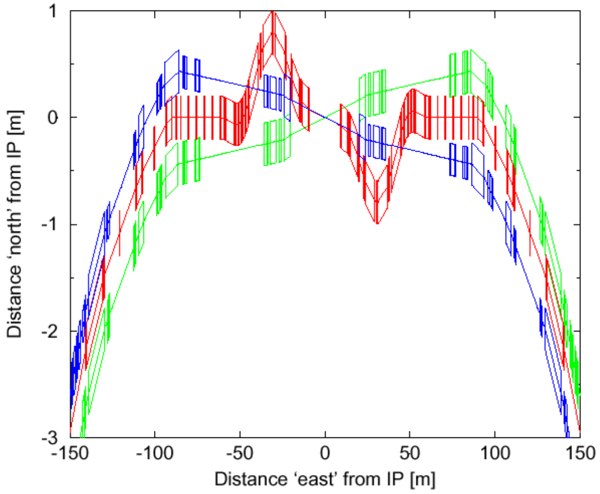
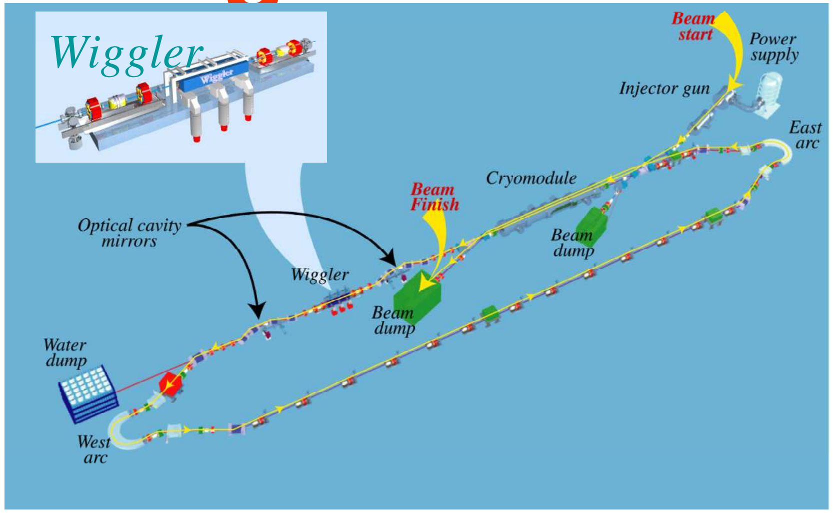
Ring-Ring or Linac-Ring Colliders





Wiggler
Beam start
Power supply
Injector gun
East arc
Cryomodule
Beam Finish
Beam dump
Optical cavity mirrors
Wiggler
Beam dump
Water dump
West arc

- Plenty of experience with ring-ring colliders
- Relatively large average current
- Relatively low RF power

- Simplified handling of e-polarization
- Synchrotron radiation does not determine size
- No spin rotators needed
- Energy quite variable

Since energy recovery linacs (ERLs) could have similar electron currents as rings, ERLs can make linac-ring colliders competitive

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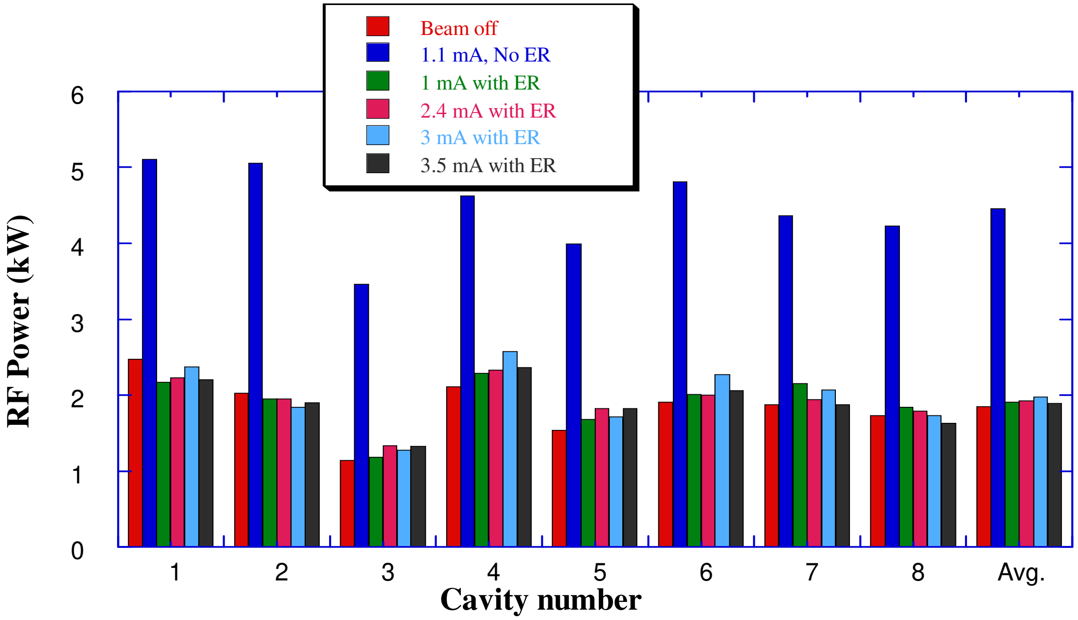
Energy-Recovery Linacs

ERL at Jefferson

- With energy recovery: 16 kW RF, nearly independent of beam
- No energy recovery: 36 kW RF



Proposal of a test ERL at Cornell:

3.5 year construction, 1.5 year measurements, proposal is submitted to NSF

Beam Energy	100 MeV	Charge per bunch	77 pC
Injection Energy	5 MeV	Emittance, norm.	2* µm
Beam current	100 mA	Shortest bunch length	100* fs

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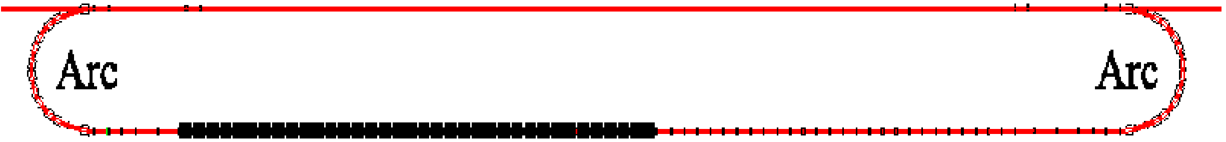
High Energy e-Cooling

At FNAL for the Recycler: 4.3MeV, 0.5A, DC

Technology limit: no more than 15MeV

Bunched e-beams:
Petra : 10MeV
HERA: 200MeV, 86mA

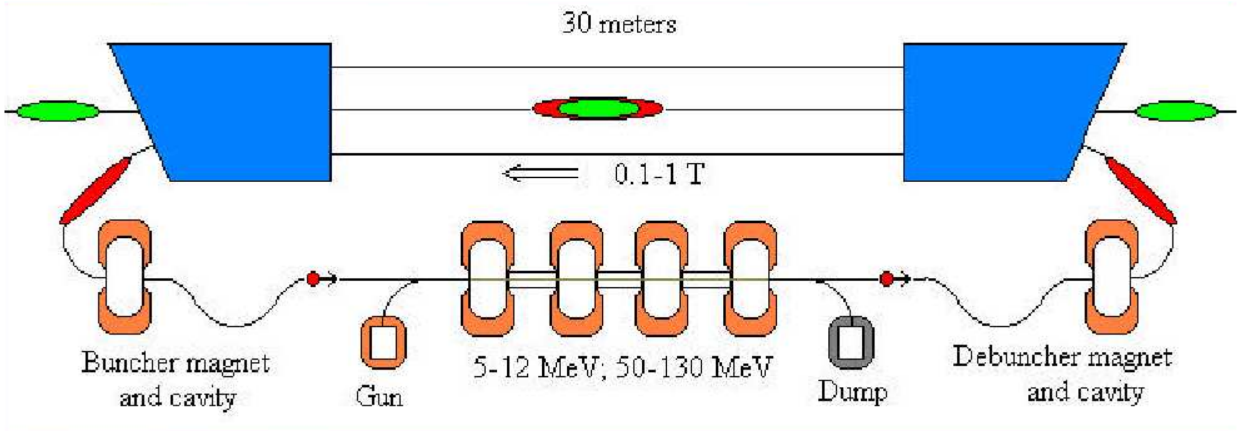

Arc
Arc
Tuning

cooling section, 120 m

HERA

37 wigglers, B = 1T

ERL cooling:
RHIC : 50MeV


30 meters
0.1-1 T
Buncher magnet and cavity
Gun
5-12 MeV; 50-130 MeV
Dump
Debuncher magnet and cavity

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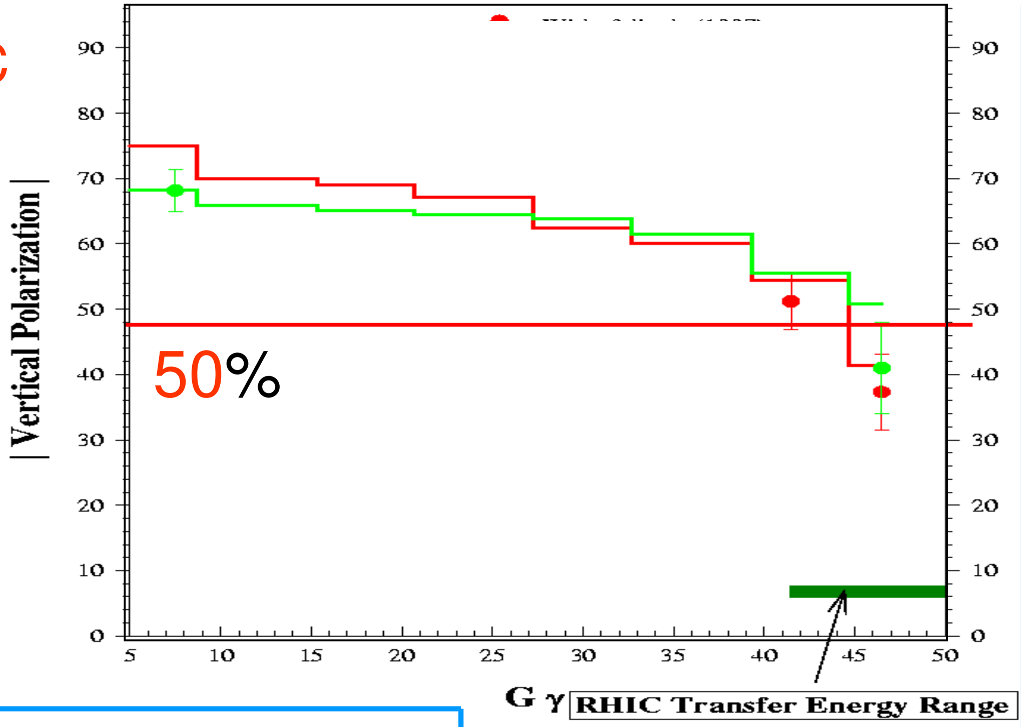
Polarized Electrons, Protons, and Deuterons

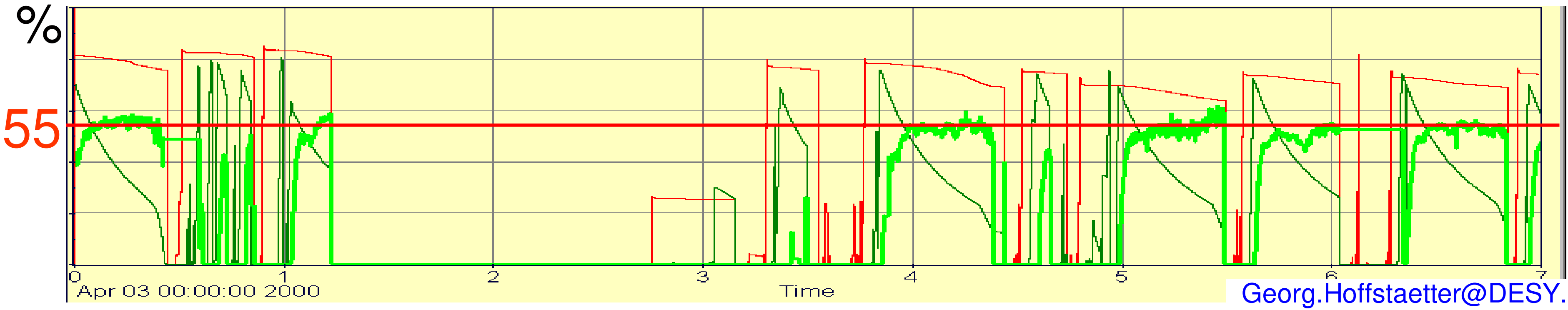
Successful p-polarization at AGS / RHIC

- Spin flip at depolarizing resonances using partial snake and a rf dipole
- Horizontally polarized Beam in RHIC



Succesful e-polarization at HERA

- Spin rotators produce longitudinal polarization



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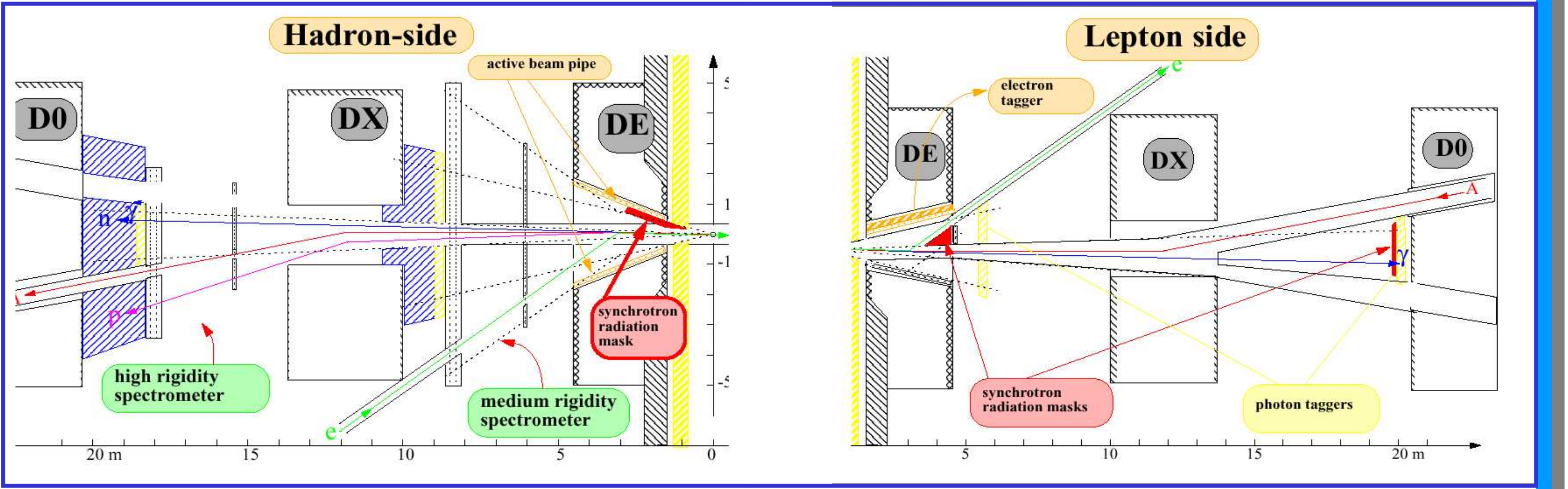
Detector and Interaction Region Issues


Hadron-side
D0
DX
DE
active beam pipe
n
γ
p
e
high rigidity spectrometer
medium rigidity spectrometer
synchrotron radiation mask
5
1
-1
-5
20 m
15
10
5
0
Lepton side
electron tagger
DE
DX
D0
e
A
γ
synchrotron radiation masks
photon taggers
5
10
15
20 m

- 4π detectors have been suggested which
  have no clear Boundary between machine and Detector
  (magnets inside detector- detectors inside magnets)

  Strong interaction between detector and accelerator will be needed
- Beam conditions must be sufficient for optimal data taking (supressed halo)

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High Current Polarized Sources

- Polarized electron sources:

  Polarized light --- polarized conduction electrons.

  GaAs --- 40% polarization high efficiency

  Thin GaAs and lifted degeneracy --- 80% polarization low efficiency

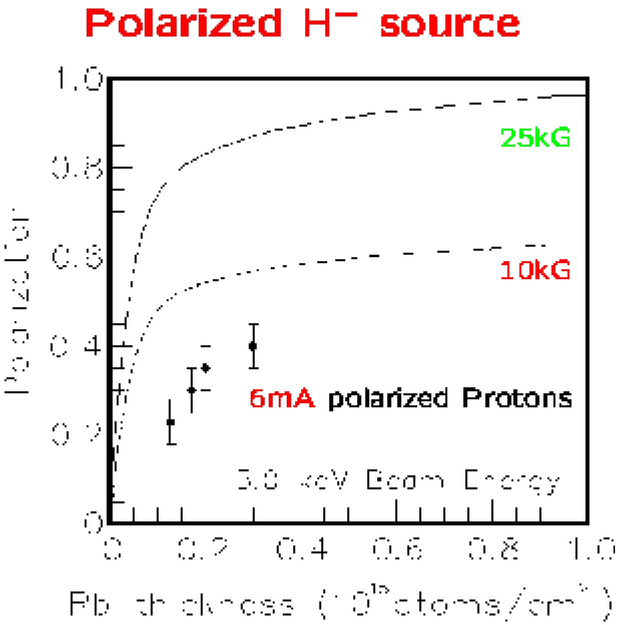
  R&D: CHALCOPYRITES have no degeneracy --- 100%, high effic.

- Polarized H^- sources (OPPIS):

  6mA, 60% polarization

  R&D for up to 20mA, 80% polarization

  R&D on the potentials of ABS



- Polarized deuteron sources:

  R&D of high current OPPIS with D^-

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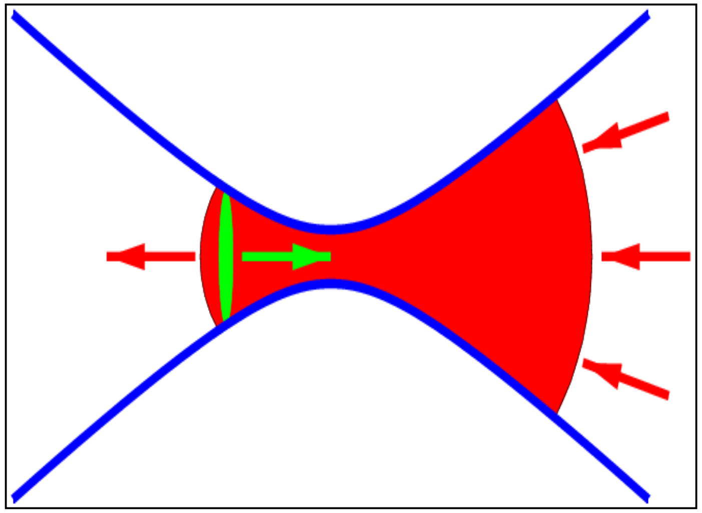
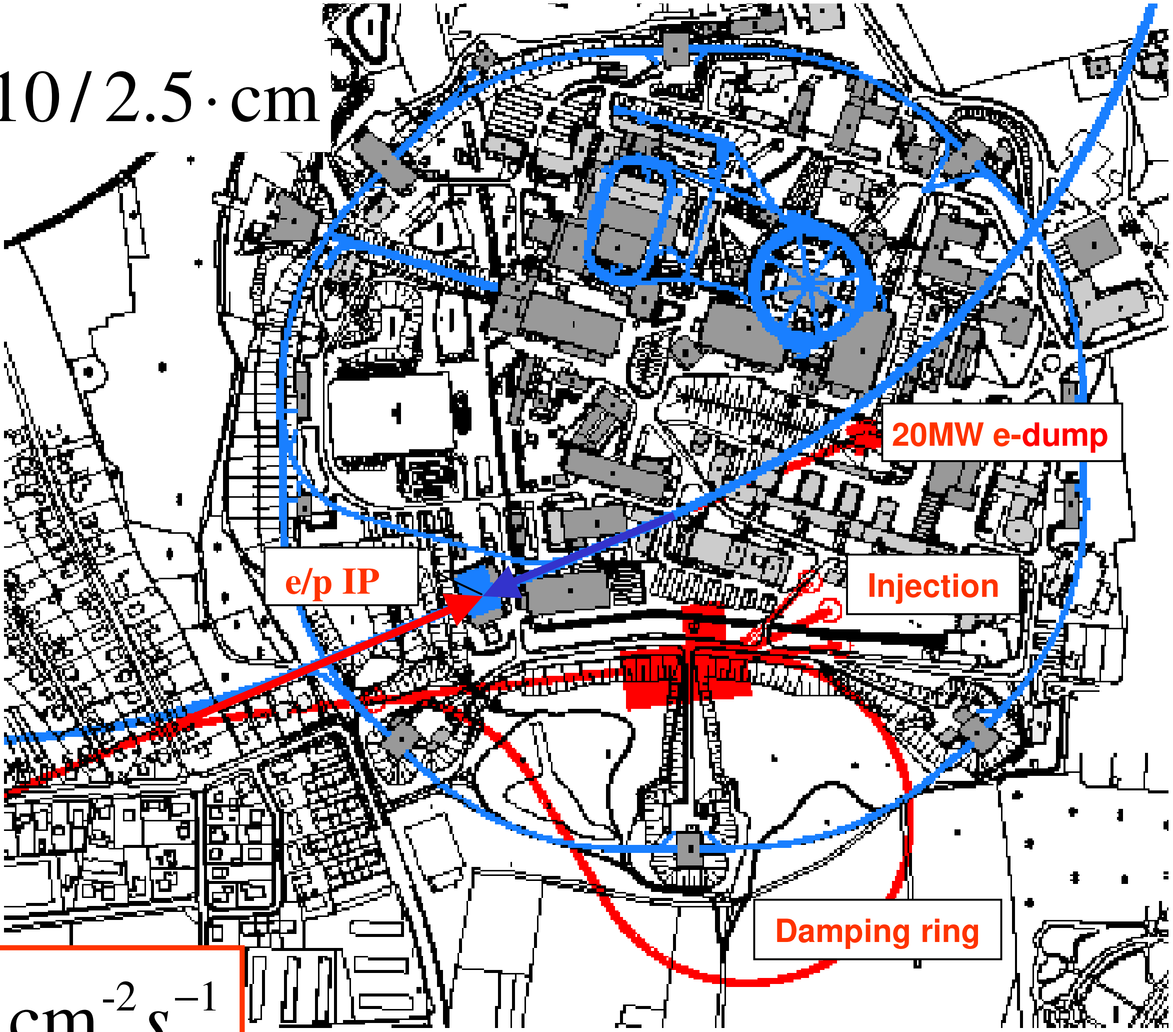
THERA: The TESLA on HERA Collider

- Cooling: $\varepsilon_{x/y} = 1/\tfrac{1}{4}\cdot 10^{-6}\,\mathrm{m}$
- Traveling focus $\beta^{*}_{x/y} = 10/2.5\cdot \mathrm{cm}$



- Variable e-energies 250-800 GeV

- Luminosity: $L \approx 2\cdot 10^{-31}\,\mathrm{cm}^{-2}s^{-1}$


20MW e-dump
e/p IP
Injection
Damping ring

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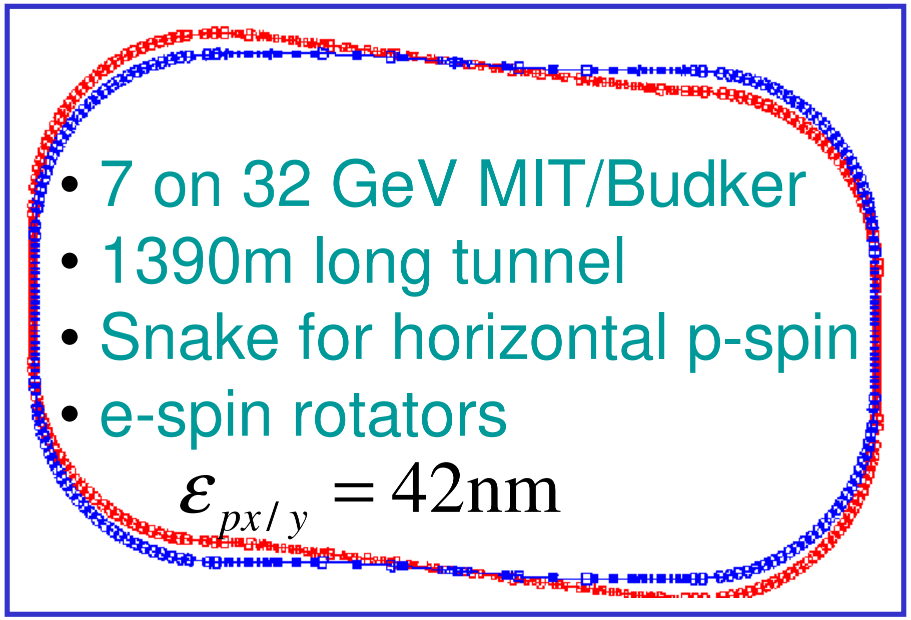
EIC: EPIC

ER Linac-Ring

- 5 on 50 GeV JLAB
- 500m long ring
- 260 mA e-current
- 1.3GW beam power
- $\varepsilon_{px/y} = 6\text{nm}$

- Luminosity: $L \approx 2 \cdot 10^{33}\text{cm}^{-2} s^{-1}$

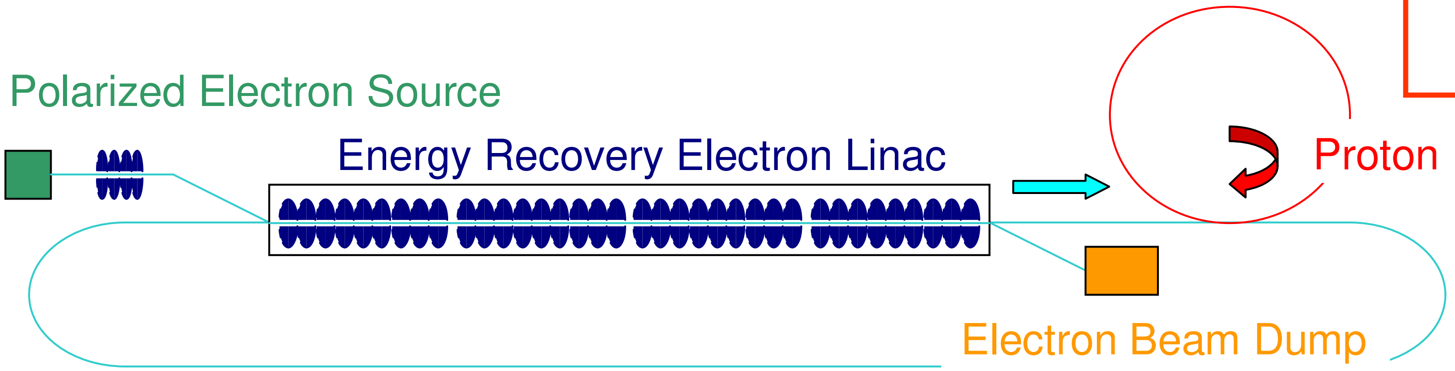
Ring-Ring



- 7 on 32 GeV MIT/Budker
- 1390m long tunnel
- Snake for horizontal p-spin
- e-spin rotators

$\varepsilon_{px/y} = 42\text{nm}$

$L \approx 10^{33}\text{cm}^{-2} s^{-1}$



Polarized Electron Source

Energy Recovery Electron Linac

Proton Ring

Electron Beam Dump

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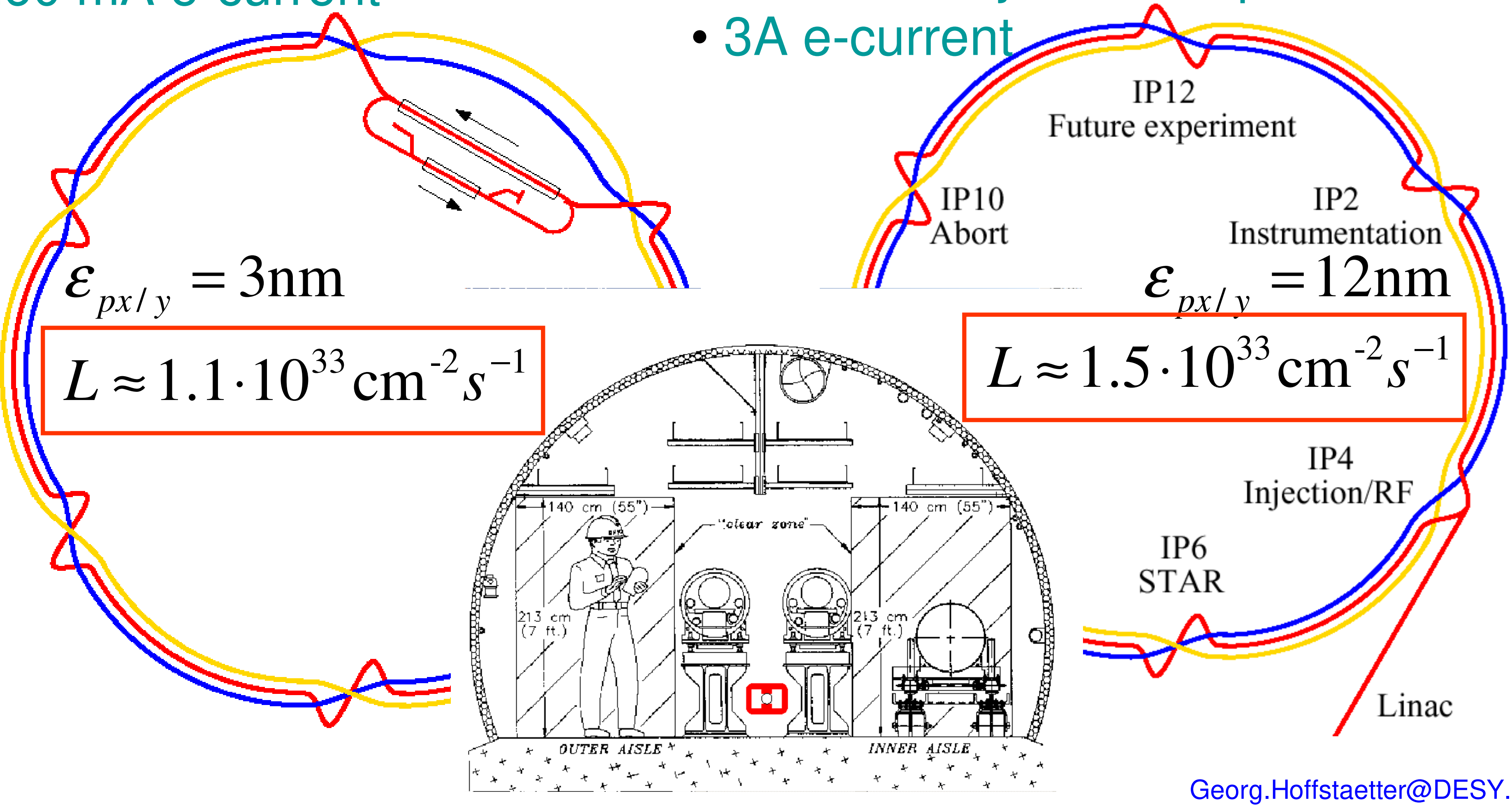
EIC: eRHIC

ER Linac-Ring 10-250GeV (100GeV Au) **Ring-Ring**

- 260 mA e-current

- Polarized injection + spin rotators
- 3A e-current


IP12
Future experiment
IP10
Abort
IP2
Instrumentation
IP4
Injection/RF
IP6
STAR
Linac
140 cm (55")
"clear zone"
140 cm (55")
213 cm
(7 ft.)
213 cm
(7 ft.)
OUTER AISLE
INNER AISLE

$$\varepsilon_{px/y} = 3\text{nm}$$

$$\boxed{L \approx 1.1\cdot 10^{33}\,\text{cm}^{-2}s^{-1}}$$

$$\varepsilon_{px/y} = 12\text{nm}$$

$$\boxed{L \approx 1.5\cdot 10^{33}\,\text{cm}^{-2}s^{-1}}$$

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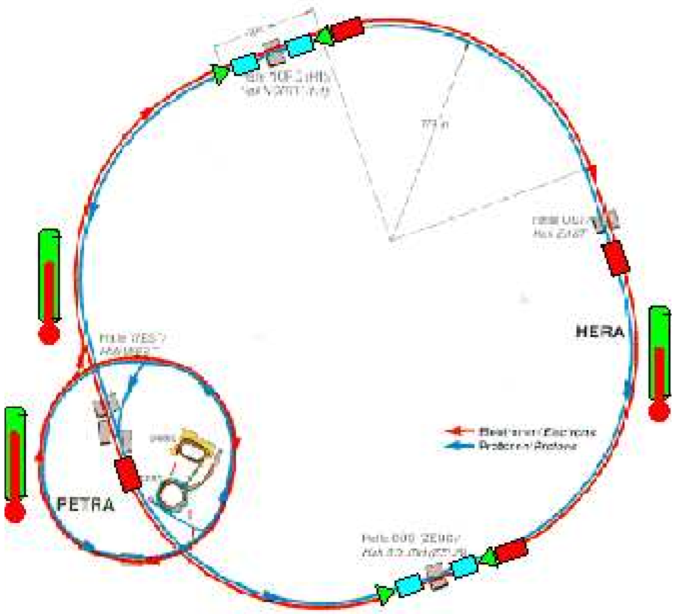
HERA III

Polarized protons in HERA



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

e-A in HERA

- Deuteron acceleration: with same Linac
- Ion Acceleration requires:
  - a new Linac
  - high energy e-cooling
- Luminosity:

$$\boxed{L_A = L_p \cdot \tfrac{1}{A} = 7 \cdot 10^{31} \cdot \tfrac{1}{A}}$$

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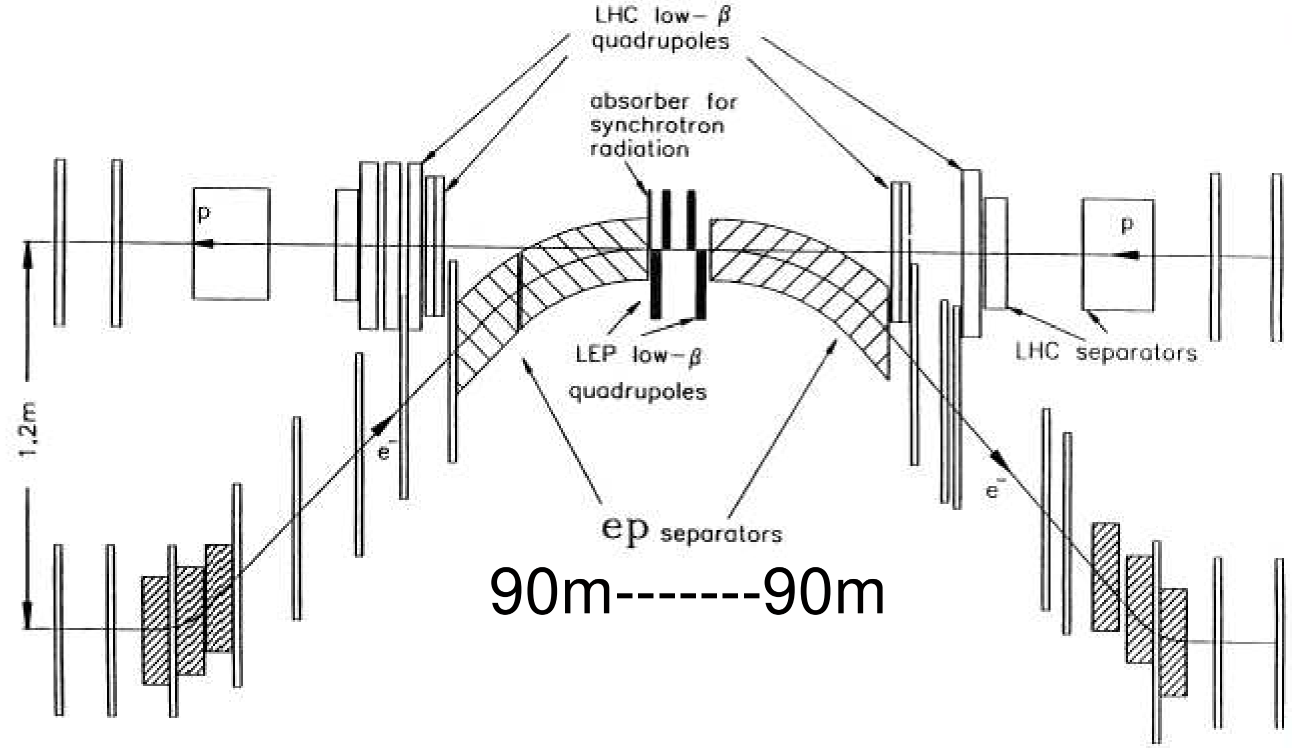
eLHC

- 60 GeV on 7 TeV e-p collider: E c.m.=1.3 TeV

$$\boxed{L \approx 2.5\cdot 10^{32}\,\mathrm{cm}^{-2}s^{-1}}$$

- Policy: Leave free passages above LHC for an e-ring.
- Assumes p-beams as in LHC and e-beams as in LEP


LHC low-β quadrupoles
absorber for synchrotron radiation
p
p
LEP low-β quadrupoles
LHC separators
1,2m
e
e
ep separators
90m-------90m

- Radiation: 2kW/m, critical E=155keV
- Non-polarized

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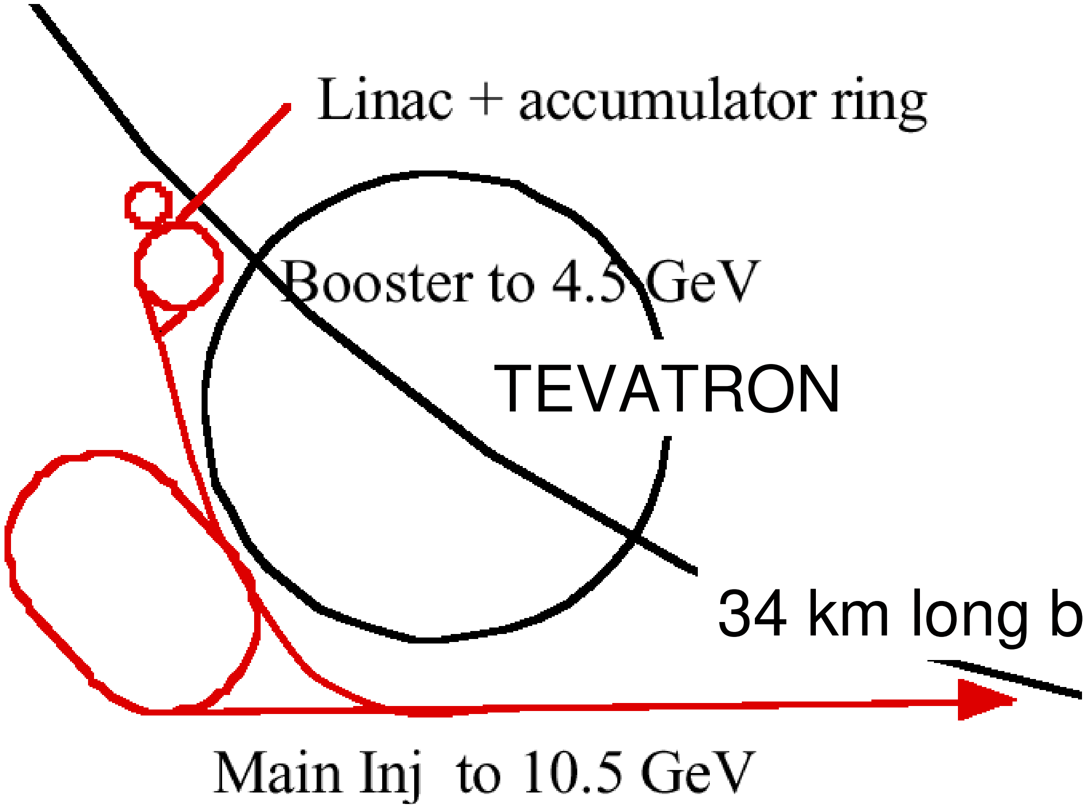
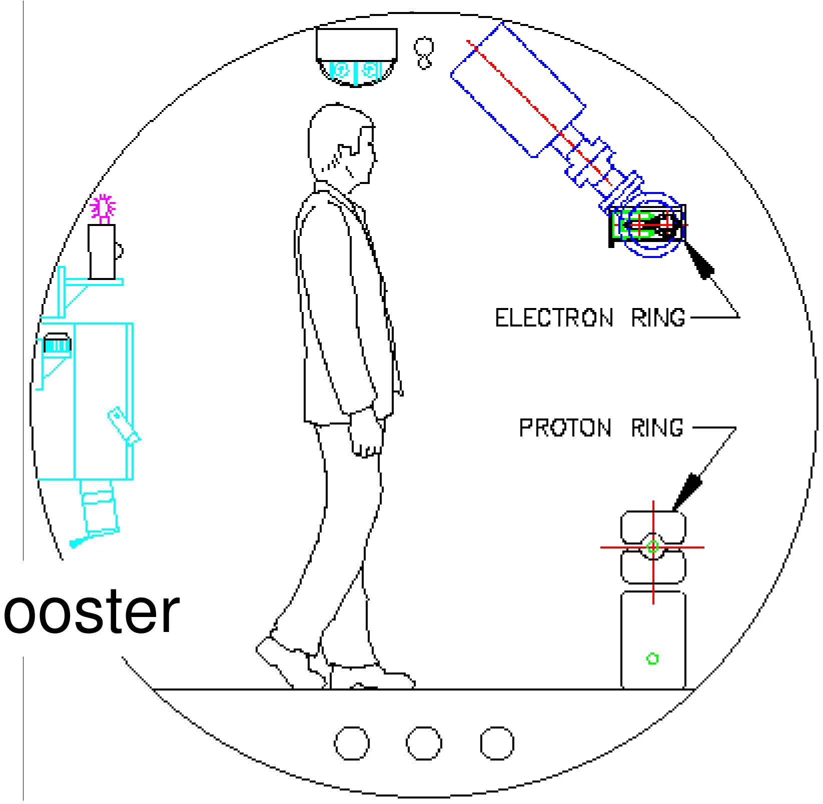
epVLHC-b

- 80 GeV on 3 TeV e-p collider: E c.m.=1 TeV
- For making e-p collisions during VLHC construction
- 40 qm/min for cooling of 50MW synchrotron radiation
- Fields from the transmission line magnets disturb e-beam

$$L \approx 2.6 \cdot 10^{32}\,\mathrm{cm}^{-2} s^{-1}$$


Linac + accumulator ring
Booster to 4.5 GeV
TEVATRON
34 km long booster
Main Inj to 10.5 GeV


ELECTRON RING
PROTON RING

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Considered Lepton-Hadron Colliders

Linac-Ring					
	Ring-Ring Colliders				
THERA	eRHIC	EPIC	HERA III	eLHC	eVLHC-b
$L_{ep} = 1.6\cdot10^{31}$	$1.1/1.5\cdot10^{33}$	$2.1/1.1\cdot10^{33}$	$L_{ep} = 7\cdot10^{31}$	$L_{ep} = 2.5\cdot10^{32}$	$L_{ep} = 2.6\cdot10^{32}$
e-cooling	e-cooling	e-cooling	e-cooling		
GeV:2X800	10-250	5-50 / 7-32	28-920	60-7000	80-3000
traveling IP	e-ring IR	polarization		radiation	water cool.

R&D requirenments:

- high current energy recovery linacs
- high energy e-cooling / bunched beam stochastic cooling
- high current high polarization e-sources
- high energy p or D polarization
- p halo reduction for increased bunch frequency
- IP construction for 4π detectors

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More Details at:

http://snowmassserver.snowmass2001.org/Working_Group_M5/

- Nearly all Transparencies
- Summaries of the talks and of the sessions
- Interim Report
- Executive summary

Physics Issues	Interaction Regions (with T1)
Linac-Ring Colliders	Ring-Ring Colliders
Cooling (with T5)	Polarization (with T5)
Ring Collider Projects	Sources (with T4)
Beam Dynamics	Physics with Colliders (with E4)