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Head-on Scheme: Design and Hardware Challenges

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Outline

- Introduction
- Final doublet design
- Electrostatic separator and alternatives
- Extraction Optics : Collimation and Beamstrahlung
- Extraction Optics : Magnets
- Post IP diagnostics

Introduction : small versus large Xing angle

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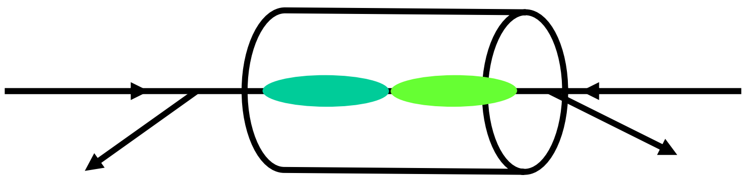
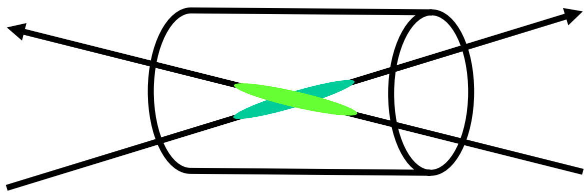
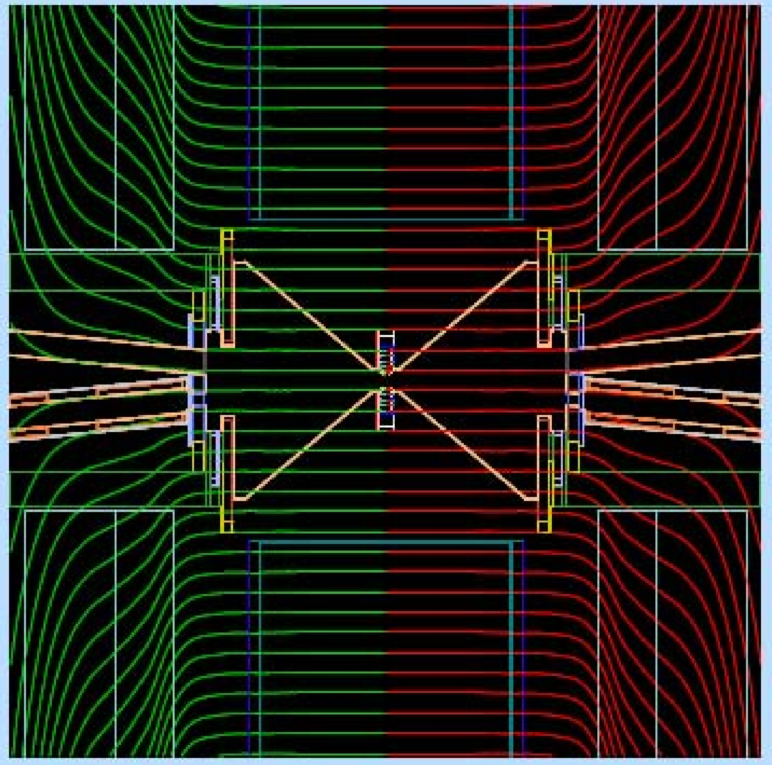
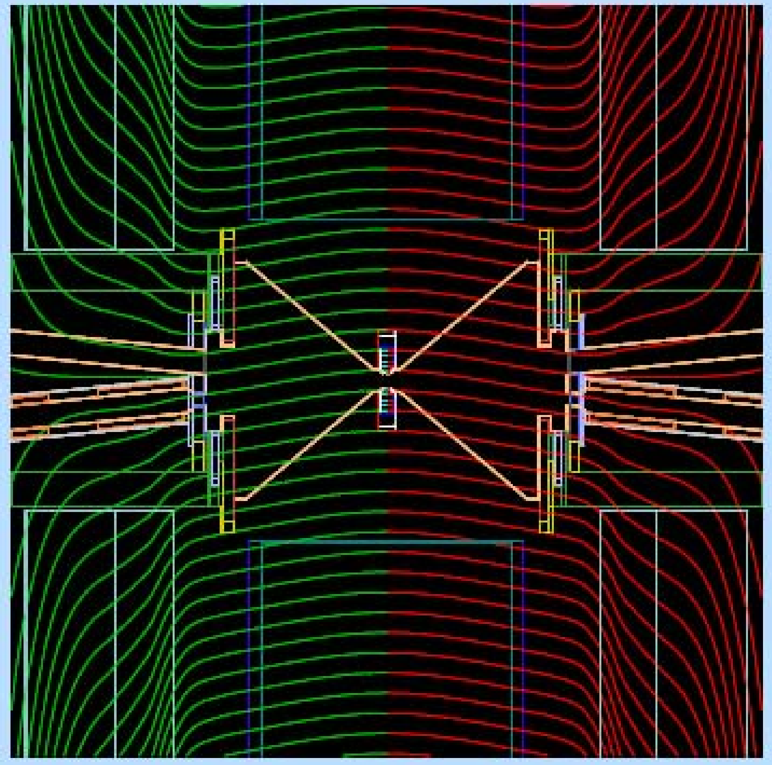
	very small 0 – 2 mrad	large 14 – 25 mrad
		
injection & extraction	• shared magnets ⇒ coupled design	• separate channels
challenges & remedies	• post-IP losses → careful optics & collimation → large magnet bores → electr. separators	• large $\mathcal{L}$ loss : < x z > → crab-crossing (R&D) • non-axial in solenoid → DID / anti-DID & post / pre-IP bumps
approach & risks	• preserve pre-IP beam • reflected background	• emphasize post-IP beam • adds pre-IP constraints

Introduction : solenoid coupled design





(A. Vogel) Plain solenoid Solenoid with DID

Realistic field maps (plus simplified quadrupoles)

Without DID IP y angle ~ 100 μrad

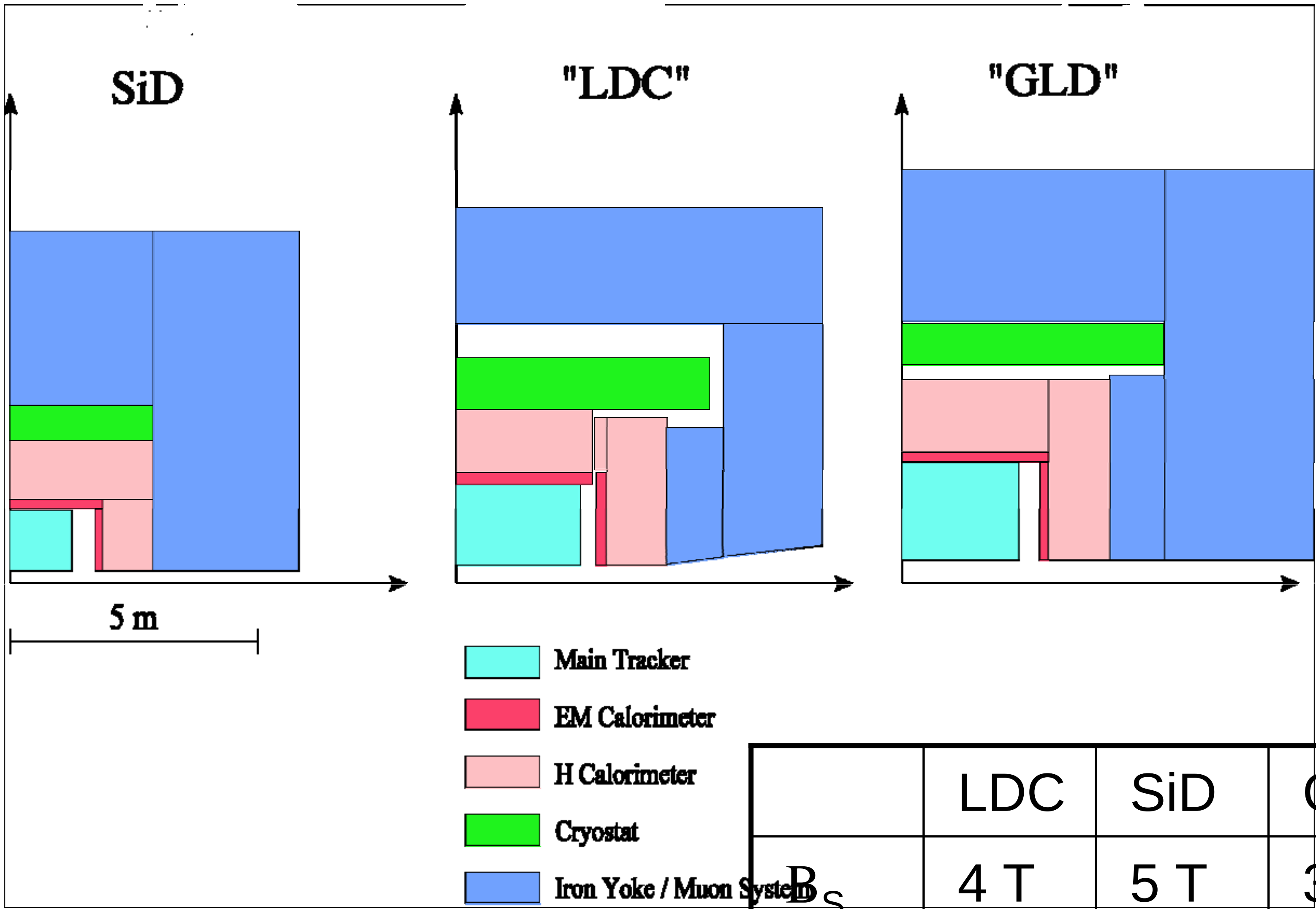
IP y offset ~ - 20 μm

anti-DID

⇓

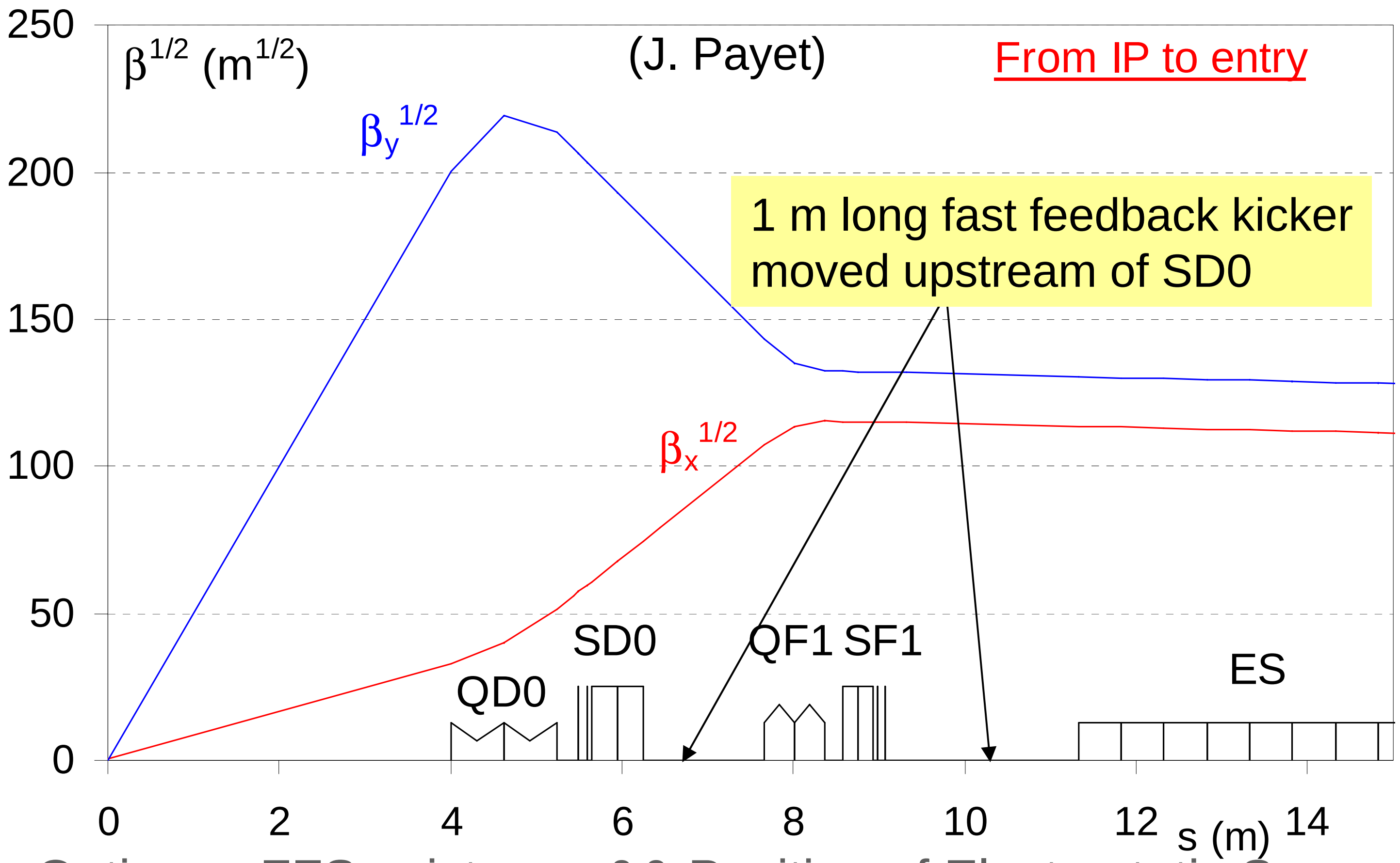
× ~ 2

Introduction : the 3 detectors magnets



	LDC	SiD	GLD
B_S	4 T	5 T	3 T
L_S	7 m	5.6 m	9 m

Head-on Scheme: final doublet optimisation



- Optimum FFS existence && Position of Electrostatic Separator : independent from *l** (3.5 m , 4 m , 4.5 m) and from final doublet

⇒ the doublet belongs to the experiment

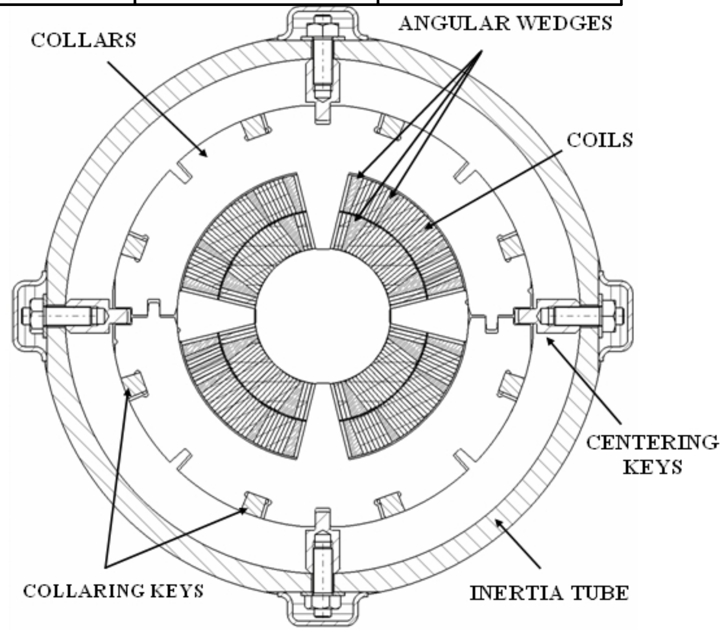
⇒ IDEAL case for Push-Pull Detectors

Head-on Scheme: final doublet

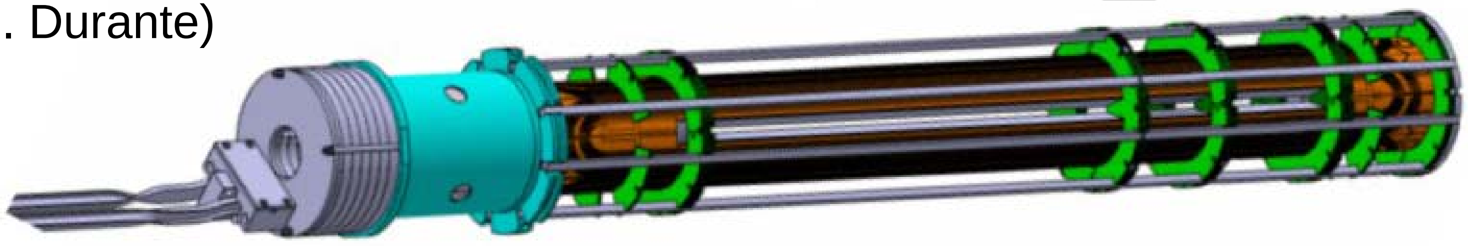
l* (m)	QD0 (m)	SD0 (m)	QF1 (m)	SF1 (m)	ES (m)
4.4	1.142	0.628	0.682	0.410	12.4
4	1.242	0.744	0.732	0.504	11.9

Quadrupole design exists:

Gradient	250 T/m
Current	14063 A
B_{peak}	9.8 T



(M. Durante)



Final Doublet : NbTi vs. Nb3Sn

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Such gradients are feasible with NbTi technology (LHC)

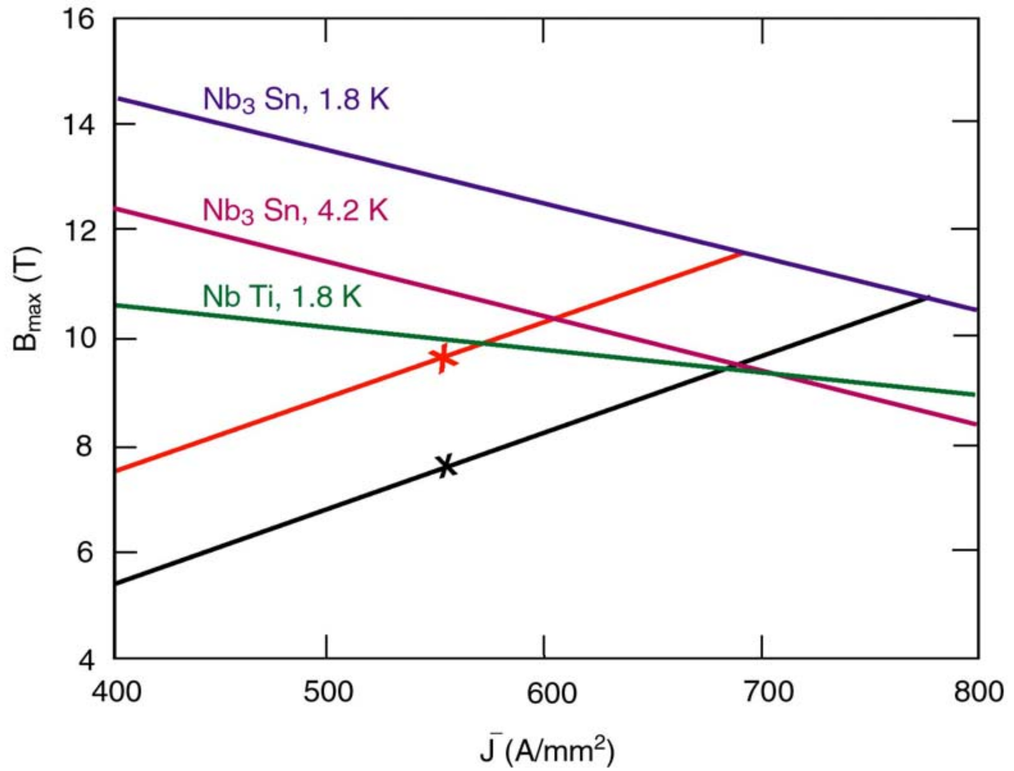
Motivation for Nb3Sn technology :

- external 4T solenoid

3D calculation needed

- possible larger safety temperature margin (beam losses)

- upgrade to 1 TeV cm



TESLA quadrupole inside the solenoid
$B_{max} = f(J_c)$

X Quadrupole alone (Ø 56 mm, G = 250 T/m)

X Quad + 4T solenoid

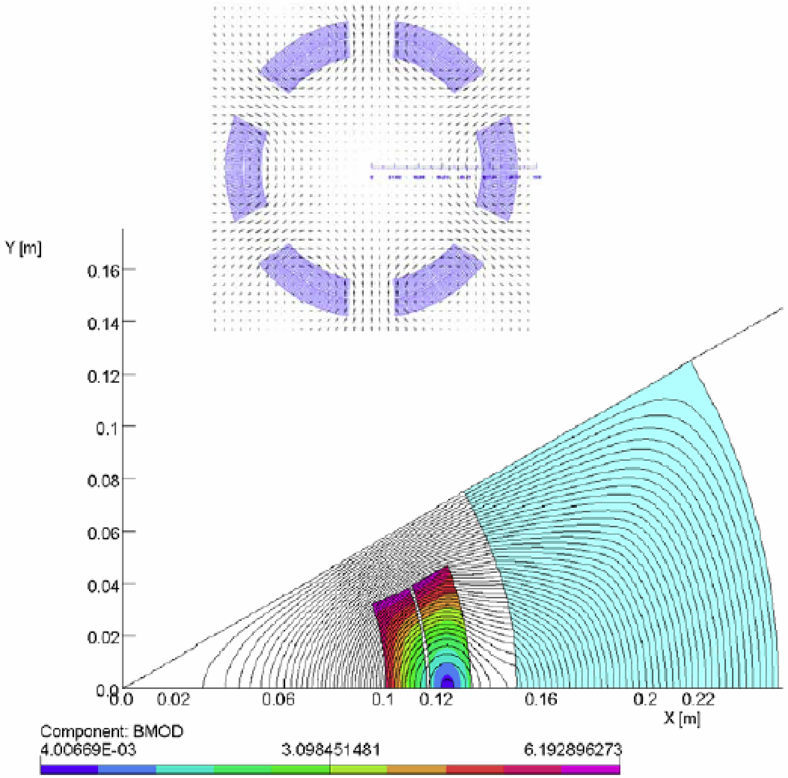
Final Doublet : Sextupole Design ??

Large aperture sextupole (Vl. Kashikhin)

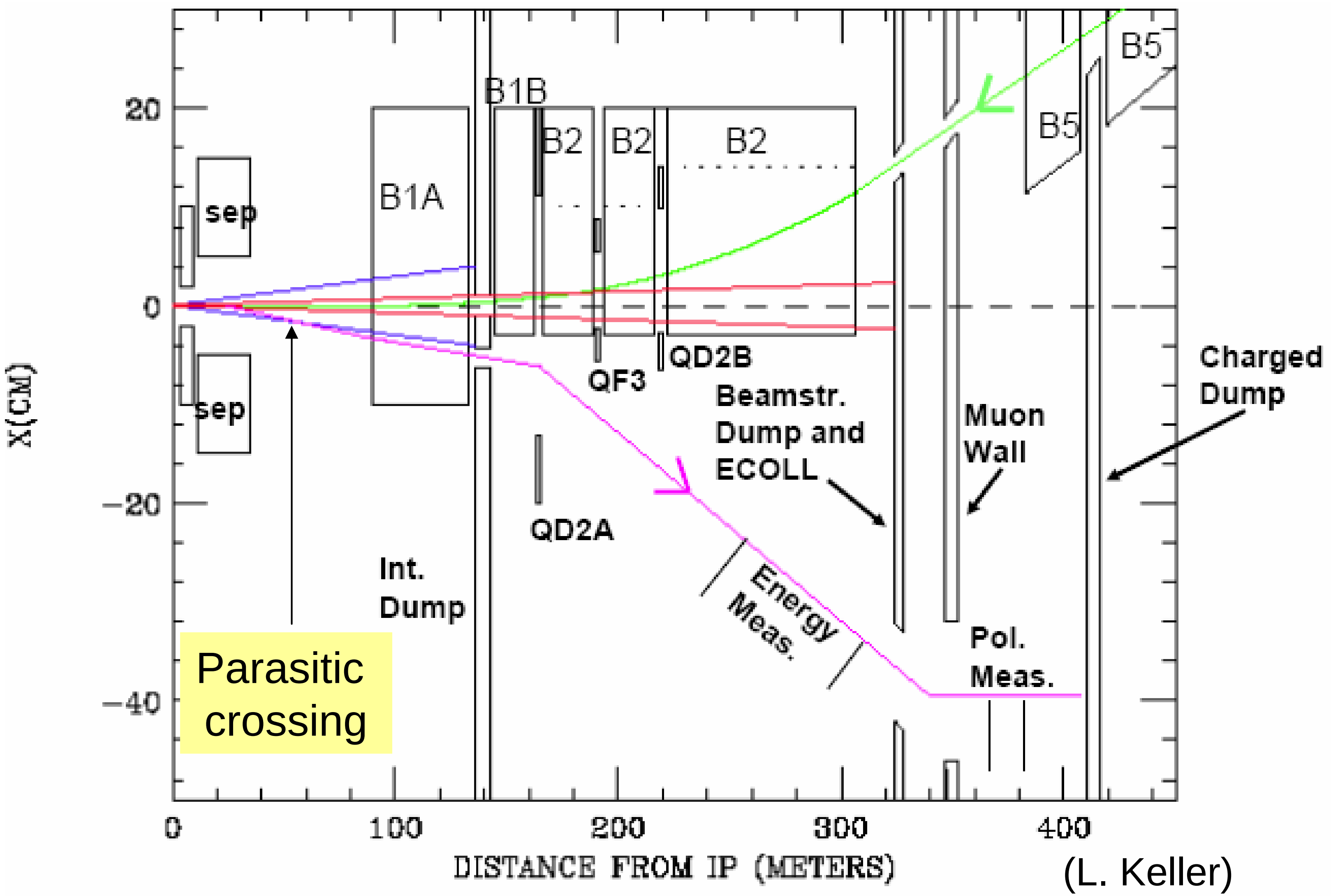
Shell type coil sextupole with cold iron

Design close to LHC IR Quadrupoles

Coil ampere-turns	**343 kA**
Current	**7 kA**
Calculated strength	**519.2 T/m²**
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/mm²**
Strand diameter	**0.808 mm**



Electrostatic Separator : the first stage extraction



(L. Keller)

Electrostatic Separator : the LEP ZL separators

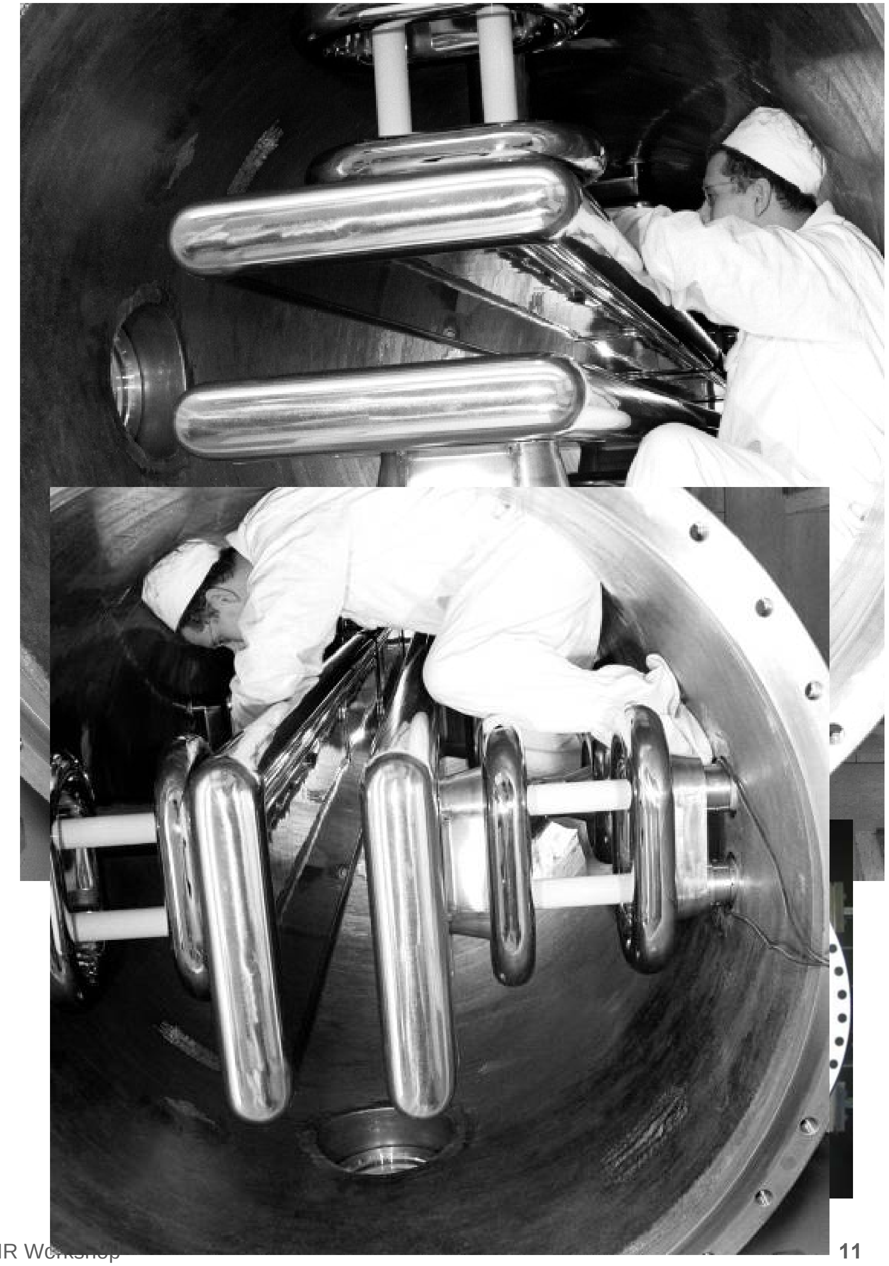
(J. Borburgh)

SS electrodes operated reliably at 25 kV/cm with 10 cm gap

Ti electrodes could operate at 52 kV/cm, OK for 1 TeV cm

Fully engineering design exists with
- adjustable gap
- adjustable bipolar voltage

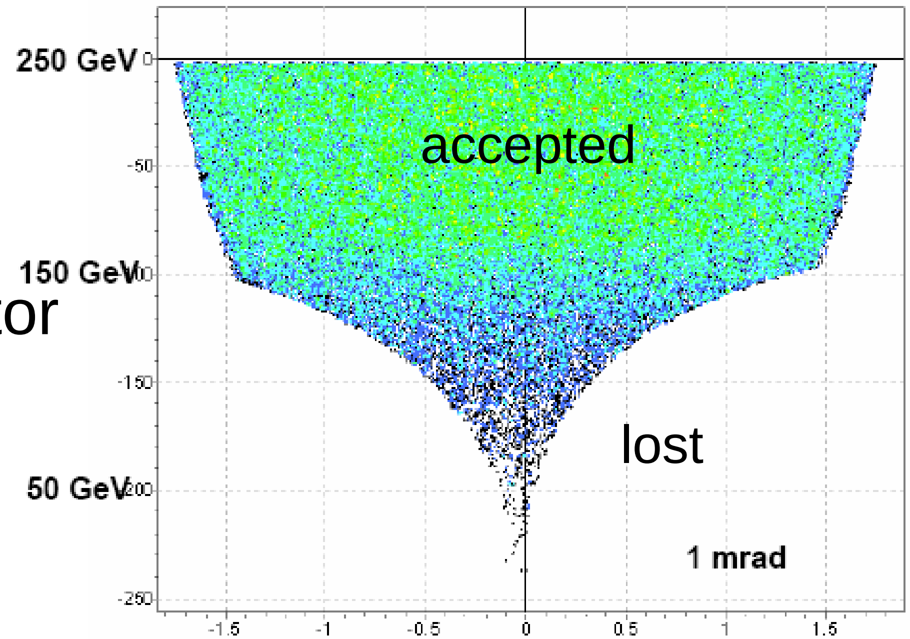
Requires R&D
- beam losses impact
- homogeneity
- horizontal vs. vertical operation



Electrostatic Separator : radiative Bhabhas

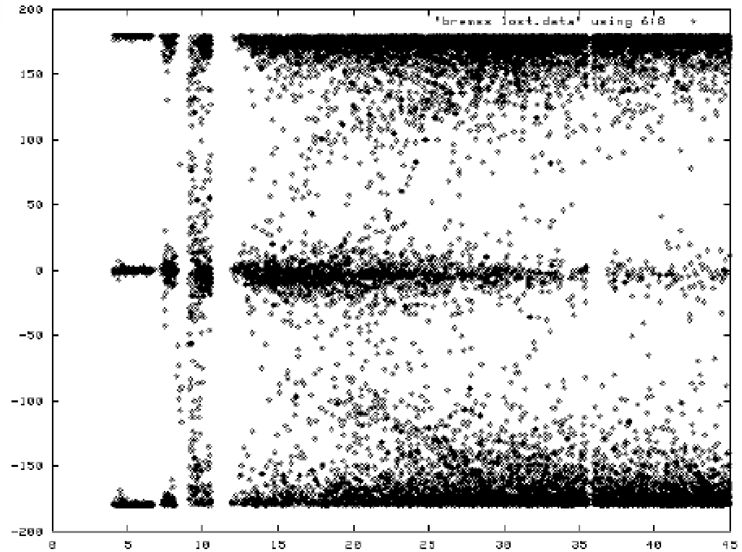
(O. Dadoun, D. Uriot)

E vs. x' phase space aperture at E. Separator exit



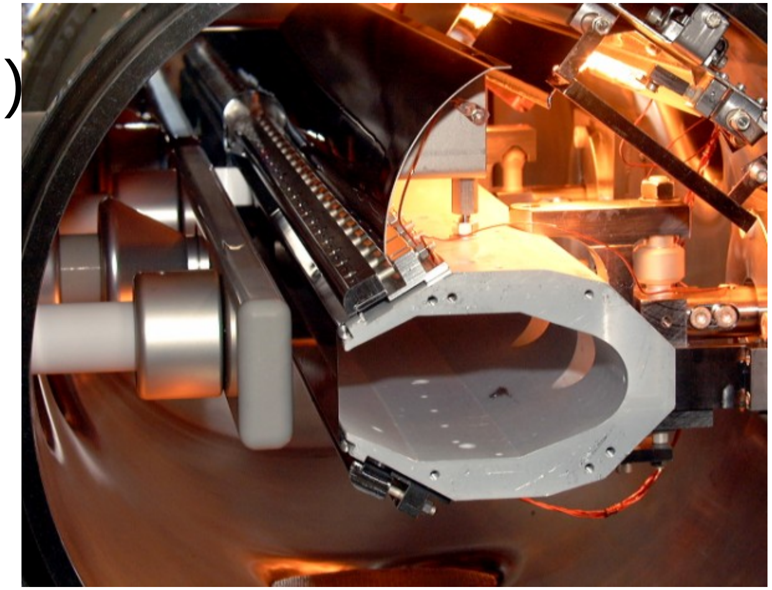
Topology of Radiative Bhabha losses

< 35 mW/m



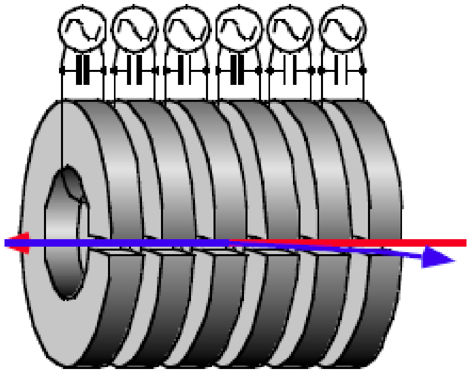
Electrostatic Separator : alternatives

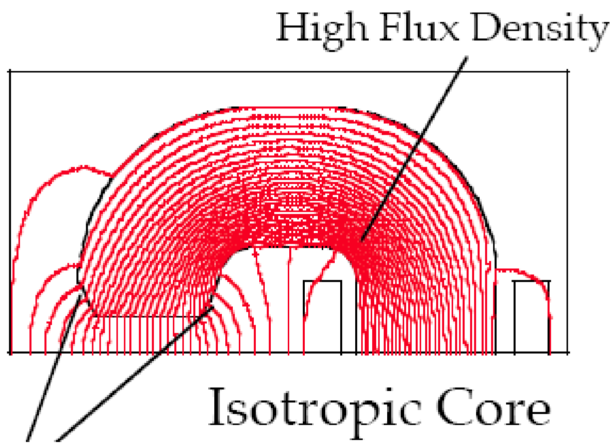
- Electrostatic septa (J. Borburgh)



  - many sparking events
  - not reliable
  - small aperture

- RF-deflectors (Y.Iwashita)





Alternatives : not competitive yet

Electrostatic Separator: failure handling

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Separator breakdown during the bunch train:
(dipole remains on)

Outgoing bunches: 0.5 mrad bend becomes 0.25 mrad bend. Bunches go backward through the incoming beamline and hit the beamstrahlung dump.

Incoming bunches: 0 mrad bend becomes 0.25 mrad bend. Bunches pass through the IP region within 1 cm of the beam axis, go backward through the incoming beamline and hit the beamstrahlung dump.

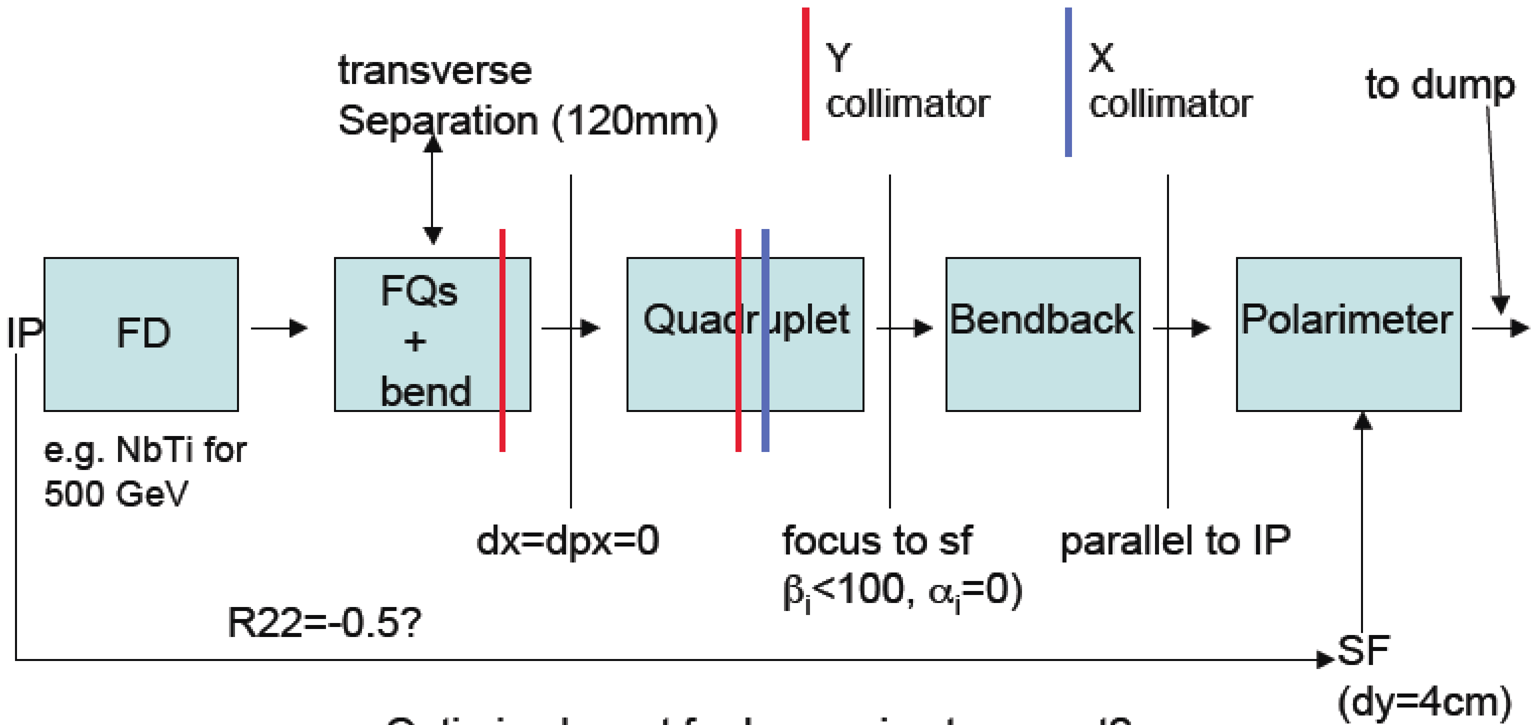
(L. Keller)

This machine protection issue MUST be better understood

Extraction Optics : collimation and beamstrahlung

First option:

New design approach with 1st order achromat to control the dispersion and beam losses (R. Appleby)

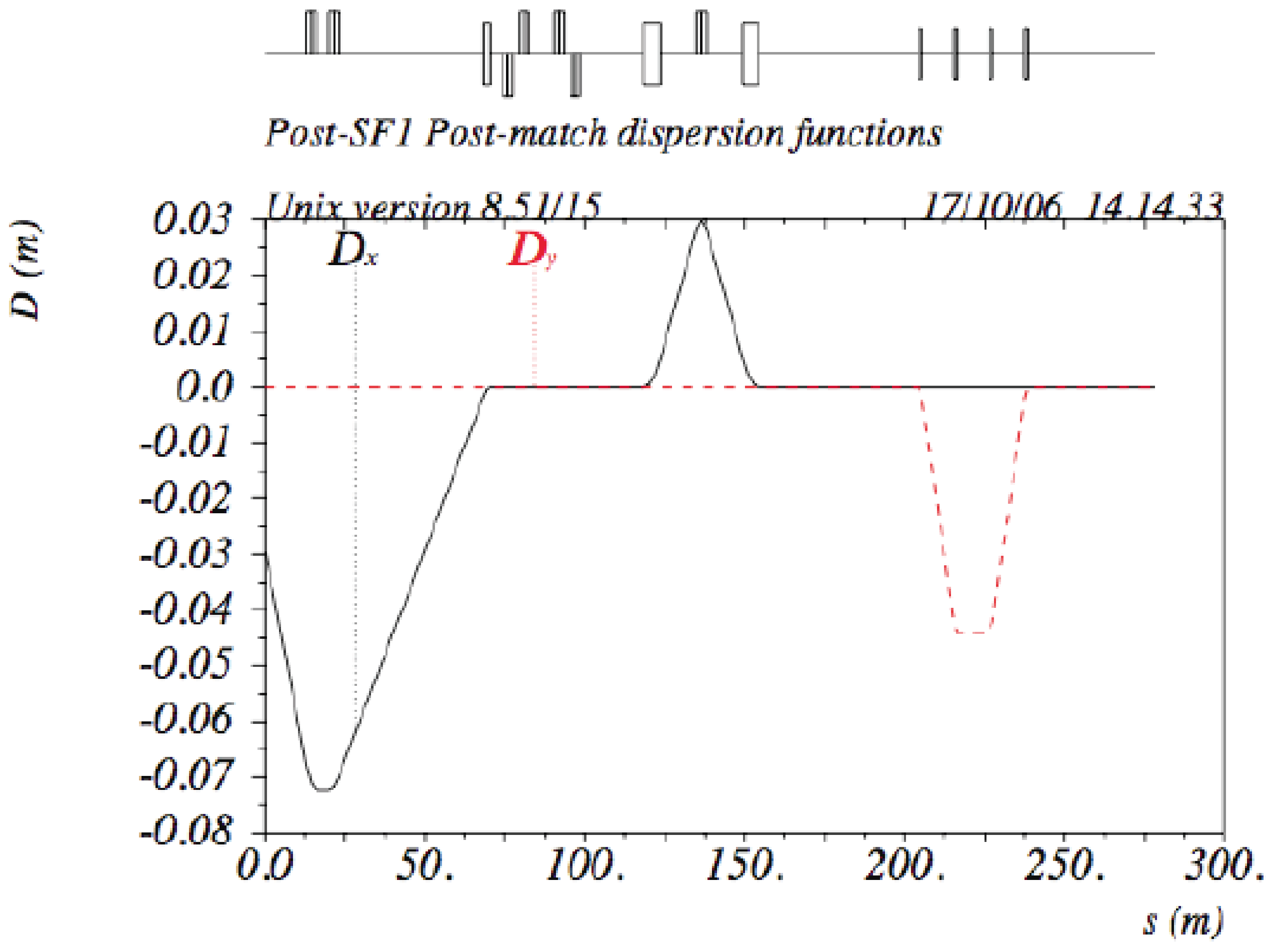


- Optimise layout for beam size transport?
- Concerns are
  1) Transport of higher order dispersion
  2) Beam shape at the SF of polarimeter

Extraction Optics : collimation and beamstrahlung

First option:

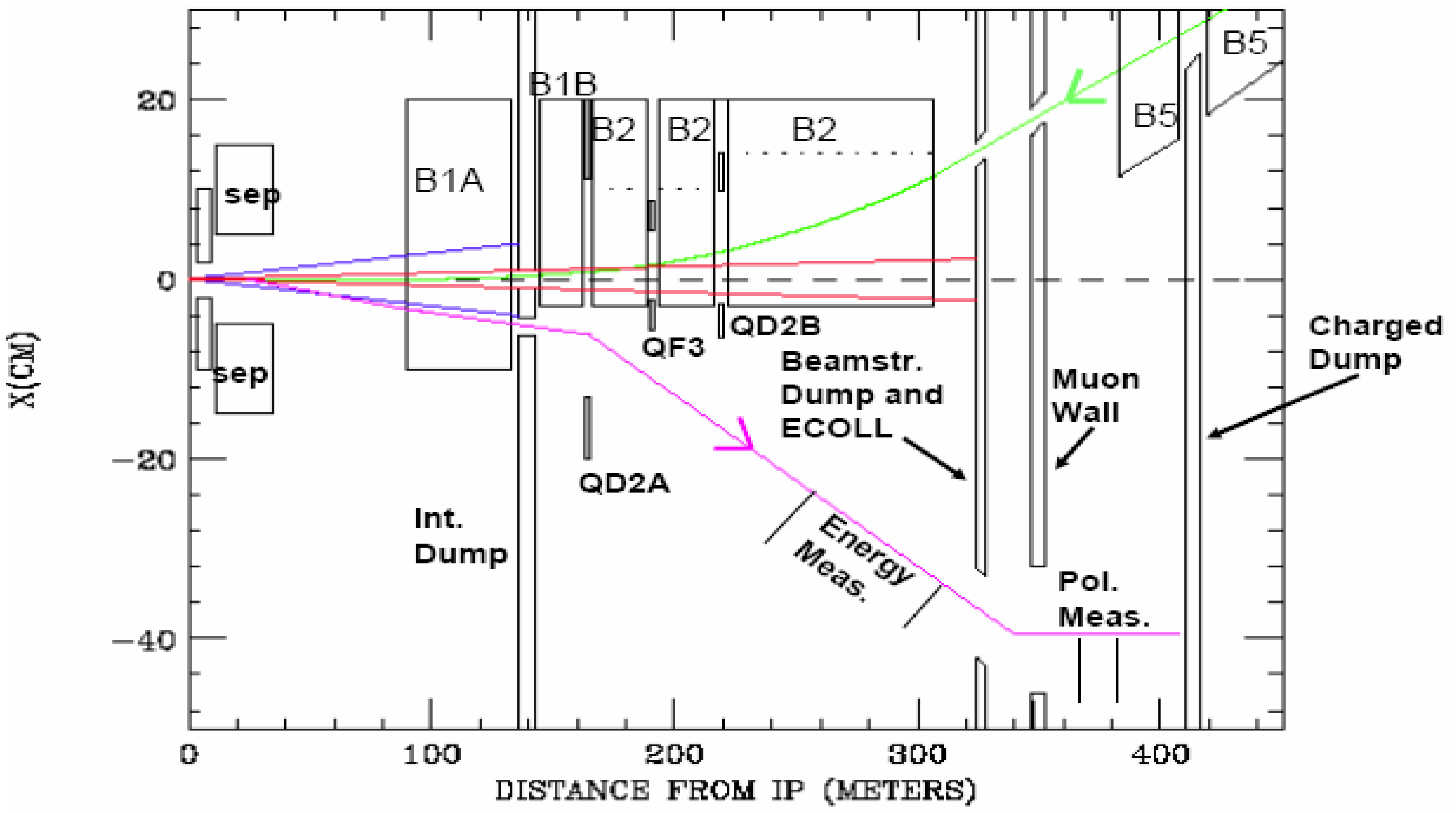
New design approach with 1st order achromat to control the dispersion and beam losses (R. Appleby)



Extraction Optics : collimation and beamstrahlung

Second options:

Stages of high power collimators (L. Keller)



Extraction Optics : collimation and beamstrahlung

Second option:

Stages of high power collimators (L. Keller)

New Estimate of Beam Losses, kW

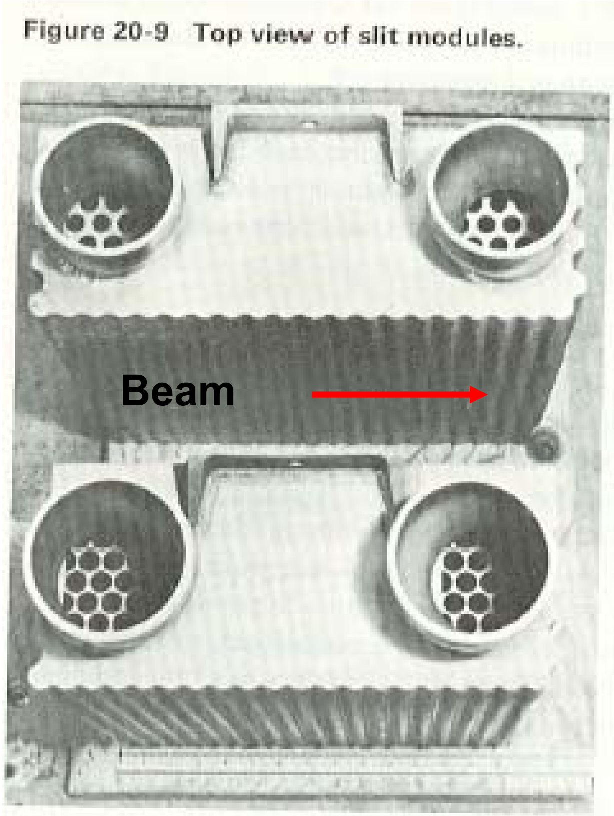
Dump Location	🟥 charged 🟦 beamstrahlung Function	Nominal Parameters Headon	 Vertical offset	Low Power Parameters Headon	 Vertical offset
Z = 139 m	Beamstrahlung and charged tail	360 165	840 315	650 225	1340 405
Z = 320 m	Beamstrahlung core and charged tail	350 100	300 60	280 90	155 40
Z = 420 m	Charged beam	~10,000	~9,500	~4500	~3600

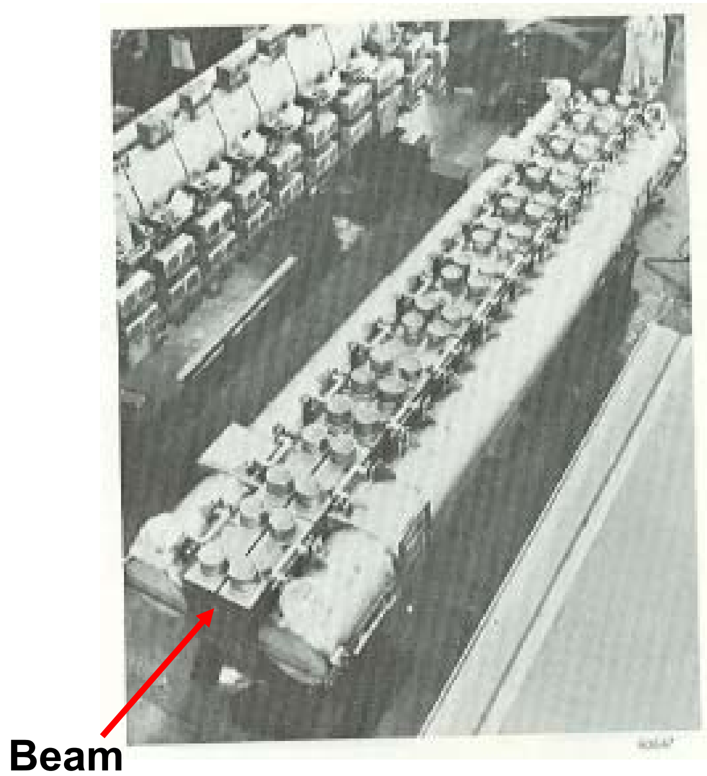
Extraction Optics : collimation and beamstrahlung

Second option:

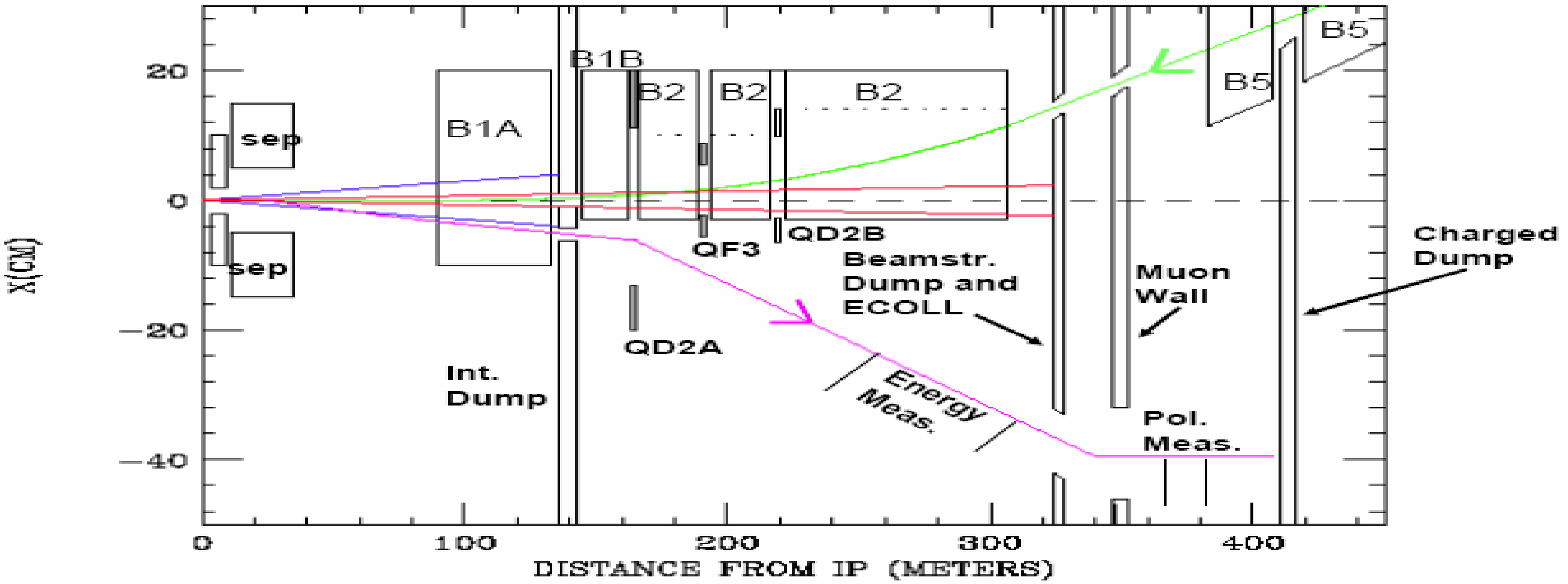
Stages of high power collimators (L. Keller)

Assembled SLAC 2 MW slits ≈ 5 m long





Extraction Optics : magnets



We need help to produce engineering designs for the extraction magnets: B1A, QD2A, QF3, QD2B, …

All options are on the table (G.L. Sabbi, Y. Iwashita)

- warm NC magnets
- permanent magnets
- superferric magnets
- superconducting magnets

Diagnostics : chicane dipoles

20 mrad

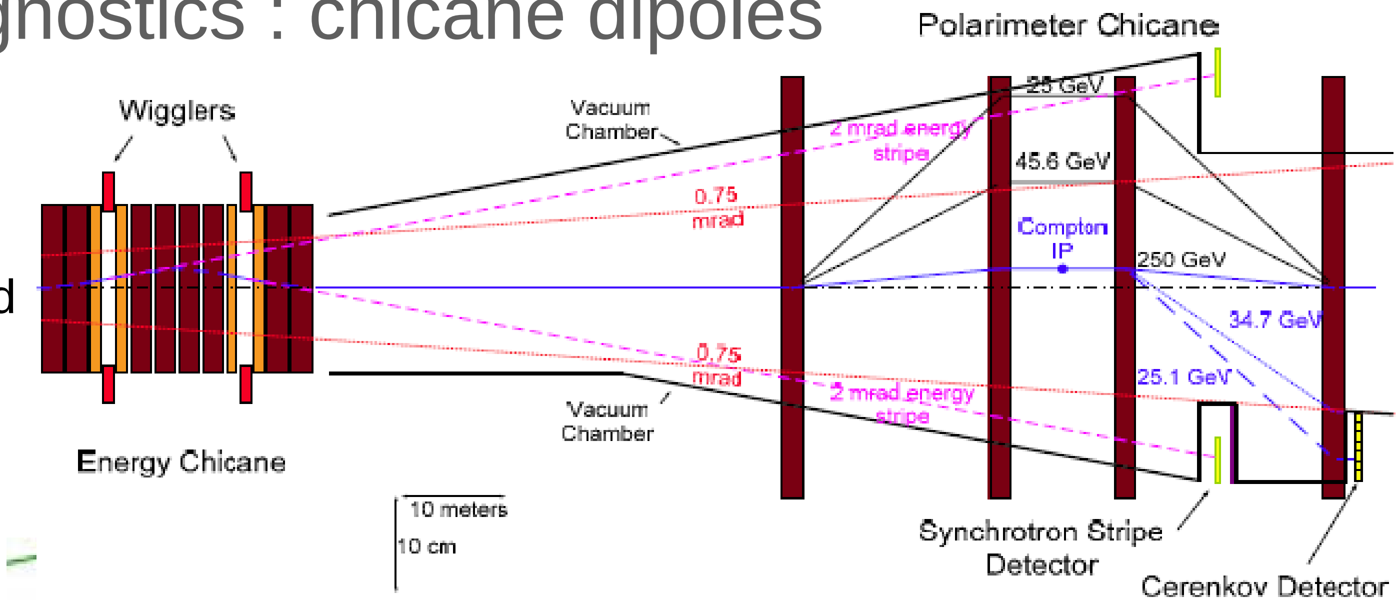
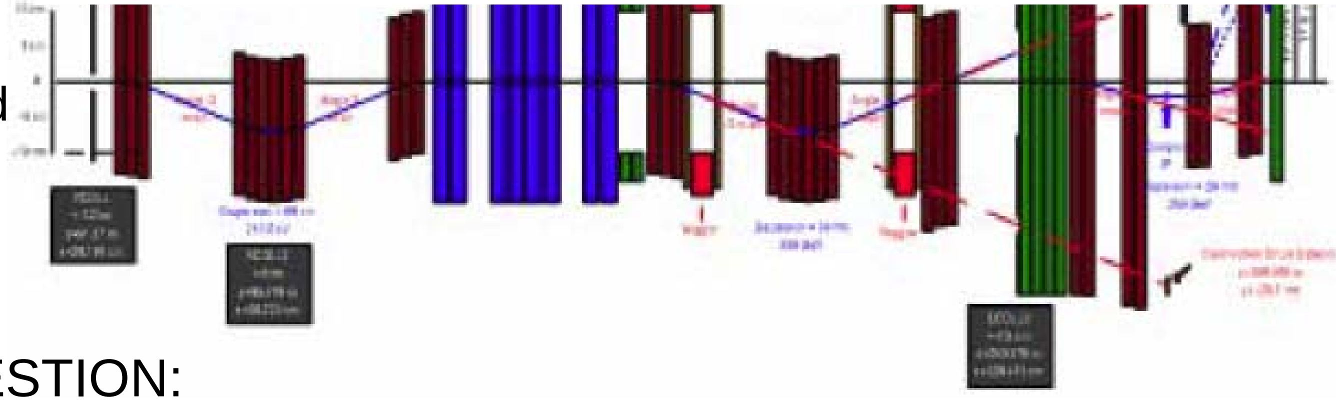


Figure 4: Diagram of the Energy Chicane and Polarimeter Chicane in the 20 mrad extraction line.

0 mrad



QUESTION:

- 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 dapnia SACM

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Conclusions : main design and hardware tasks

Final doublet:

- 3D magnetic configuration of Solenoid + Doublet
    - NbTi vs Nb3Sn
    - variable l*
- SD0, SF1 superconducting sextupole design
- integrated FD cryostat design and costing

Electrostatic Separator:

- performance of bakeable Ti electrodes
- sparking rate under beam loss
- check failure handling

Extraction Optics:

- feasibility of high power intermediate dumps
- detector background from intermediate dumps
- achromatic beam extraction
- extraction magnet design

Post IP instrumentation vs. None : impact on tunnel and cost

Conclusions : main design and hardware tasks

Input from post lunch discussion:

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