Ring-ring Z factory ?

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- a name:
  -
- Luminosity
- Synchrotron radiation
- Polarization?

Ring-ring parameters

- HERA ring:
  - no crossing angle ⇒ both beams in the same pipe.
  - How to avoid parasitic collisions?
  - Electrostatic separation in straight sections N, E, S ?
  - ⇒ **2 bunches** in each beam.
  - Maximize bunch charge: **3 10^{11}**.
  - L = 6336 m ⇒ f_{rev} = 47.35 kHz single bunch revolution frequency.
  - ⇒ beam current **3 mA**.
- HERA RF:
  - SynRad loss per e per turn: $W = 88.5\ E^4[\mathrm{GeV}]\ /\ \rho[\mathrm{km}]$ eV.
  - HERA bending radius in the arcs: $\rho = 0.60$ km.
  - $P = n\,N f\ W / \eta = 2$ **MW /** $\boldsymbol{\eta}$ for 3 mA at **45.6 GeV** per beam.

Lumi spreadsheet: ring-ring

$$L = f\,N\,\frac{n_1\,n_2}{4\,\pi\,\sigma_x\,\sigma_y} = \frac{I^2}{4\,\pi\,e^2\,\nu\,\sigma_x\,\sigma_y}$$

beam energy	45.6	GeV	M_Z	91.2	GeV
particles	**2.00E+11**	**/bunch**	length	6336	m
bunches	**2**	**/beam**	freq	47.35	kHz
beam current	3.0	mA	e	1.60E-19	C
total SR loss	3.9	MW			
eps x	**50**	**nm rad**			
eps y	1	nm rad	**coupling**	**0.02**	
beta* x	**50.0**	**cm**			
beta* y	**2.0**	**cm**			
beam width	158.1	um			
beam height	4.5	um			
tune shift	0.028	/IR	r_e	2.82E-15	m
Lumi	4.26E+31	$/cm^2/s$	pi	3.141593	
Z	18	M/year/IR	year	1.00E+07	s

Synchrotron radiation

- radiative loss per turn: $\Delta E\,[eV] = -88.5\,\dfrac{E^4\,[GeV]}{\rho\,[km]}$
- energy spread: $\delta E/E = \gamma\sqrt{C_q/J_E\,\rho}$
  - $C_q = \dfrac{55}{32\sqrt{(3)}}\,\dfrac{\hbar c}{m_e c^2} = 3.84\cdot 10^{-13}\,m$
  - longitudinal damping: $J_E \approx 2$
- characteristic energy: $E_c = \dfrac{3}{2}\,\hbar\,c\,\dfrac{\gamma^3}{\rho}$

Synchrotron radiation

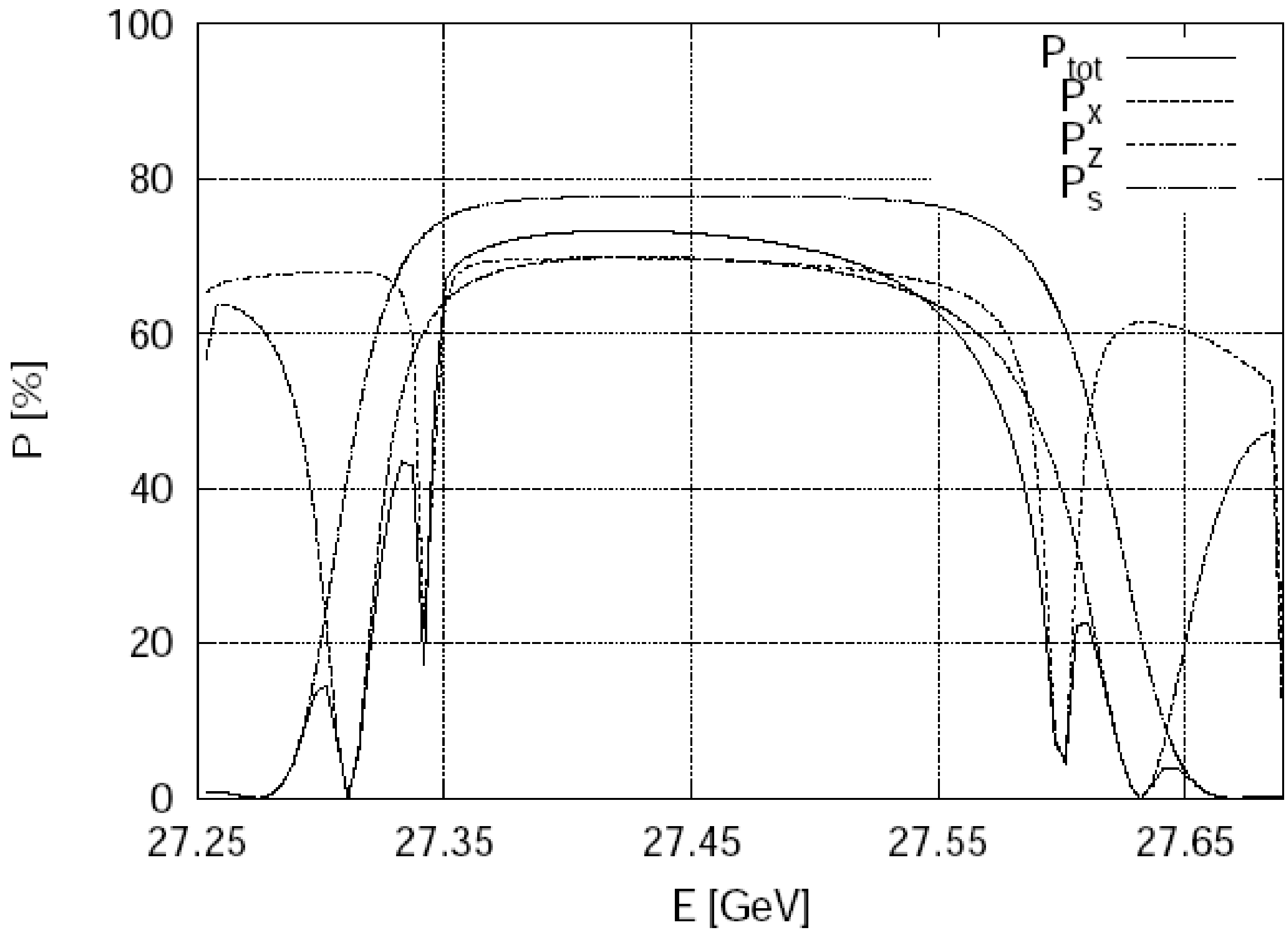
beam energy	27.5	45.6	GeV	m_e	5.11E-04	GeV
bending radius	480	480	m	length	6336	m
energy loss	105	797	MeV/turn			
rel. energy spread	1.1	1.8	‰			
abs. energy spread	30	81	MeV			
SynRad Ec	96	437	keV			
particles	1.5E+11	2.0E+11	/bunch	e	1.60E-19	C
bunches	42	2	/beam			
beam current	47.7	3.0	mA/beam	freq	47.35	kHz
total SR loss	5.0	2.4	MW/beam	r_e	2.82E-15	m

Polarization and energy spread

- Spin precession: $\nu = \gamma \frac{g-2}{2}$
- positrons at 27.53 GeV: $\gamma = E/m_e c^2 = 53'875$.
- anomalous magnetic moment: $(g-2)/2 = 1.1597 \cdot 10^{-3}$

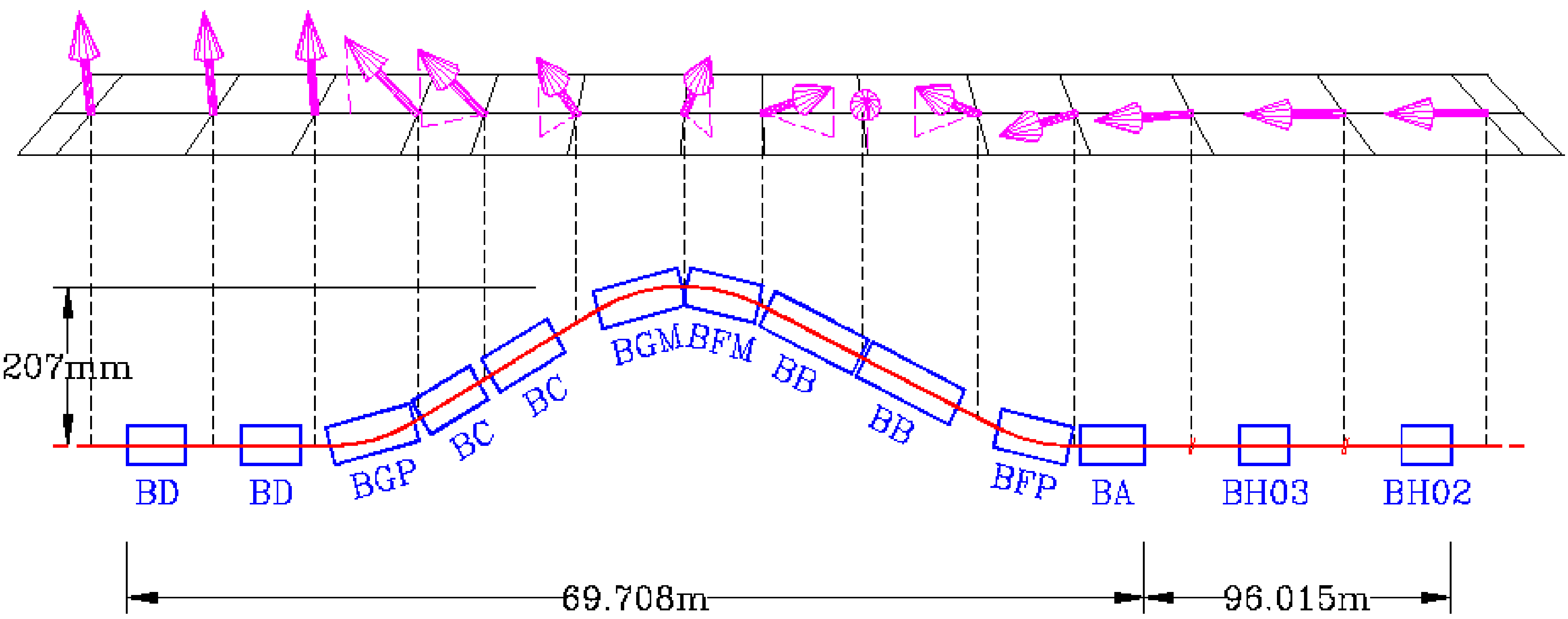
  ⇒ Spin tune $\nu = 62.5$
- energy dependence:
  - $\Delta\nu = 1$ for $\Delta E = 441$ MeV.
- what energy spread can be tolerated?
  - LEP: 'no sign of polarization above E = 61 GeV'.
  - energy spread at 61 GeV, $\rho = 3$ km: $\delta E/E = 0.95$‰ ⇒ $\delta E = 58$ MeV.
  - HERA at 27.5 GeV: $\delta E = 30$ MeV, achieved polarization.
  - HERA at 45.6 GeV: $\delta E = 81$ MeV, polarization?

HERA II polarization vs energy



- Thesis of M. Berglund, 2001, p110, fig 6.19c
- HERA II optics 3.2e⁻ with 'realistic distortions'.
  - P
- Width of the polarization plateau is about ±80 MeV

HERA spin rotator at 27.5 GeV



Challenges for HERA e

- 45.6 GeV:
  - Polarization ?
  - Magnet cooling ?
- Factor 3 higher bunch current:
  - Space charge ?
  - Injection efficiency ?
- Factor 2 smaller horizontal normalized emittance:
  - New lattice ? New bending dipoles in the arcs ?
- Factor 7 smaller vertical emittance coupling:
  - 2% instead 15%. Should be possible.
- Factor 2 shorter bunches:
  - New RF ?