LHeC Ring-Ring Option

Summary

Bernhard Holzer

contributons from ...

Ed Ciapala
Louis Rinolfi
Luke Thompson
Nathan Bernard
Stephan Russenschuck
Helmut Burkhardt
Tatiana Pieloni
Uli Wienands
Karl-Hubert Mess
Miriam Fitterer
Chiara Bracco
Oliver Bruening
Davide Tomassini
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et al in discussions

Electron / Positron Injection

ELFE@CERN design,

to some extend based on CEBAF

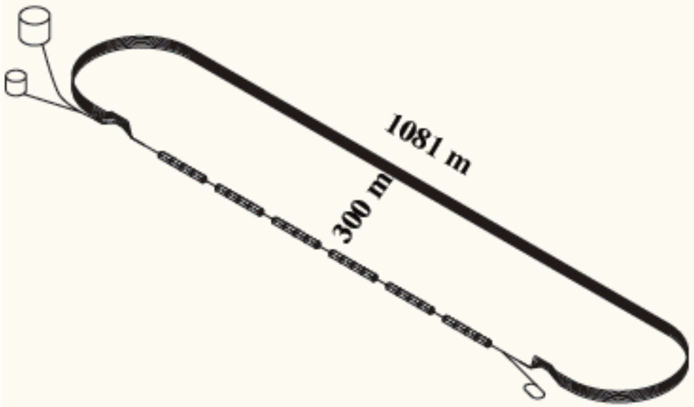
f_{rf} = 352 MHz, gradient 8 MV / m

V_{rf} = 3.5 GV, 72 rf-modules

7 passes (last at 21.5 GeV)

L = 3924 m of which Linac 1081 m

ϱ = 56.9 m



LHeC injector

f_{rf} ~ 1.3 GHz, 20 MV/m all inclusive as ILC

Linac L = 156 m 7× shorter

0.6 GeV e+/e- EPA LEP pre-injector/ accumulator

V_{rf} = 3.13 GV, 3 passes ; last 6.9-10 GeV

energy loss scaling E^4

allows for much shorter bends

6.9 GeV, ϱ = 2 m

gives 1% energy loss

and 10^{-3} energy spread

Helmut Burkhardt

Pre-injector Accumulator

Accumulator needed for e+

also helps to get 2×10^{10} for e-

the old LEP-EPA would do :

from Vol.I LEP design report:

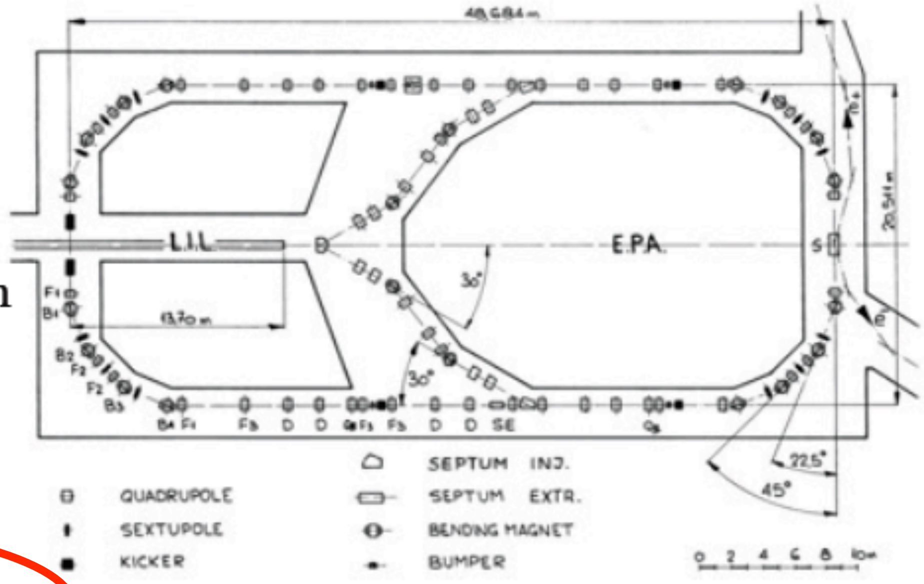
E = 0.6 GeV, Circumference = 125.665 m

8 bunches, total 2.e11

or **2.5e10 / bunch**

1.14s cycle length

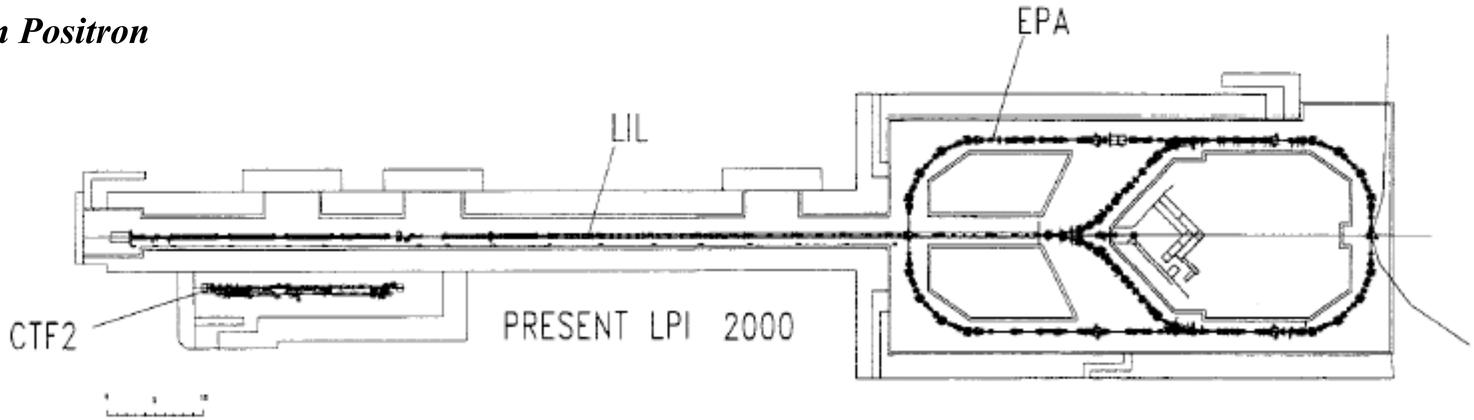
would allow to fill the e-ring in **7 minutes**



Helmut Burkhardt

The LPI as an e^- and e^+ sources*

(*) LPI = LEP Pre-Injector
LIL = LEP Injector Linac
EPA = Electron Positron Accumulator



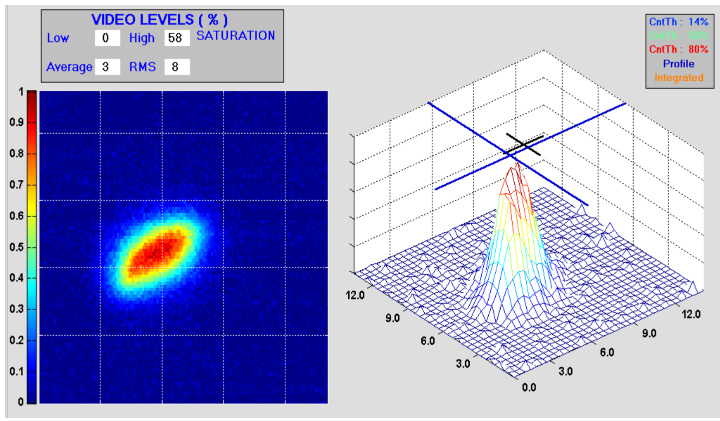
LIL Beam Characteristics

Energy : 200 to 700 MeV

Intensity : 5×10^{8} to 2×10^{10} e^- / pulse
Pulse length 10 to 35 ns (FWHM)

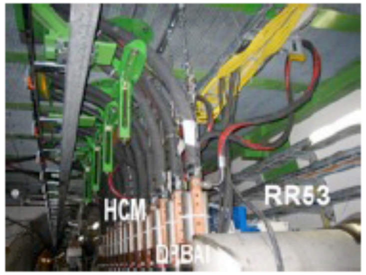
Frequency: 1 to 100 Hz

Beam sizes: $\sigma_x = \sigma_y = 3$ mm



Louis Rinolfi

Overall Layout



Lattice Design dominated by geometry:

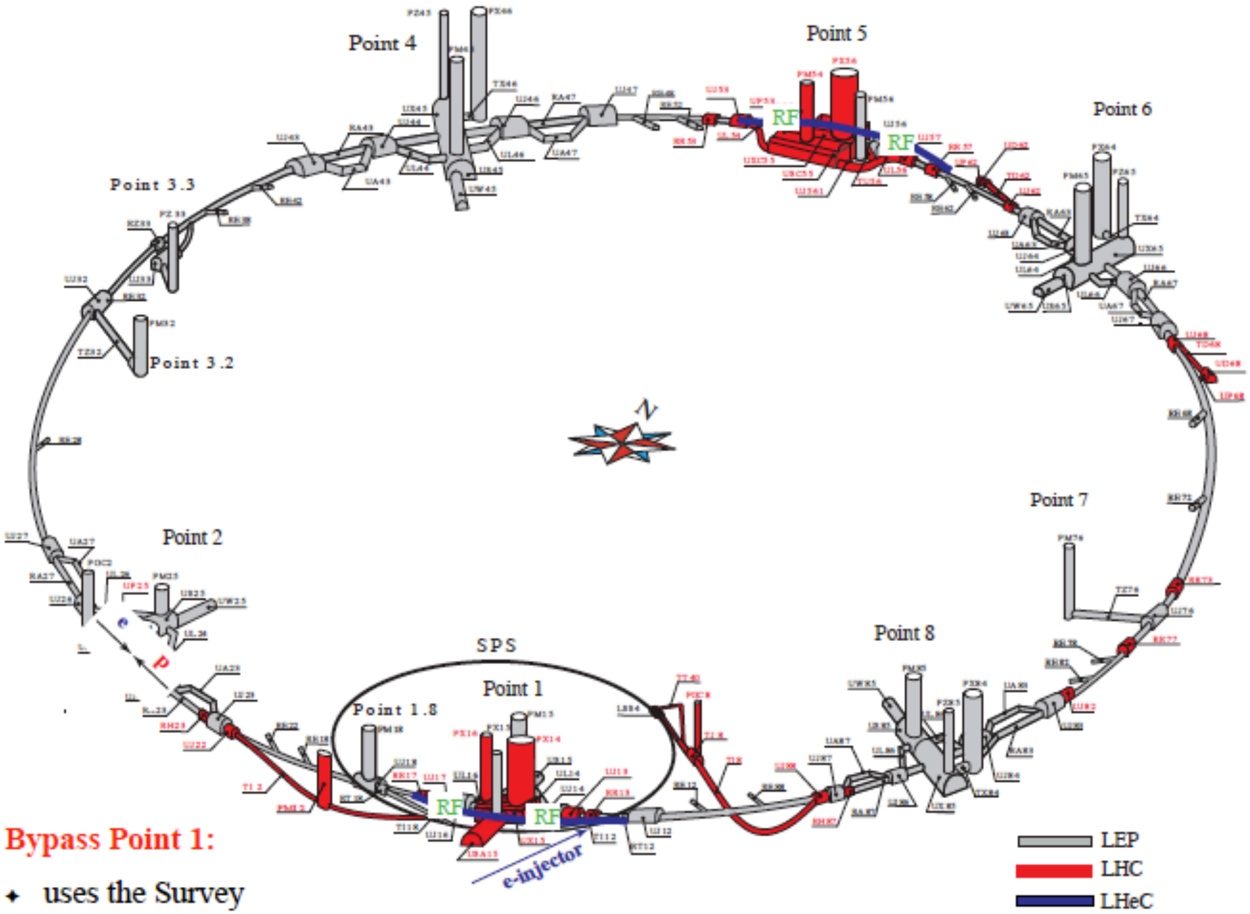
- forbidden space (usually DFBMs) induces an asymmetric lattice
- asymmetric lattice needs to be matched to the symmetric LHC lattice
- ➡ most choices for the LHeC lattice structure are made due to integration

Bypass Design:

- Bypasses increase the circumference of the ring
- ➡ Compensation of the increase in circumference by placing the electron ring 0.61 cm to the inside of the LHC (Idealized Ring)

Bypass Point 5:

- adjustment of the circumference by varying the separation
- Δ=20.56 Meter



Bypass Point 1:

- uses the Survey Gallery
- Δ=16.25 Meter

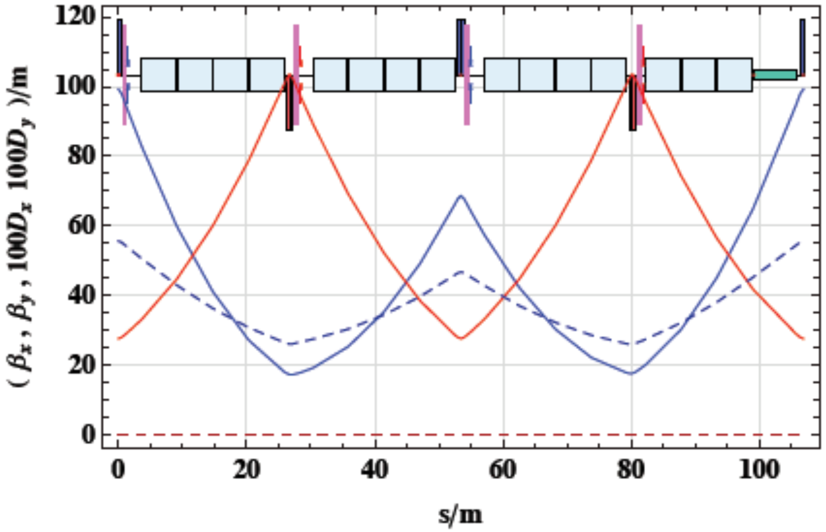
Miriam Fitterer

Arc Module

23 arc cells, L_{Cell}=106.881 m

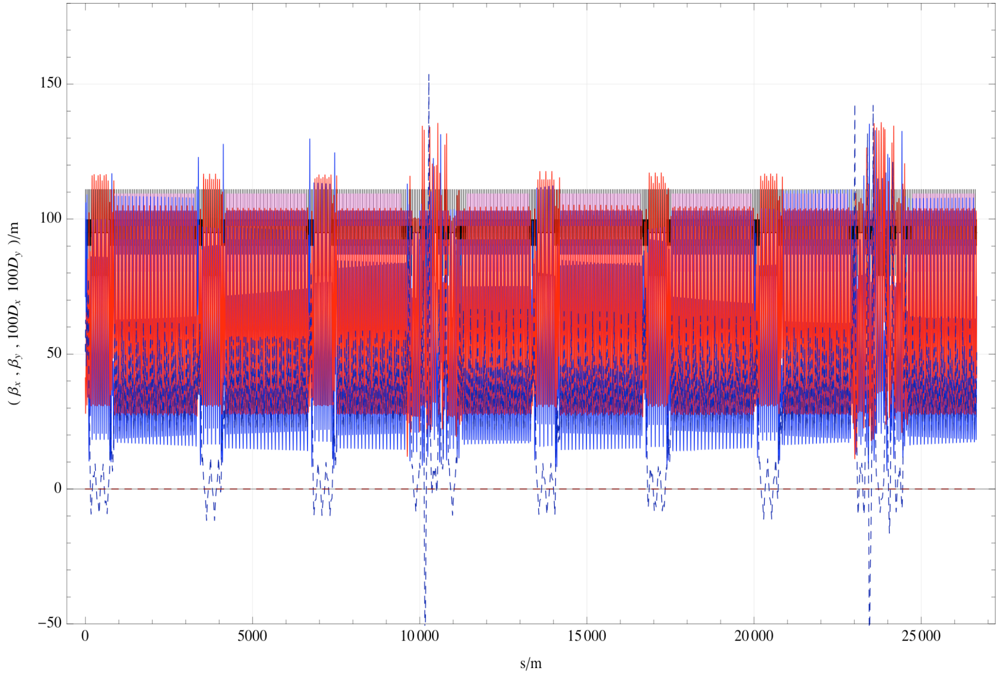
Optics:

Beam Energy	60 GeV
Phase Advance per FODO Cell	$\approx 90°/60°$
Cell length	106.881 m
Dipole Fill factor	0.75
Damping Partition $J_x/J_y/J_e$	1.5/1/1.5
Coupling constant κ	0.5
Horizontal Emittance (no coupling)	4.70 nm
Horizontal Emittance ($\kappa = 0.5$)	3.52 nm
Vertical Emittance ($\kappa = 0.5$)	1.76 nm



Geometry:

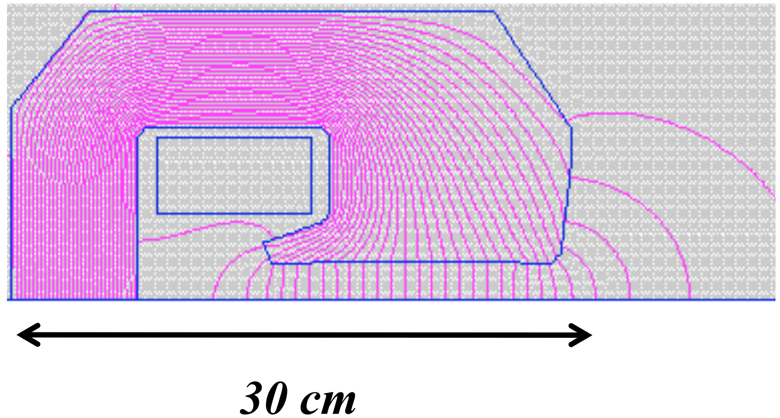
To meet the LHC geometry the dipoles must be shortened
➡ trade off between synchrotron radiation loss and geometry

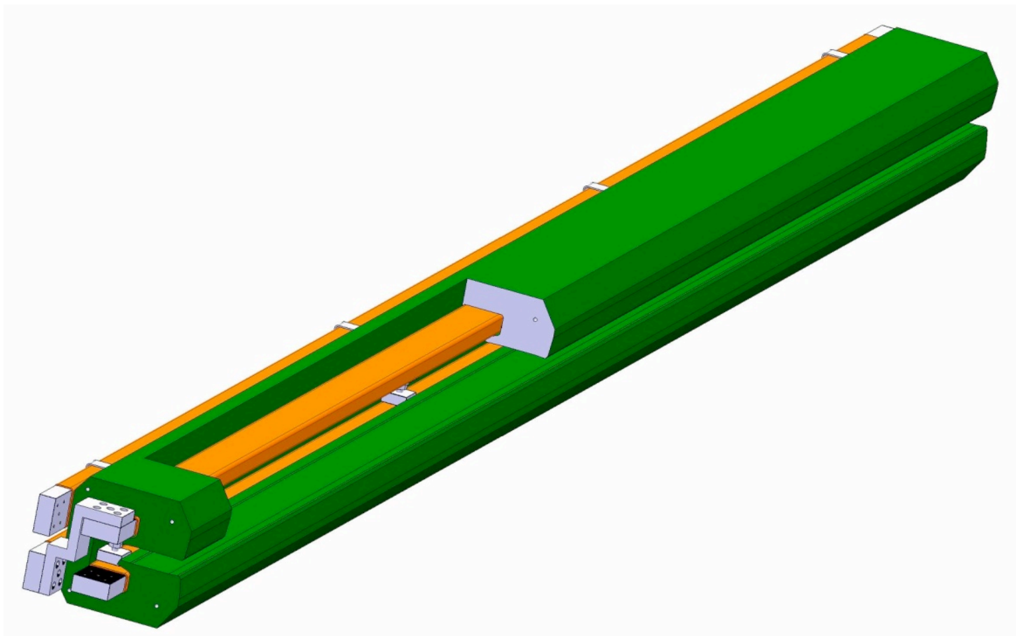


Miriam Fitterer

RR: Ring Bending

Parameters for Bending	
Beam Energy [GeV]	60
Magnetic Length [m]	5.35
Magnetic field [Gauss]	763
Number of magnets	3080
Weight [kg]	
Vertical aperture [mm]	40
Pole width [mm]	150
Number of coils	2
Number of turns/coil	1
Current [A]	1300
Conductor material	aluminum
Magnet Inductance [mH]	0.15
Magnet Resistance [mΩ]	0.20
Power per magnet [W]	340
Cooling	air

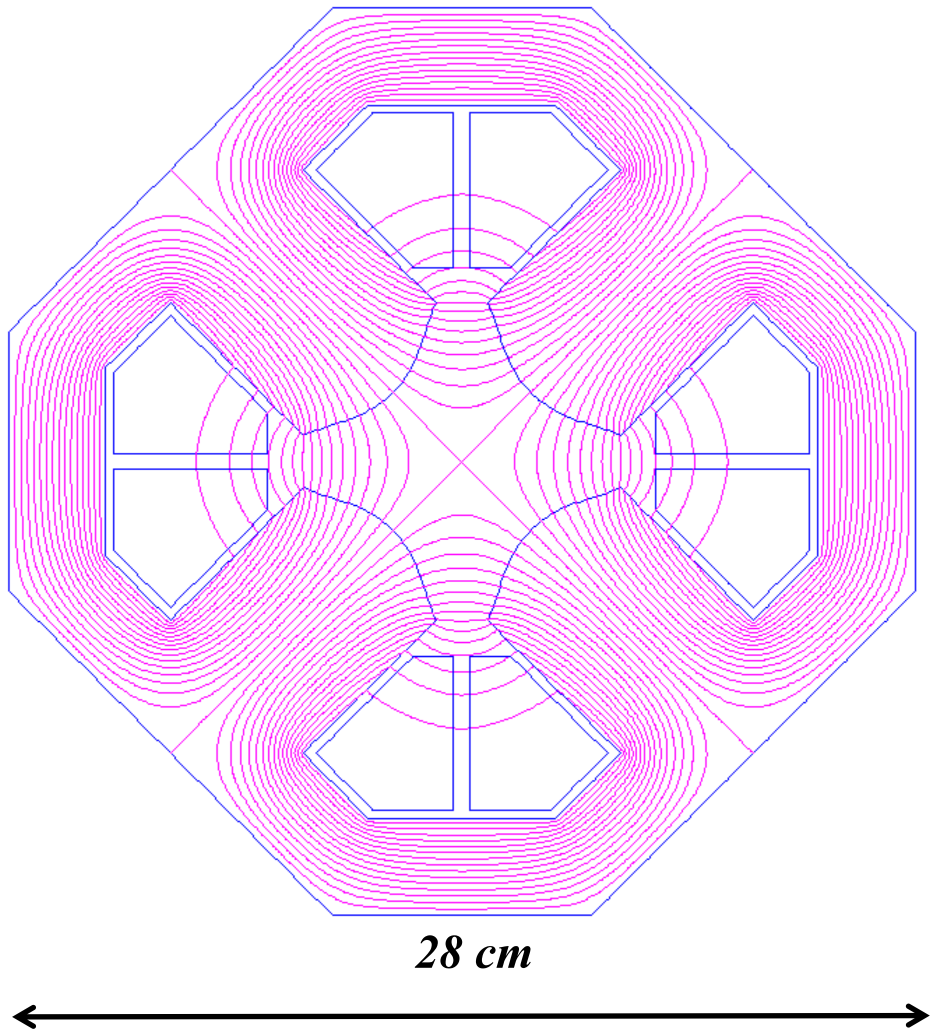




Davide Tommassini

RR: Ring Quadrupoles

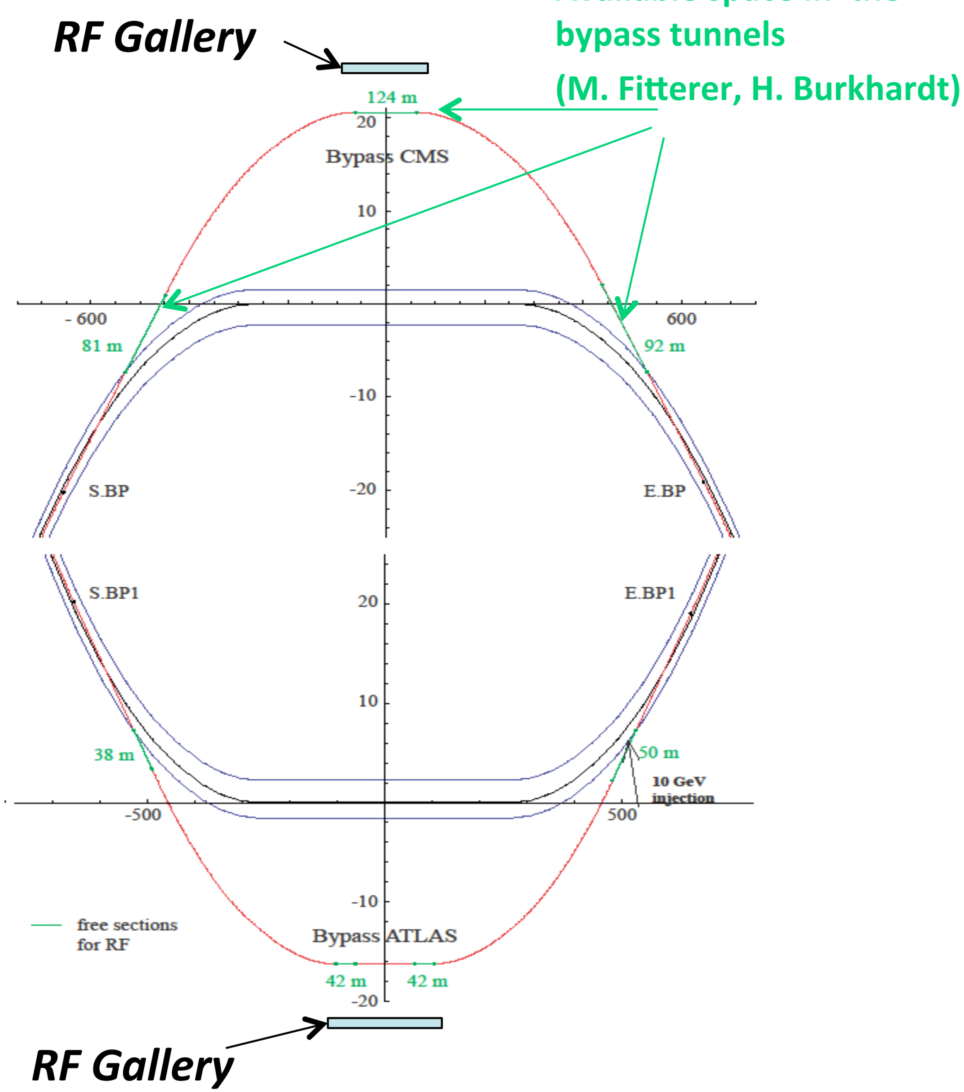
Parameters for Quadrupoles	
Number of magnets	736
Aperture radius [mm]	30
Field gradient [T/m]	10.5
Magnetic Length [mm]	1000
Yoke length [mm]	980
Total length [mm]	1200
Weight [kg]	500
Number of turns/pole	1
Current [A]	3850
Conductor material	copper
Current density [A/mm^2]	2.5
Resistance [mΩ]	0.12
Power [kW]	1.8
Inductance [mH]	0.05
Cooling	water/air



made with one-piece laminations

Davide Tommassini

RF Layout for Ring-Ring Option



Ed Ciapala

Energy = 60 GeV, 400 MHz RF, 500 MV, 60 MW.

Like 400 MHz LHC RF (3 MV/cavity)

168 cavities, 3MV/cavity => 42 LHC style 4-cav

SC modules (8m long) => 168 m + 20%

- *350 kW/cavity, within existing LHC*
- *variable power coupler ratings*

=> RF Config: 168 klystrons, or 84 700 kW klystrons, each driving 2 cavities

***Simplest option*:**

Install only in the IR bypass sections

208 m available

15 x 12m Cryomodules ***Total***

9 at CMS bypass = 108m

2 x 3 at ATLAS bypass = 2 * 36m

Total 180 m

This layout forces the 60 klystron option

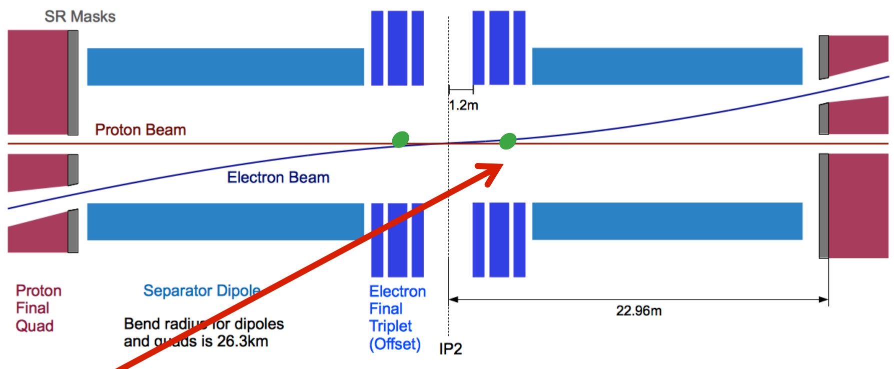
LHeC Ring-Ring Option ***IR-Optics***

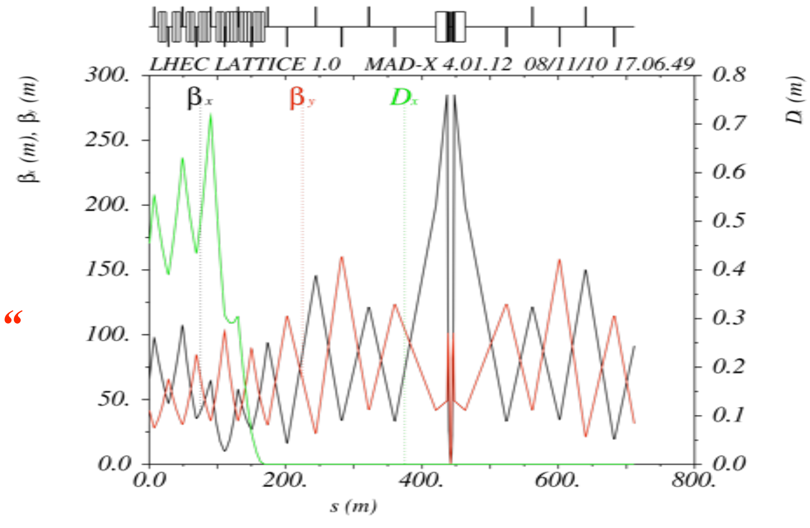
10° Optics:

Luminosity limited by β_{max} at first proton quadrupole

→ determines the quadrupole design
→ determines the separation scheme

→ determines the crossing angle (parasitic encounters)





Luke Thomson

Goal: "somehow in the range of L= 10^{33} "

$\sigma_x = 30\ \mu m$ $\quad \beta_{xp} = 1.8\ m$ $\quad \beta_{xe} = 18\ cm$

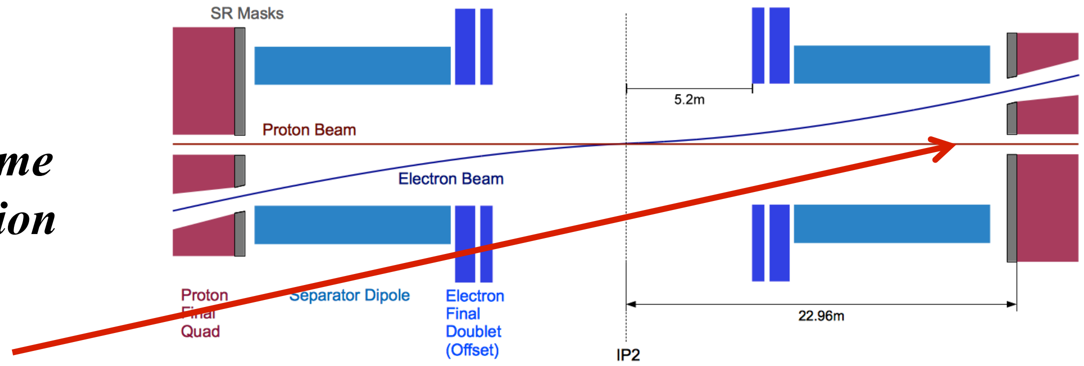
$\sigma_y = 15.8\ \mu m$ $\quad \beta_{yp} = 0.5\ m$ $\quad \beta_{ye} = 10\ cm$

LHeC Ring-Ring Option
IR-Optics

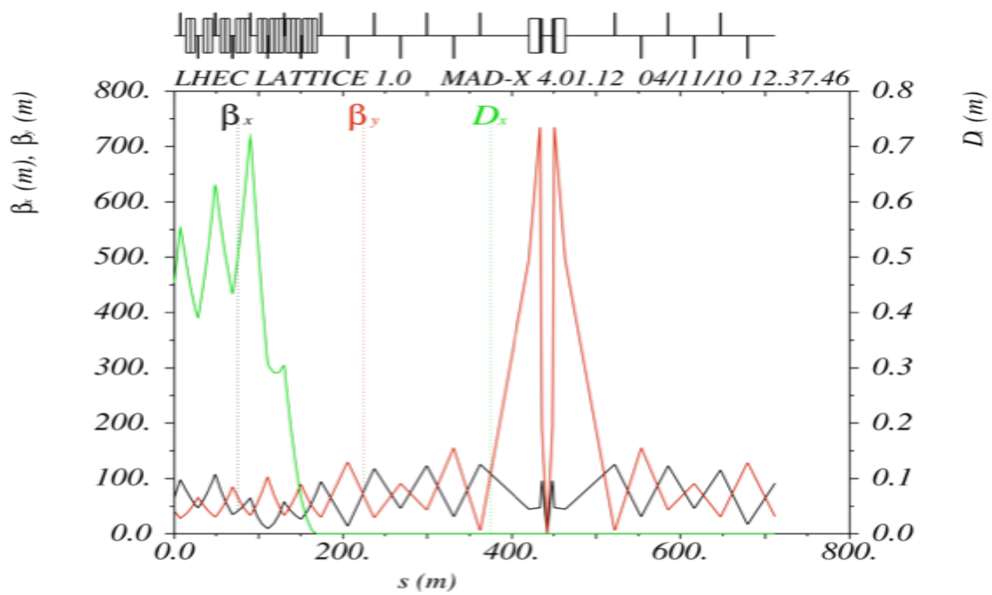
1° Optics:

Luminosity limited by β_{max} at first proton quadrupole

... but more by (late) separation scheme
→ determines the synchrotron radiation power



Goal: "as close as possible to the 10°option"



$$\sigma_x = 44.7\ \mu m \quad \beta_{xp} = 3.9\ m \quad \beta_{xe} = 40\ cm$$
$$\sigma_y = 22.4\ \mu m \quad \beta_{yp} = 1.0\ m \quad \beta_{ye} = 20\ cm$$

Luke Thomson

Synchrotron Radiation in the IR

10 degree Option

10 Degree RR Option: Parameters	
Characteristic	Value
E [GeV]	60
I [mA]	100
B [T]	0.025
θ_c [mrad]	1
Separation** [mm]	50.1
γ/s	4.76×10^{18}

10 Degree RR Option: Power and Critical Energy		
Element	Power [kW]	Critical Energy [keV]
DL	4.5	60
QL3	5.1	307
QL2	4.3	216
QL1	0.5	87
QR1	0.5	88
QR2	4.3	216
QR3	5.2	304
DR	4.5	60
Total/Avg	28.9	124

10 Degree RR Option: Comparison				
	Power [kW]		Critical Energy [keV]	
	Geant4	IRSYN	Geant4	IRSYN
Total/Avg	28.9	31.4	124	132

Nathan Bernard

*RR Option 1 degree**

1 Degree RR Option: Parameters	
Characteristic	Value
E [GeV]	60
I [mA]	100
B [T]	0.0435
θ_c [mrad]	1
Separation** [mm]	51.3
γ/s	5.73×10^{18}

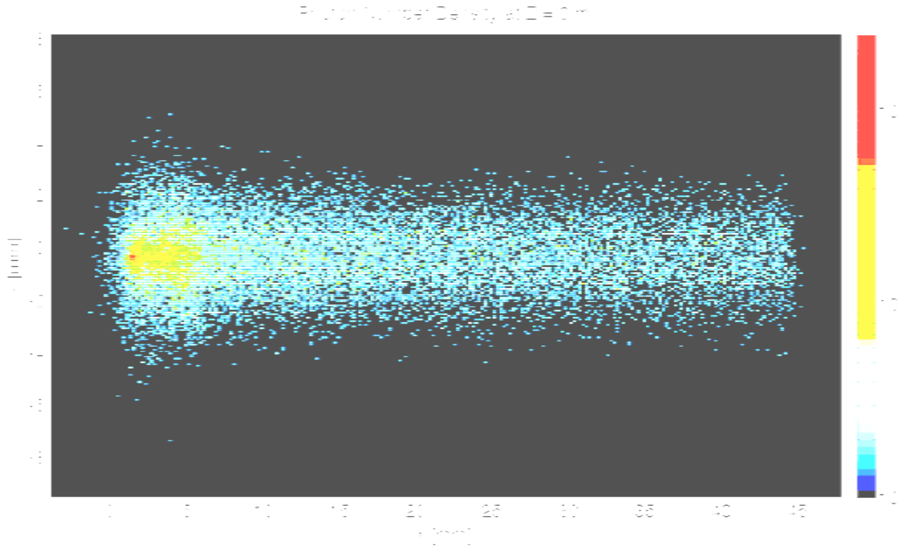
1 Degree RR Option: Power and Critical Energy		
Element	Power [kW]	Critical Energy [keV]
DL	10.8	104
QL2	6.1	316
QL1	5.2	283
QR1	5.2	288
QR2	6.1	313
DR	10.8	104
Total/Avg	44.2	156

1 Degree RR Option: Comparison				
	Power [kW]		Critical Energy [keV]	
	Geant4	IRSYN	Geant4	IRSYN
Total/Avg	44.2	44	156	153

****Simulations use optics created by L. Thompson***

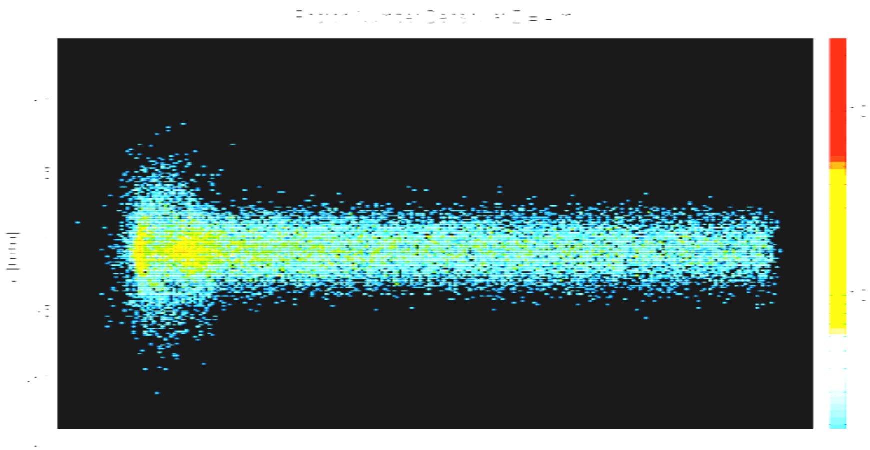
***Separation refers to the separation between the interacting beams at the face of the proton triplet*

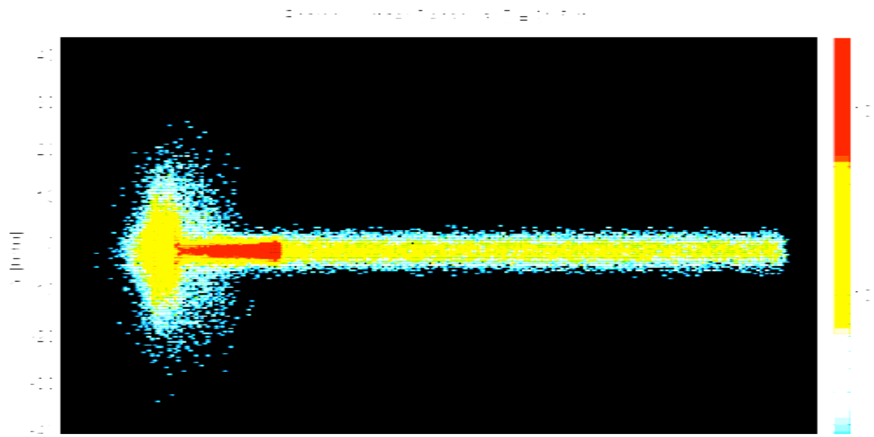
Photon Number Density Growth in Z



• ***The focusing and bending of the beam determines the photon distribution as it traverses in Z.***

• ***Quadrupole fields add more significant Y component, and change density in X.***



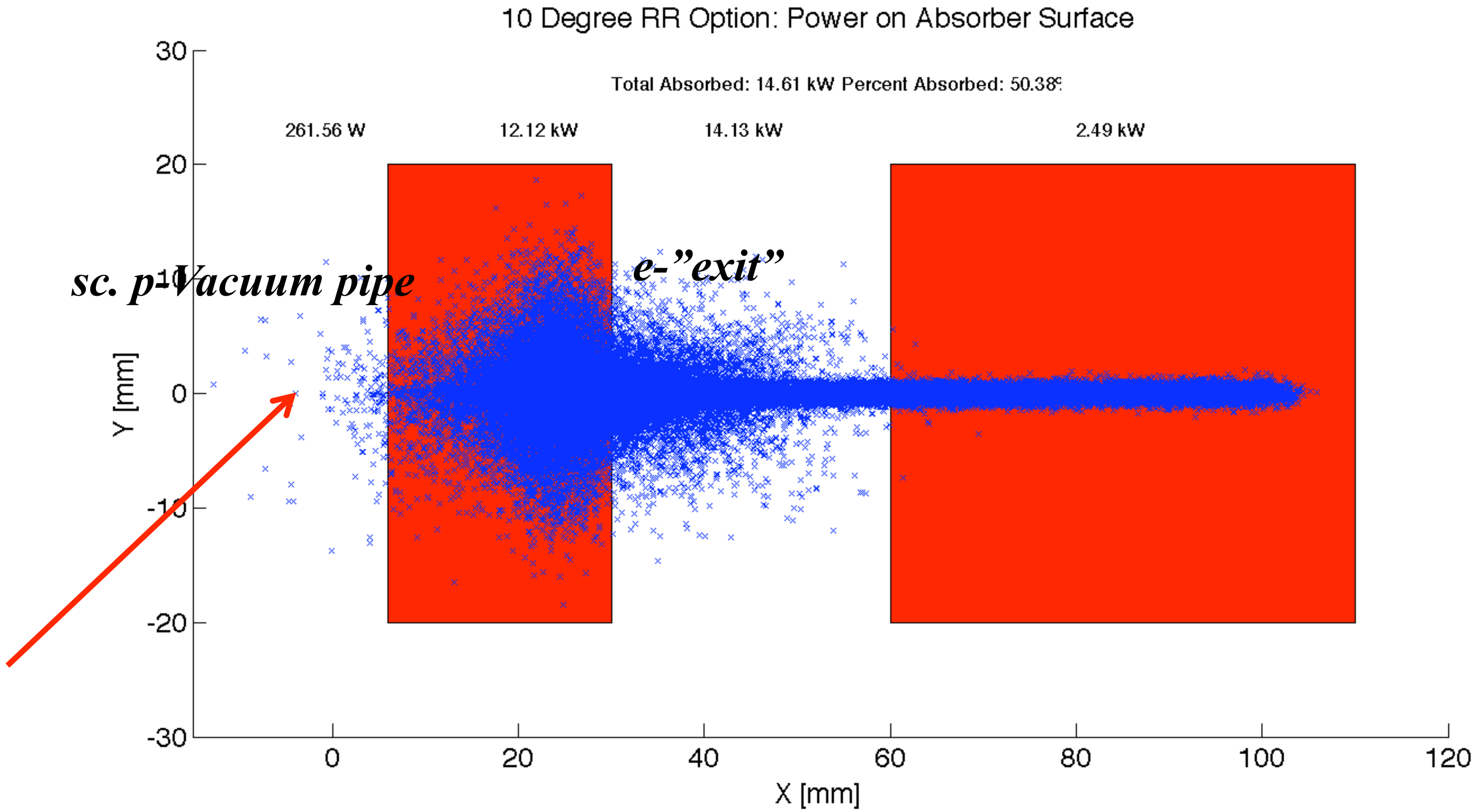


Nathan Bernard

Power on Absorber

10 degree Option

- *14.61 kW or 50.38% will hit the absorber surface.*
- *Backscattering hasn't been taken into account.*
- *14.39 kW will continue into the proton triplet.*

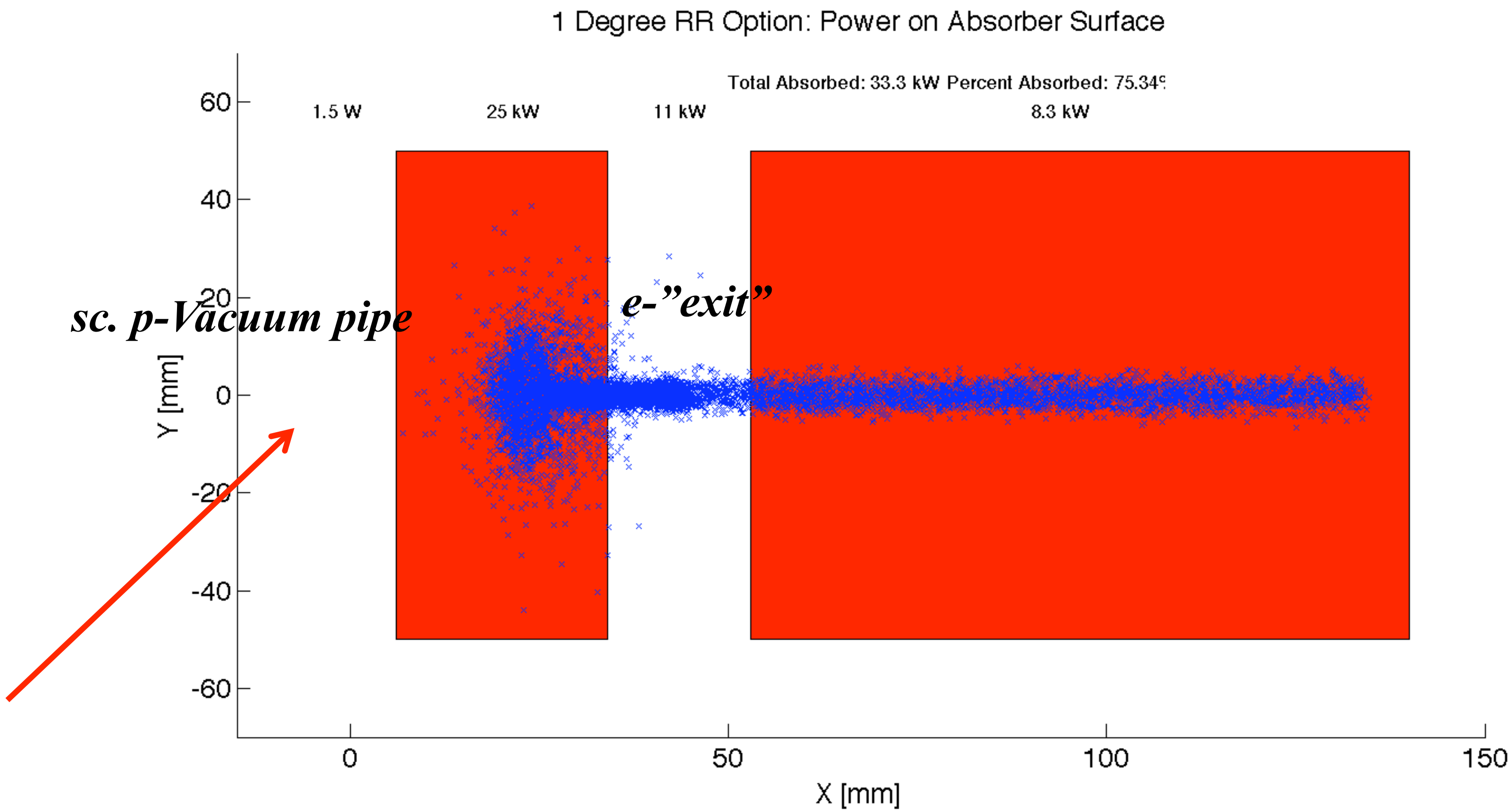


Nathan Bernard

Power on Absorber

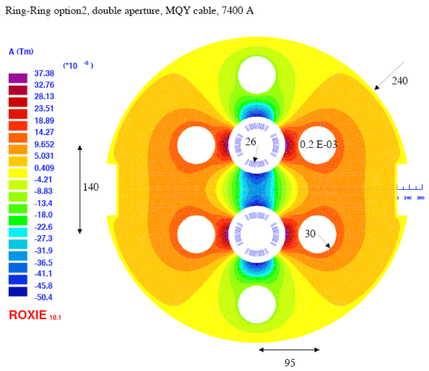
1 degree Option

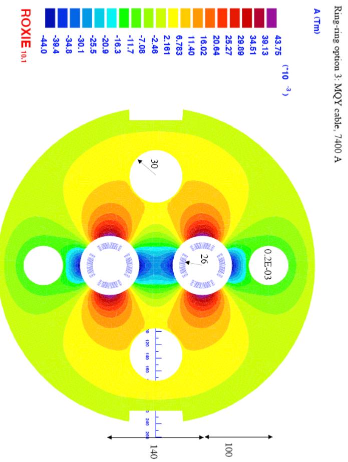
- *33.3 kW or 75.34% will hit the absorber surface.*
- *Backscattering hasn't been taken into account.*
- *11 kW will continue into the proton triplet.*

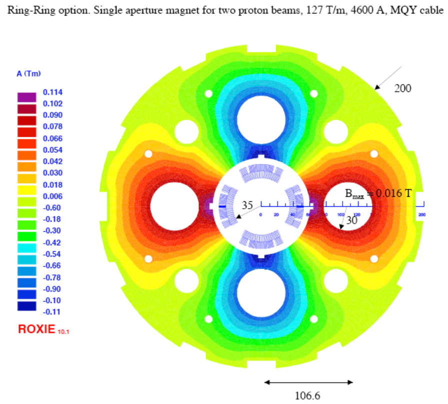


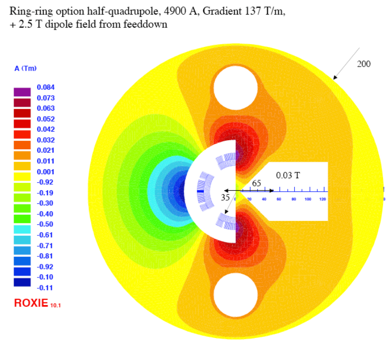
Nathan Bernard

Four Remaining Options for Ring-Ring





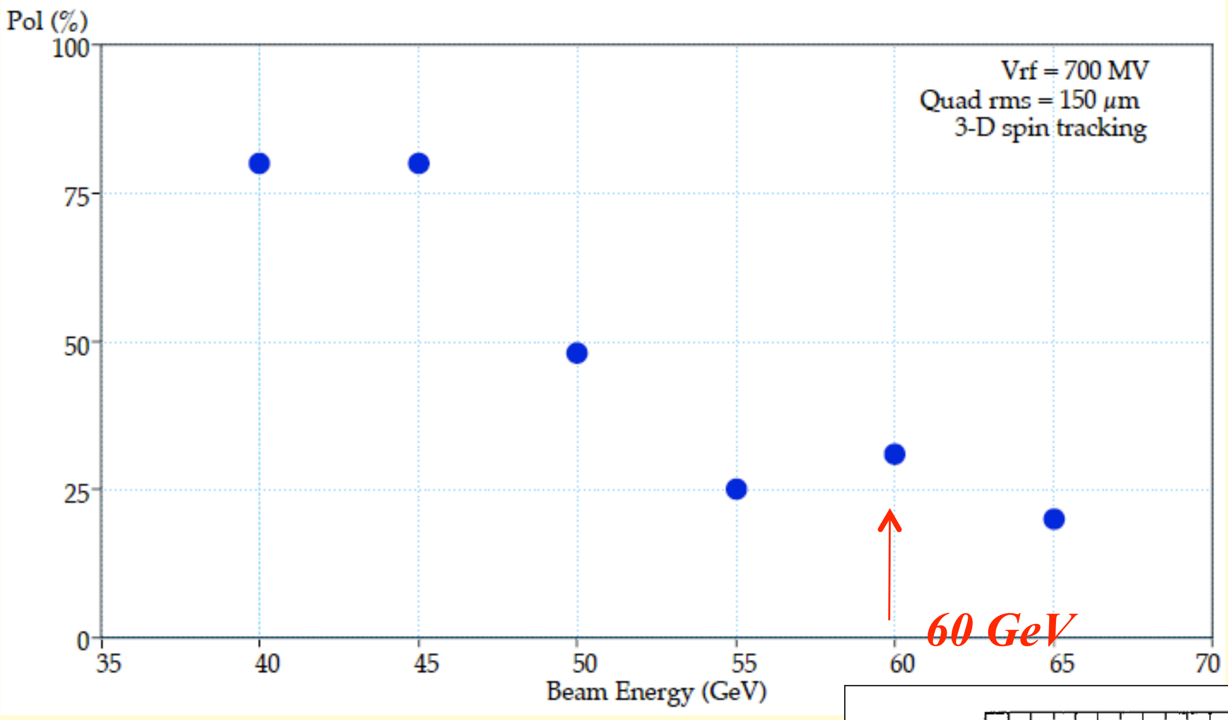


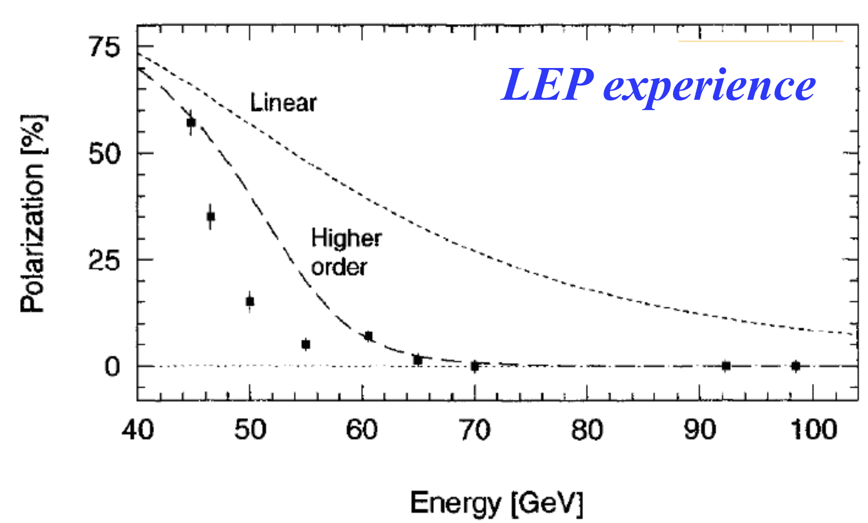


Double aperture (vertical)	Double aperture (horizontal)	Single aperture (for pp) (Q2)	Mirror (Q1)
7400 A MQY cable	7400 A MQY cable	4600 A MQY cables	4900 A MQY cables
95 mm Septum	100 mm	107 mm	65 mm
0.2 E -3 T Fringe field in e-pipe	0.2 E -3 T	0.016 T	0.03 T

Stephan Russenschuck

Polarization *vs* Energy

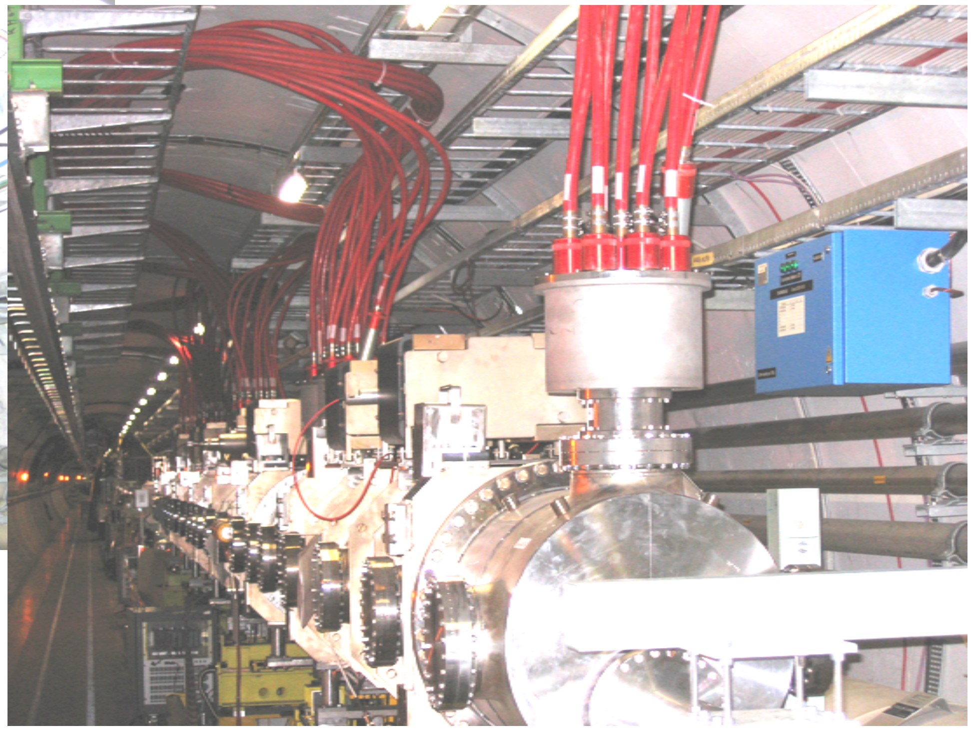




– Can run at lower energy
  - but τ_{ST} becomes 5 h at 45 GeV!

Uli Wienands

Integration and machine protection issues



- Installation of an e ring is challenging
- Modifications of the existing installations will be necessary
- No show stopper
- Activation of Tunnel and Hardware

Karl-Hubert Mess

Production time:

-Ring-Ring: ca. 4000 magnets (3000 dipole & 1000 quadrupoles)
-Linac-Ring: ca. the same number of magnets for ER option!

- ➔ *LHC transfer lines (ca. 6km); 350 warm magnets in 3 years (10/month)*
- ➔ *LHeC magnet production requires industrial production*
- ➔ *requires several contractors and production lines: pre-series and QA!*
- ➔ *1-2 years of pre-series production.*
- ➔ *assume 80 magnets / month (8 * TL) ➔ 5 years of production*

  Total of ca. 10 years for magnet production time?

Requirements:

- ➔ *The above work can not be done with the current arrangement and requires a focused team and sufficient resources*

Conclusion:

- ➔ *Decision on LHeC option should be taken by 2012*

LHeC Ring-Ring Option

Main Parameters

	Electrons	Protons		
Energy	60 GeV	7 TeV		
Current	100mA	860mA		
Part. per Bunch	$2*10^{10}$	$1.7*10^{11}$		
ε_x	$5*10^{-9}$ m	$5*10^{-10}$ m		
ε_y	$2.5*10^{-9}$ m	$5*10^{-10}$ m		
P_γ	43.5 MW			
	1 degree		10 degree	
	Electrons	Protons	Electrons	Protons
β_x	40cm	4.05 m	18 cm	1.8 m
β_y	20cm	0.97 m	10 cm	0.5 m
σ_x	45μm		30μm	
σ_y	22μm		15.8μm	
L_0	$8.5*10^{32}$		$1.8*10^{33}$	
crossing angle	0.7mrad		1mrad	
loss factor	92 %		75%	
P_γ	44kW		28kW	
L_{eff}	$7.9*10^{32}$		$1.34*10^{33}$	

LHeC Ring-Ring Option

Summary

Bernhard Holzer

highly motivated and talented team
excellent work
... from the seniors
as well as
... from the new comers

a lot of progress and encouraging results

Than'x to all of you !!!