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Design Challenges of the 2 mrad Scheme

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Outline

- Luminosity at 2 mrad Crossing
- Orbit and Dispersion matching in 4 T Field
- Final Doublet Magnets
- Extraction Optics
  - Dipoles and Quadrupoles
  - Beam losses handling
  - Tunnel Length
  - Costs
- Post IP diagnostics

Luminosity at 2 mrad crossing-angle

$$\frac{\mathcal{L}}{\mathcal{L}_0} = \frac{1}{\sqrt{1 + \left(\tan\left(\frac{\alpha}{2}\right)\frac{\sigma_z}{\sigma_x^*}\right)^2}}$$

		Nominal	Large Y	Low P	High L	TESLA	Med Q P
σ_x	nm	626.5	495	452	452	554	443
σ_z	µm	300	500	200	150	300	200
L/L0	%	0.90	0.70	0.91	0.95	0.88	0.91

- Beam-beam effect usually increases the luminosity loss
- Crab-crossing via dispersion matching will depend on E vs. z linear correlation

Orbit and Dispersion matching in 4 T solenoid

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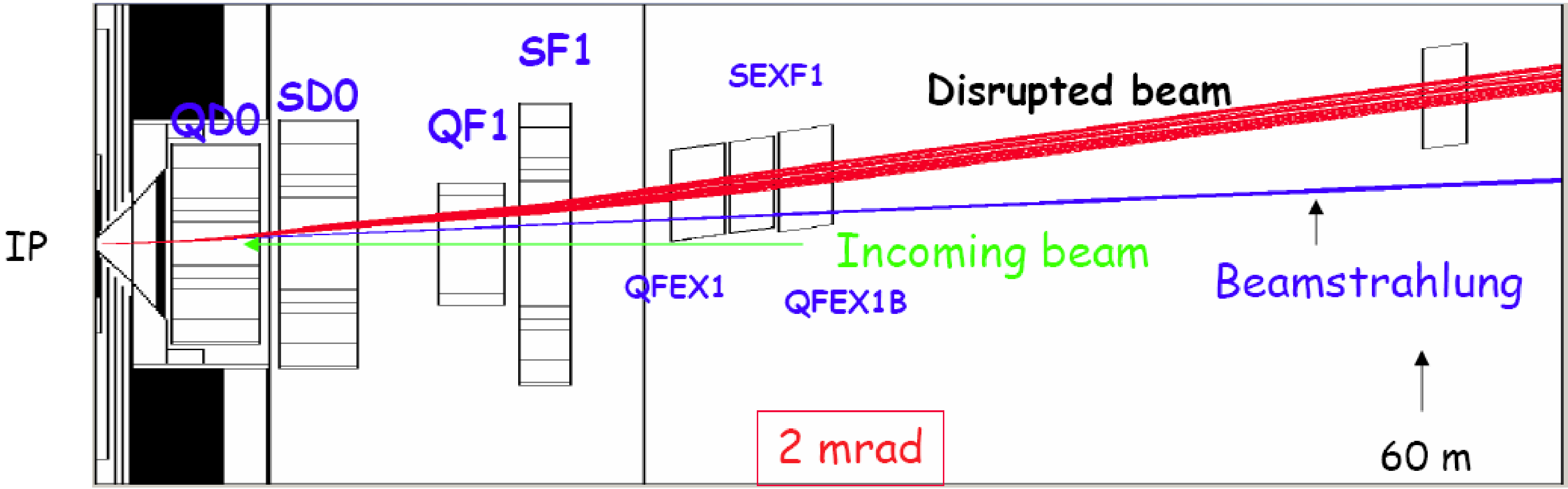
Single beam $\delta y^* = \delta(Dy)^* = \frac{1}{2}\,(L_S/2)^2\,(B_S\,\alpha/2)\,/\,(B\rho)$

		LDC	SiD	GLD
B_S	T	4	5	3
L_S	m	7	5.54	9
δy^*	µm	29.4	23.0	36.5
σ^*_y	nm	5.7	8.1	3.8

I hope I am wrong ; 14 mrad is 7 times more !!

Final Doublet Magnets

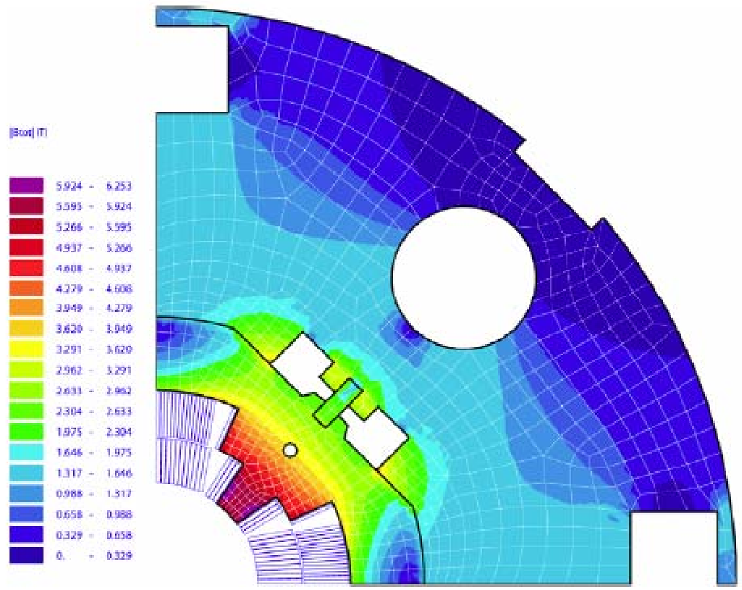


Magnet type	Bore radius, mm	Field at radius, T	Eff. length, m	type
Quad QD0	35	5.6	2.5	SC
Sextupole SD0	88	4.0	3.8	SC
Quad QF1	10	0.68	2.0	NC
Sextupole SF1	112	2.12	3.8	NC
SeptumQEX1A	113	1.33	3.0	NC

cf. Robert and Gian Luca 's discussion

Final Quadrupole QD0 from LHC IR

QD0 Design (Vl. Kashikhin)



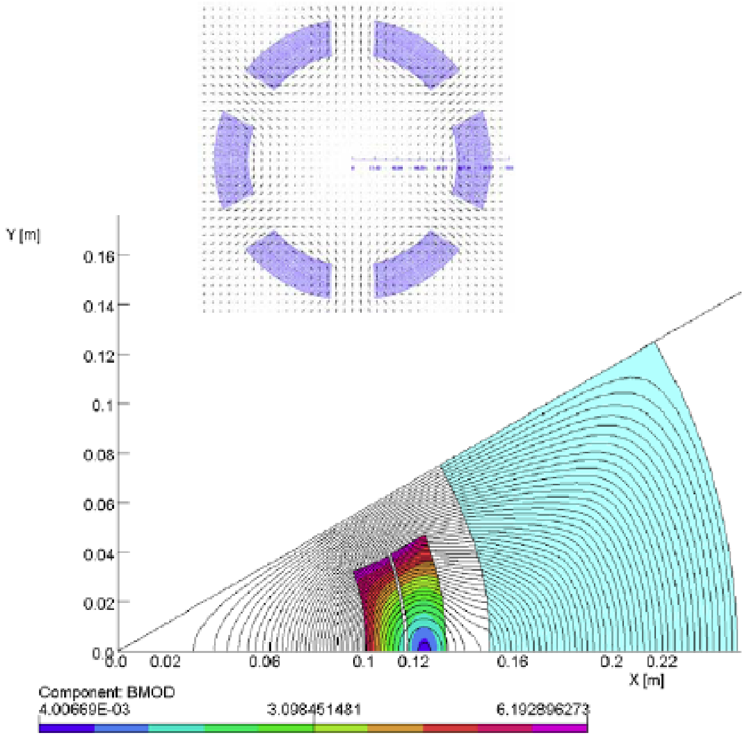
Parameter	Unit	Value
G_{nom}	T/m	160.0
I_{nom}	kA	8.8
B_{p_nom}	T	6.3
$B_{p\_q}(I_{nom})$	T	9.9
Field margin	T	3.6

QUESTIONS:
- Is there an Iron yoke and do we need it ?
- Field margin in LDC, SiD, and GLC solenoid (0.9 T in 2.7 T)?
- Mechanical support and stability in 1 mrad angle w.r.t. B0 axis ?
- Is Nb3Sn the way to go ?

Final Sextupole SD0

Design close to LHC IR Quadrupoles

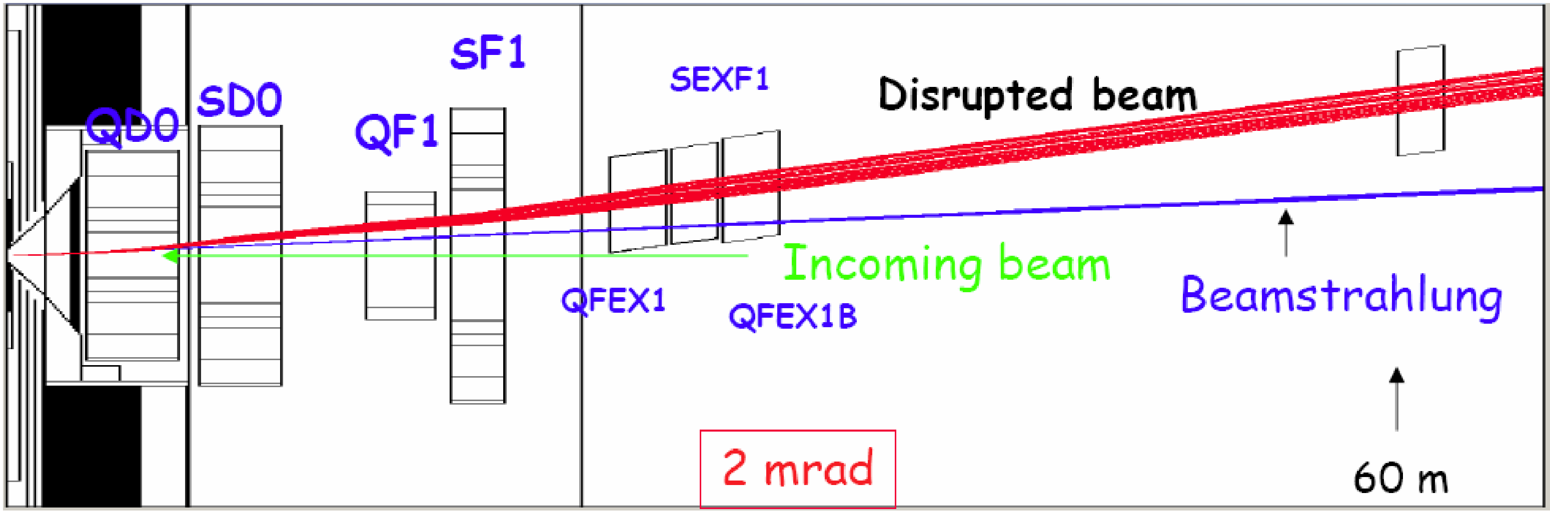
Coil ampere-turns	343 kA
Current	7 kA
Calculated strength	519.2 T/m^2
Coil maximum field	6.2 T
Iron core field (max)	3.8 T
Field energy	376 kJ/m
Lorentz force, Fx	56.5 t/m
Lorentz force, Fy	-83.2 t/m
Number of turns	22(inner) + 27(outer)
NbTi Superconducting cable	LHC IR inner
Jc at B=5 T, 4.2	2750 A/mm^2
Strand diameter	0.808 mm



QUESTIONS (same):

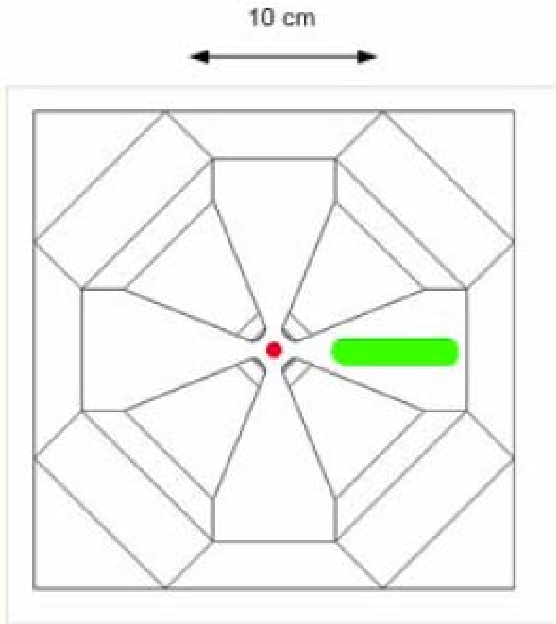
- Is there an Iron yoke and do we need it ?
- Field margin in LDC, SiD, and GLC solenoid (0.9 T in 2.7 T)?
- Mechanical support and stability in 1 mrad angle w.r.t. B0 axis ?
- Is Nb3Sn the way to go ?

Final Quadrupole QF1 and Sextupole SF1



- Assuming warm magnets, can one design them with horizontal clearance apertures, i.e. no yoke in the x > 0 half-plane ?

QF1



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Extraction diagnostics dipoles

Present design assumes 49 dipoles, 400 mm full gap, 2 m long, 0.42 T @ 250 GeV beam energy, per beam line

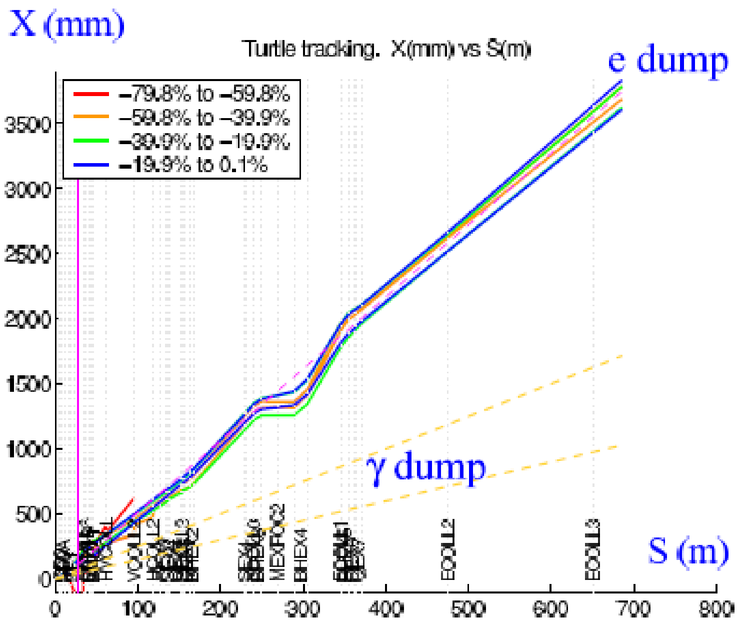
- 18 BX dipoles for horizontal extraction , with vertical gap
- 32 BY dipoles for the vertical chicanes, with horizontal gaps

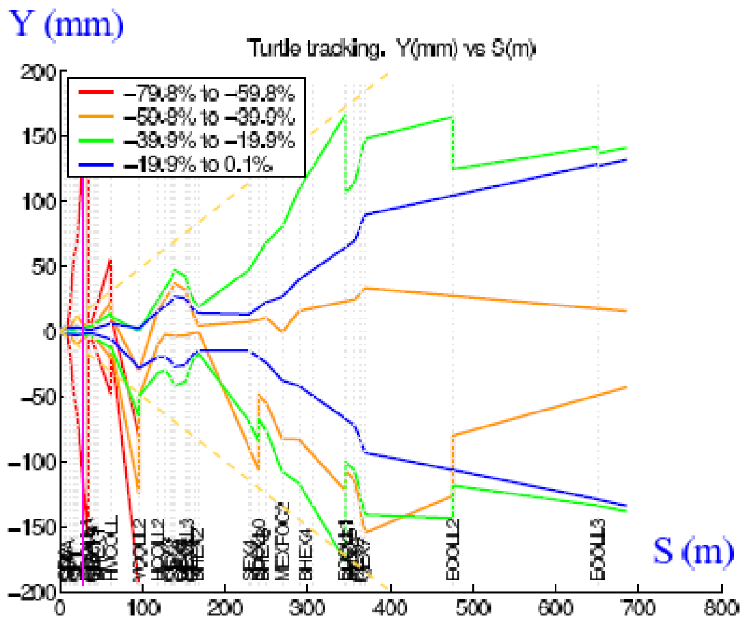
300 kW per dipole at 1 TeV c.m. ♦ 30 MW total both sides.

QUESTION #1:

- Do we need the large aperture all along ?

The magnet power scales like the aperture and energy squared





Diagnostics chicane dipoles

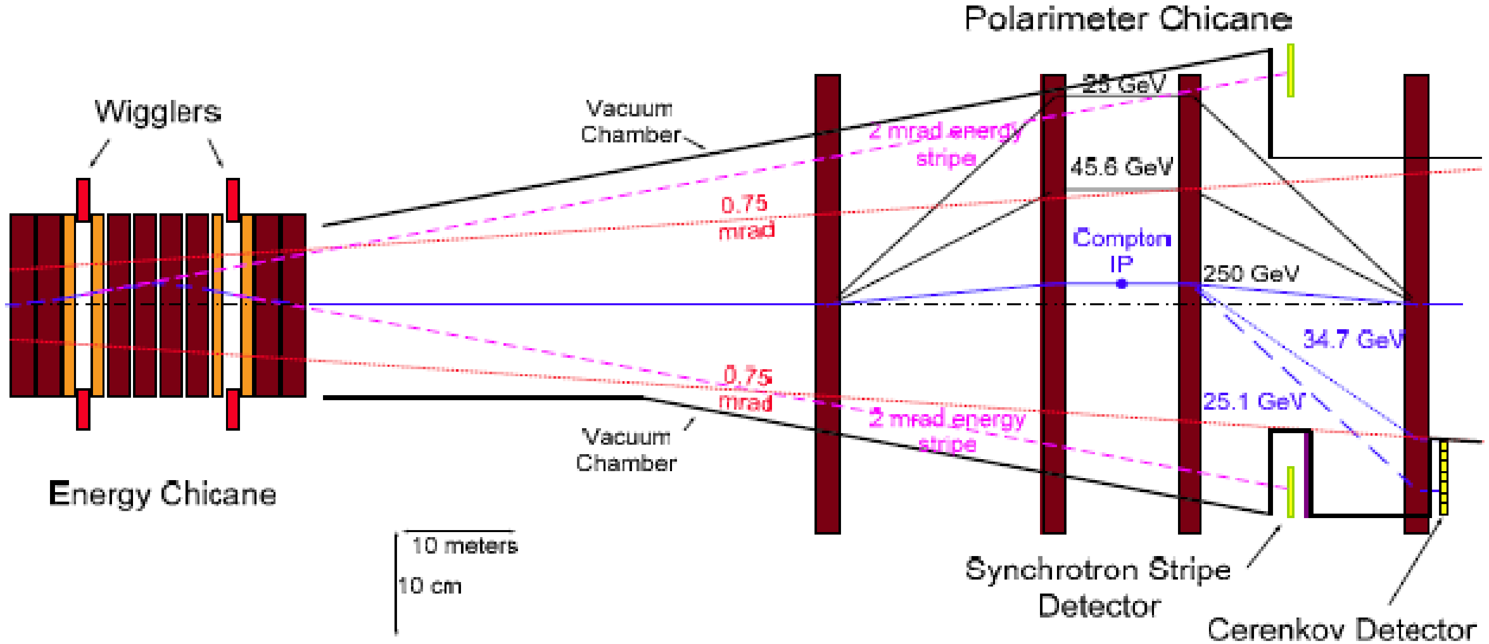


Figure 4: Diagram of the Energy Chicane and Polarimeter Chicane in the 20 mrad extraction line.

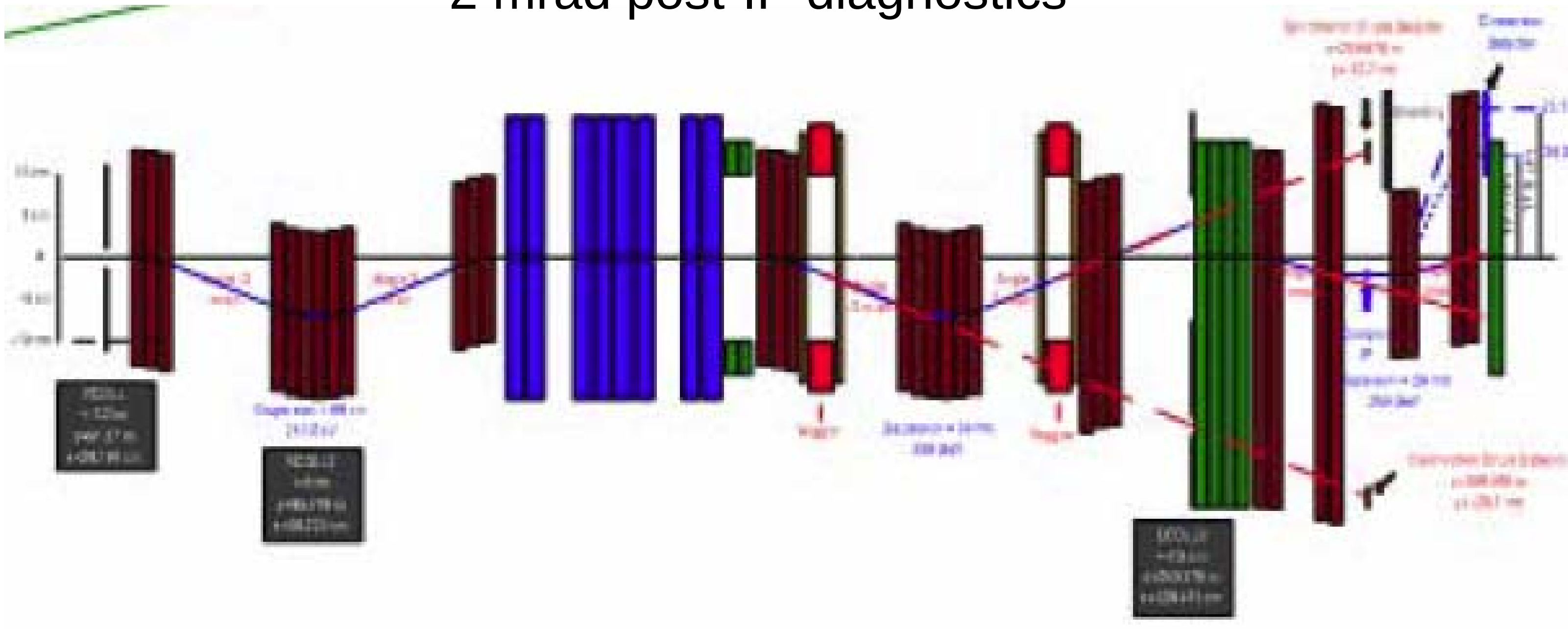
QUESTION #2:

• Do we need that many magnets ? 12 + 12 + 8 BY dipoles for the vertical chicanes with horizontal gaps

0 + 8 + 4 BY dipoles are used in the 20 mrad scheme

Diagnostics chicanes dipoles

2 mrad post-IP diagnostics



QUESTION #2 bis:

- Do we need the extra quadripoles QEX3,QEX4,QHEX5 and dipoles BHEX2, BHEX3 ?

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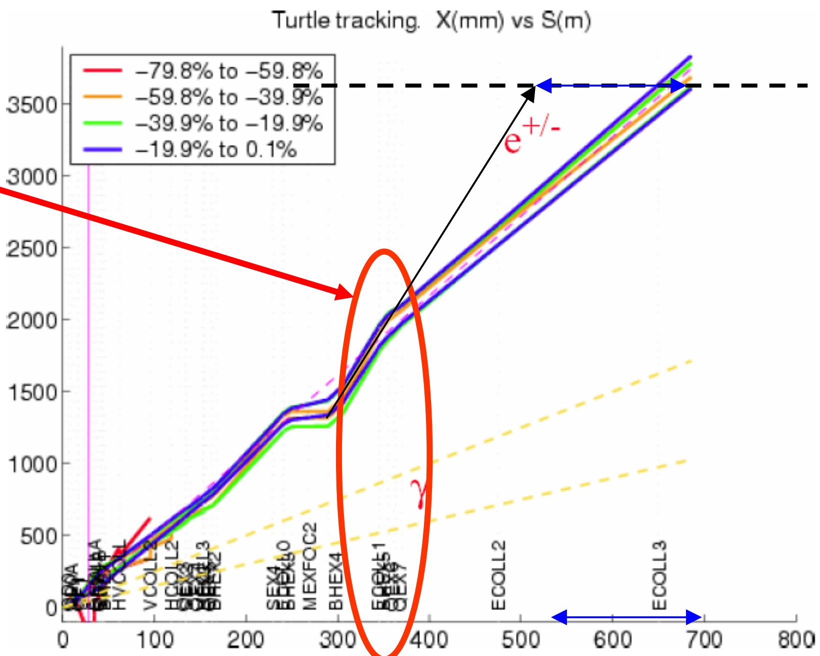
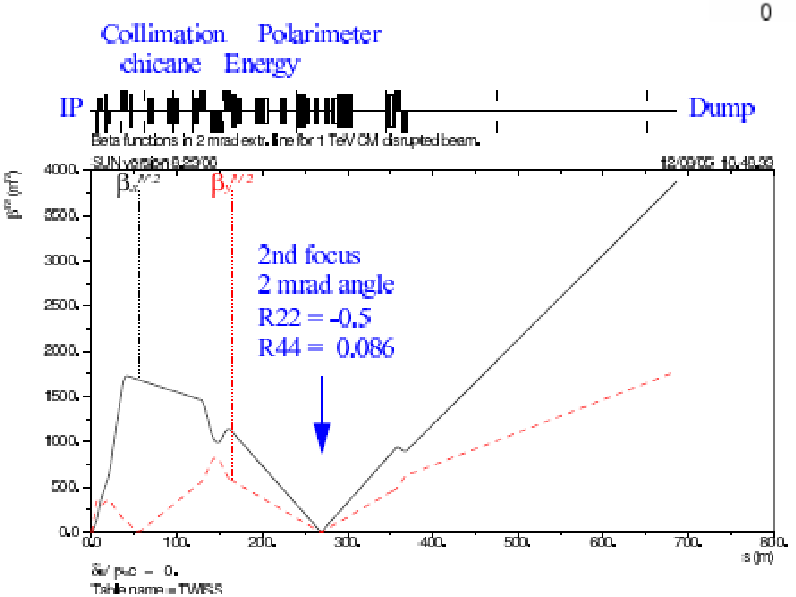
Extraction dipoles

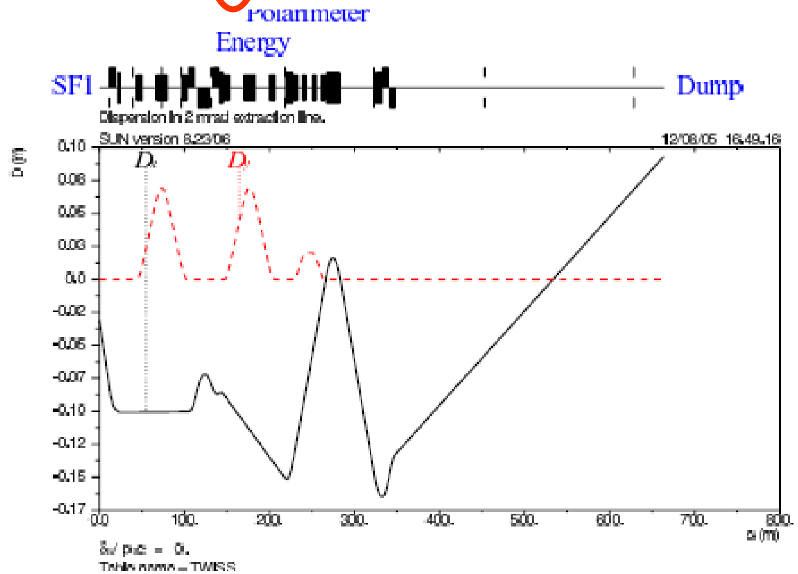
QUESTION #3:

• Do we need BHEX5 + QEX6, QEX7 doublet ?



roughly saves
150 m tunnel





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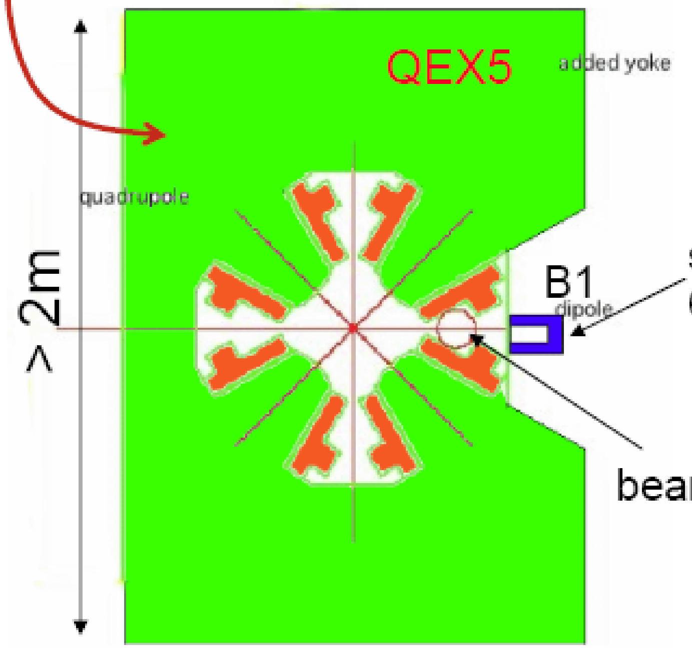
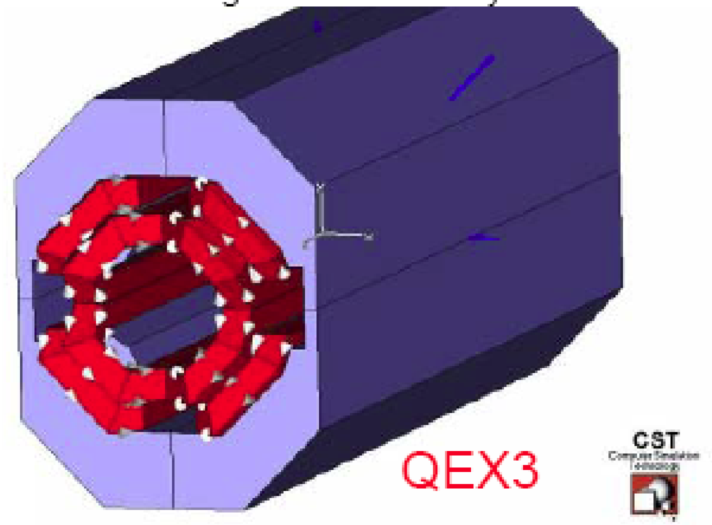
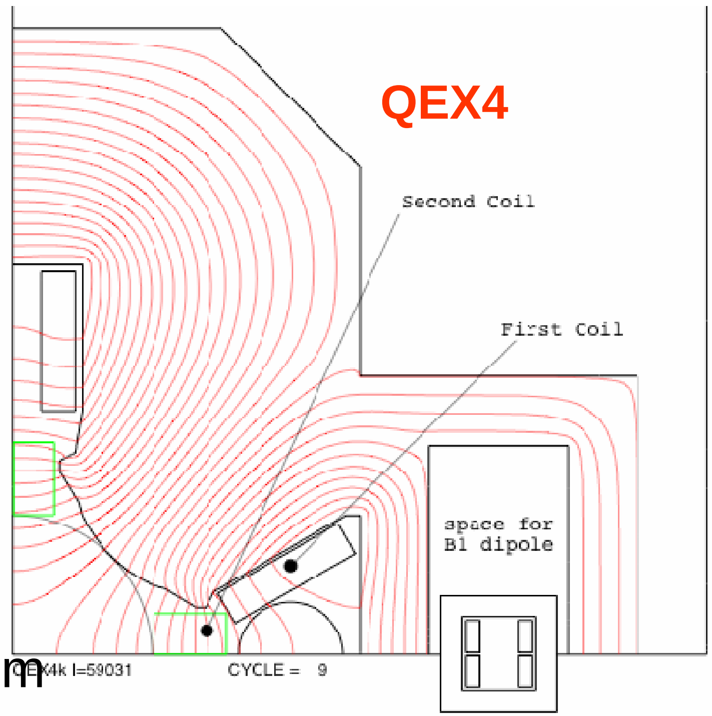
Extraction quadripoles "the unfeasible magnets" ?

Power @ 1TeV CM is 1MW/magnet. Temperature rise is very high. Use of HTS? Pulsed? Further feasibility study and design optimization are needed



Power @ 1TeV CM is 635-952 KW/magnet. Pulsed may be feasible?





Challenges:

- three useful apertures
- large aperture for extracted beam
- power consumption ~1 MW @ 1 TeV cm