ILC
Head-On Interaction Region: Progress Report

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For the Head-on Task Group

European LC Workshop
8 January 2007

Head-on Task Group

- GOAL : *Work on the ILC Head-on Scheme to make it more attractive from the* ***Collider Performance*** *and* ***BDS Cost*** *viewpoints.*

- Head-on Task Group ≈ Attendance of the *Small IR Mini-Workshop* at Orsay-Saclay on 19-20 October 2006

  http://ilcagenda.linearcollider.org/conferenceDisplay.py?confId=1150 1st day
  http://ilcagenda.linearcollider.org/conferenceDisplay.py?confId=1149 2nd day

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2	**ANGAL-KALININ Deepa**	CCLRC
3	**APPLEBY Robert**	Univ. Manchester
4	**BAMBADE Philip**	IN2P3/LAL
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13	**KIRCHER François**	CEA/DAPNIA
14	**IWASHITA Yoshihisa**	Kyoto University
15	**JACKSON Frank**	CCLRC
16	**KELLER Lewis**	SLAC
17	**KURODA Shigeru**	KEK
18	**NAPOLY Olivier**	CEA/DAPNIA
19	**PAYET Jacques**	CEA/DAPNIA
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22	**SABBI Gian Luca**	LBL
23	**TOPREK Dragan**	Univ. Manchester
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Outline

- Motivation for Head-on Collisions
- Final Focus System
- Final Doublet
- Extraction Scheme
- Electrostatic Separator
- Collimation and Beam losses
- Conclusions

Motivation for Head-on Collisions

For the collider operation :

- **Head-on** makes focusing and colliding easier, while extraction is more difficult
- **Crossing angle** makes extraction easier, while colliding and focusing is more difficult

Pros: Four machine devices are not needed upstream of the IP

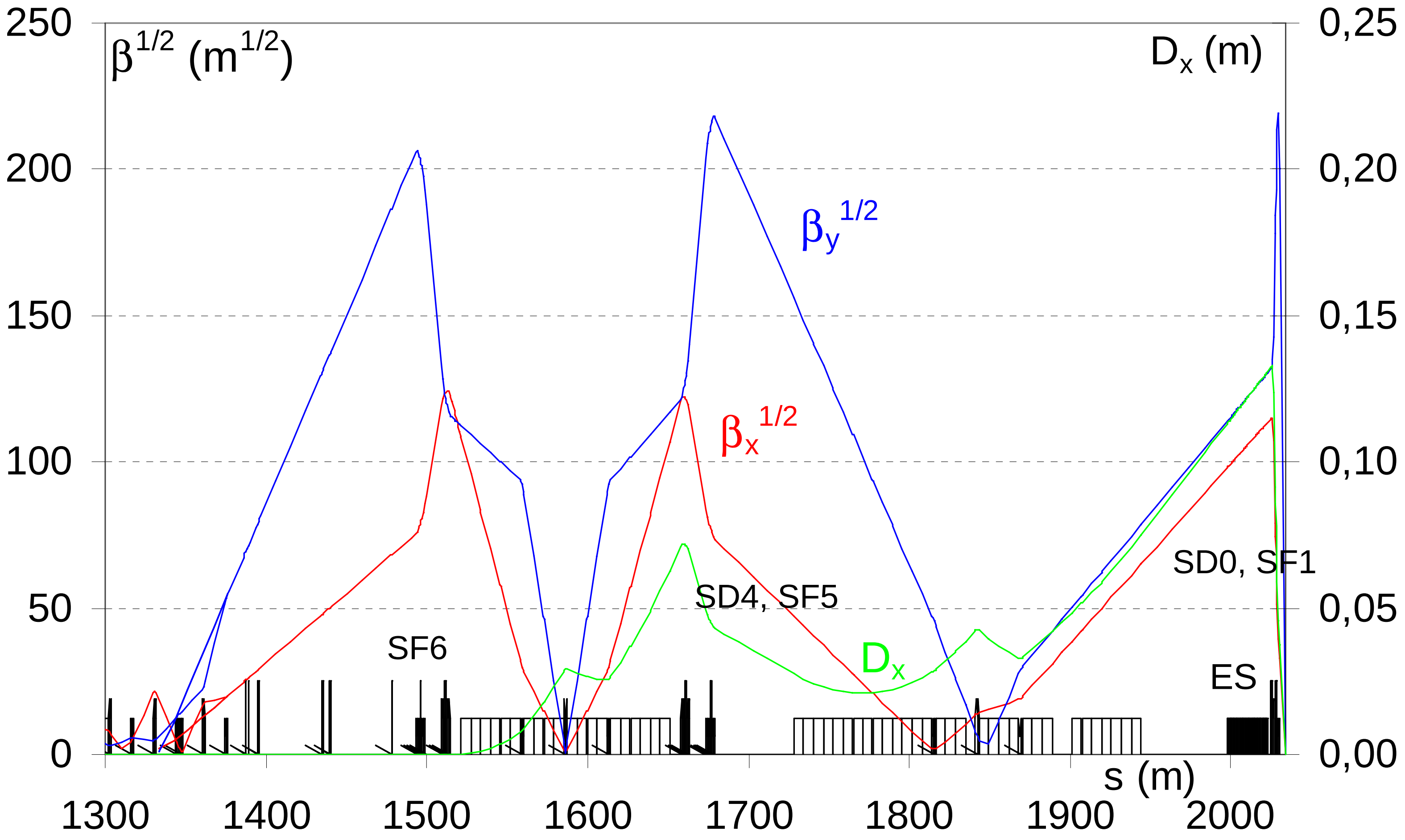
1. Crab RF-cavities
2. Anti-DID (Detector Integrated Dipoles)
3. Anti-solenoids around each QD0
4. Dipole correctors on top of each QD0

Cons : Beam extraction requires bending the spent beams after the IP and before the first parasitic crossing ~ $(c\tau_b/2)$

$\Rightarrow$ dispersion of the low energy tails

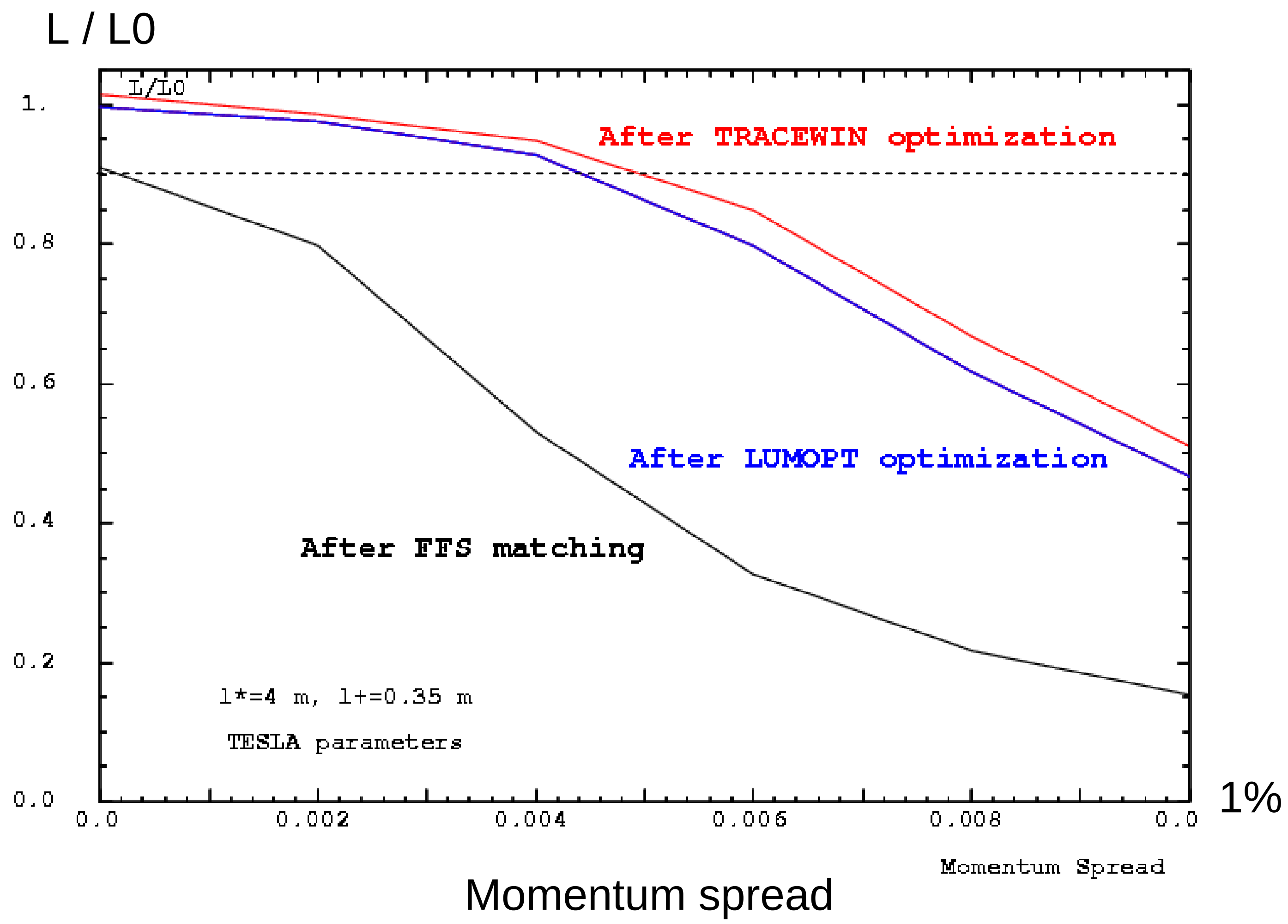
$\Rightarrow$ challenging beam usage and transport to the dump.

Final Focus System



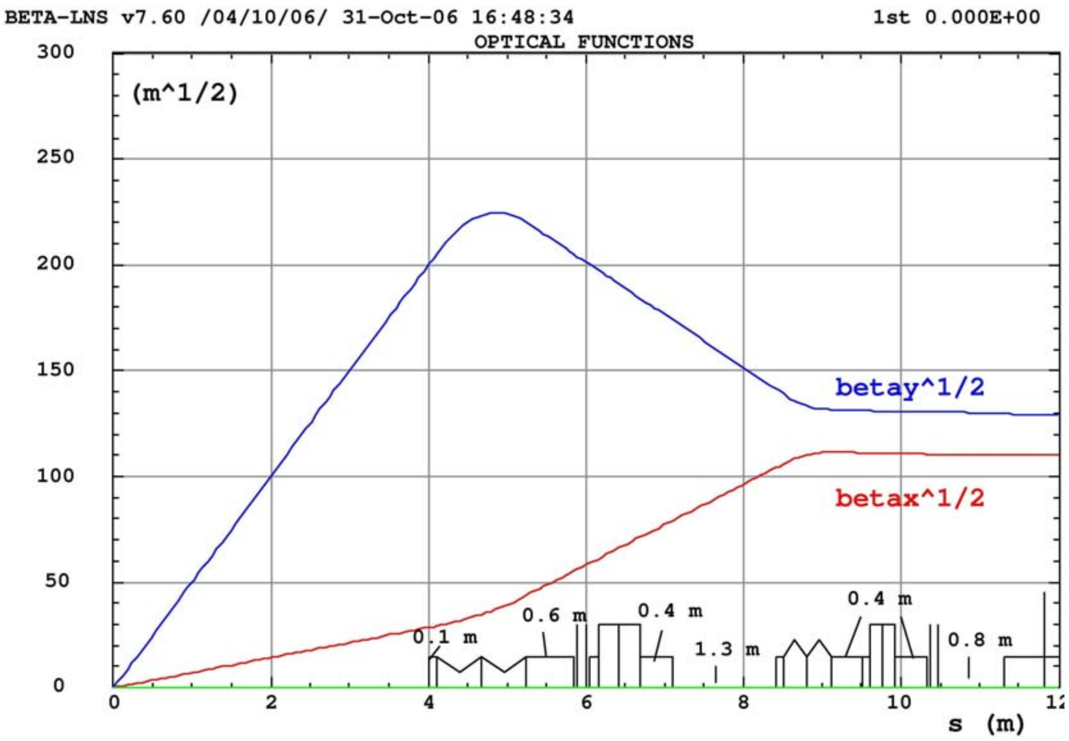
Final Focus and Chromatic Correction functions are combined

Final Focus System

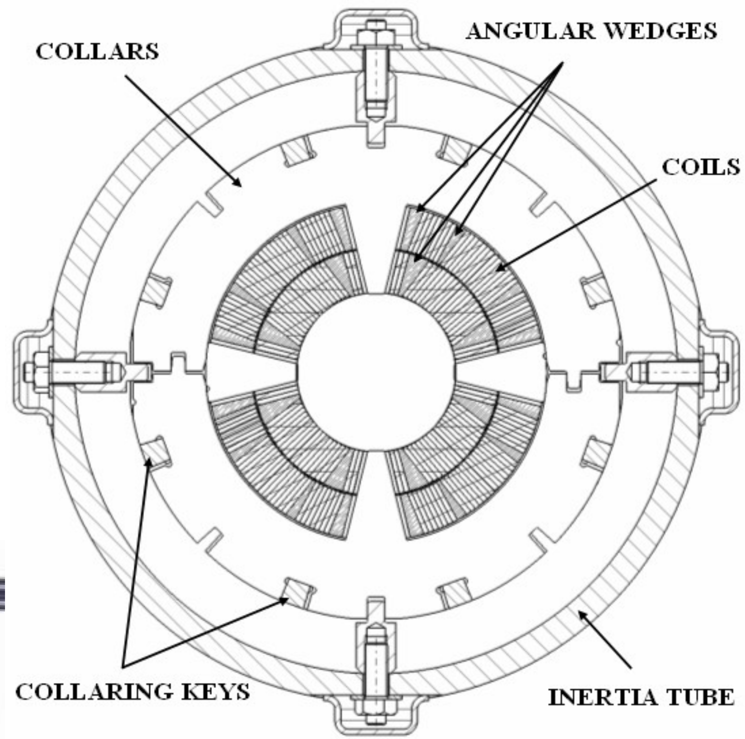


Automatic CCS matching based on Luminosity optimisation

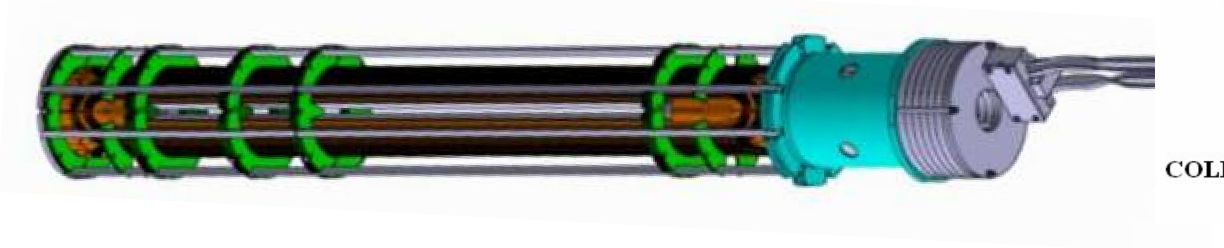
Final Doublet for 500 GeV cm Energy



Final doublet design assumes engineered LHC arc superconducting Quadrupoles and Sextupoles with 56 mm bore diameter



Nb3Sn Prototype under fabrication at Saclay



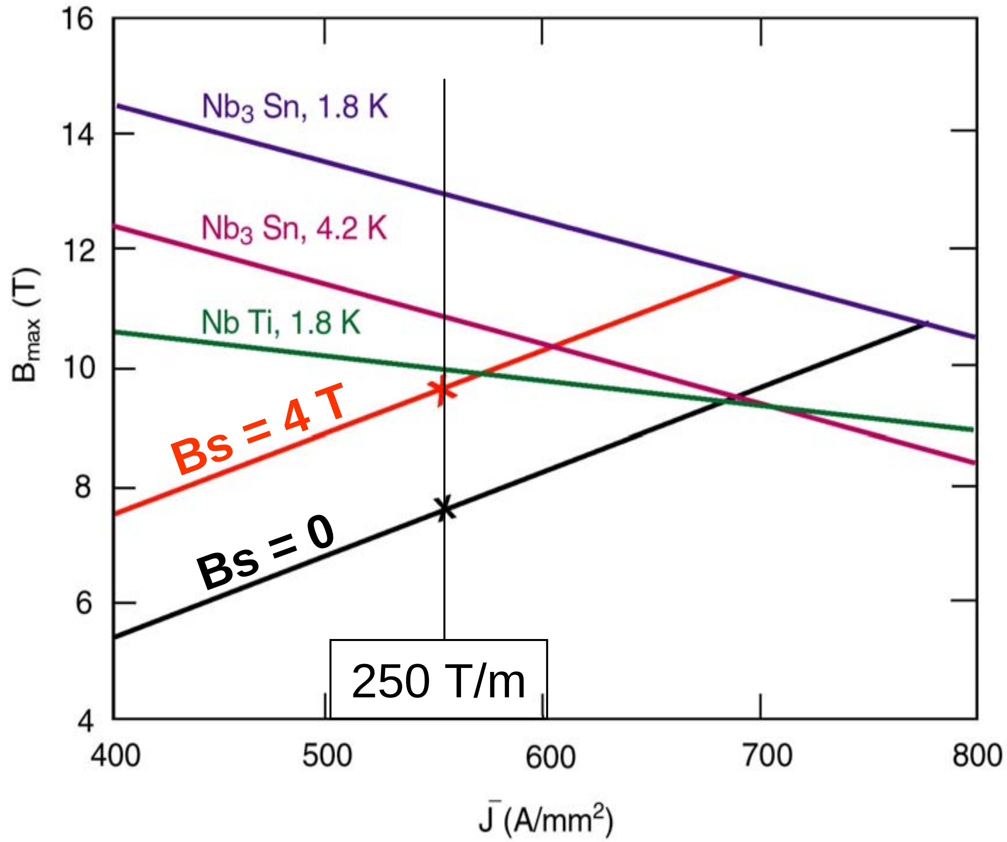
Final Doublet for 500 GeV cm Energy

	QD0	QF1	SD0	SF1
Length [m]	1.146	0.593	0.548	0.314
Gradient	250 T/m	250 T/m	3880 T/m2	3662 T/m2
Field @ bore	7 T	7 T	3 T	2.9 T

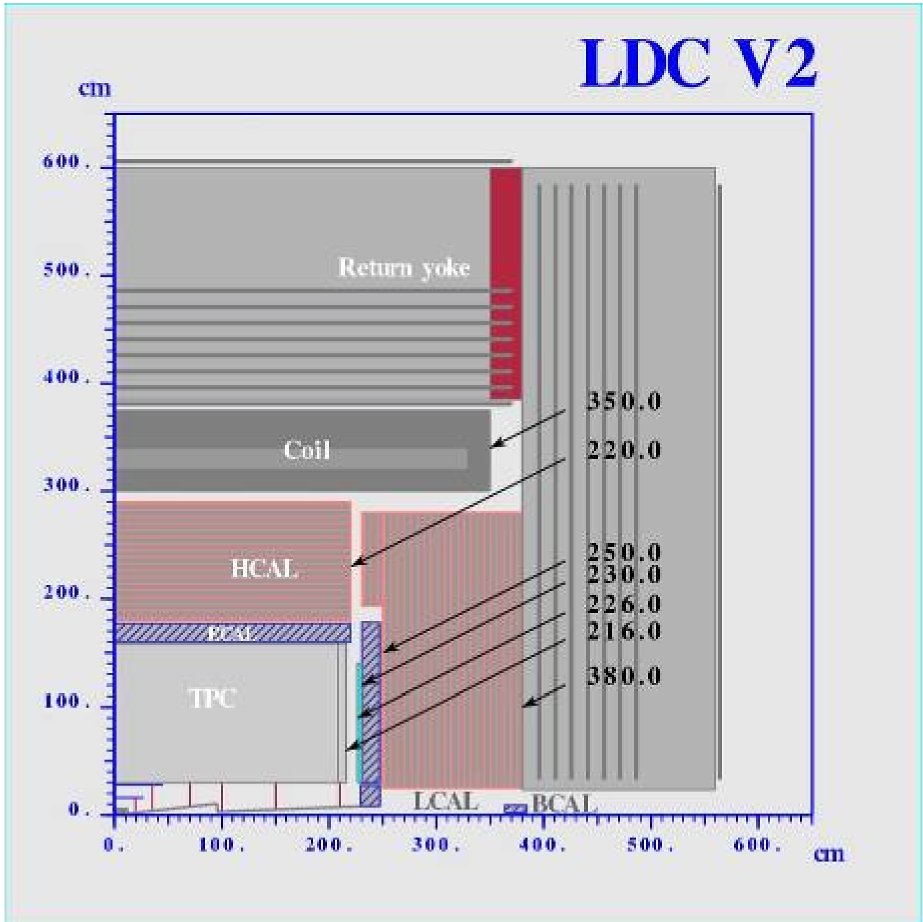
G = 250 T/m ⇒ Bmax = 7.65 T

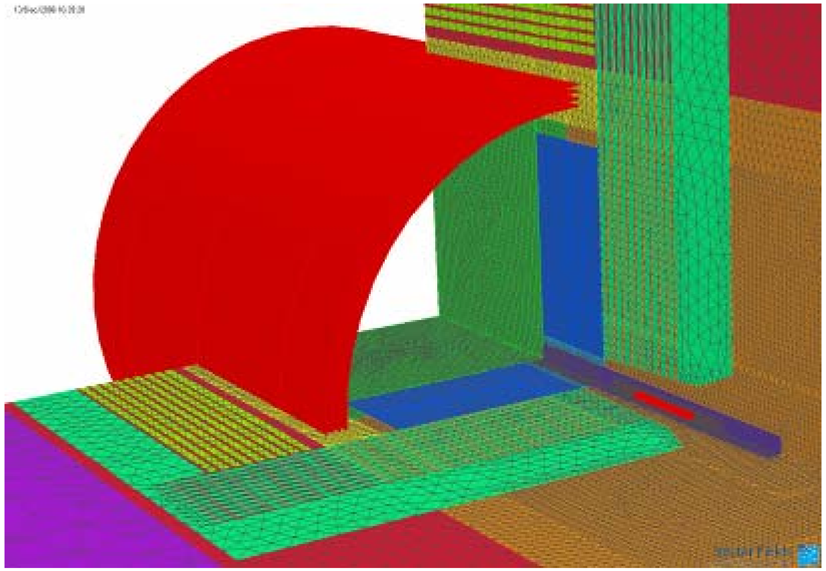
SC Quadrupole technology ?

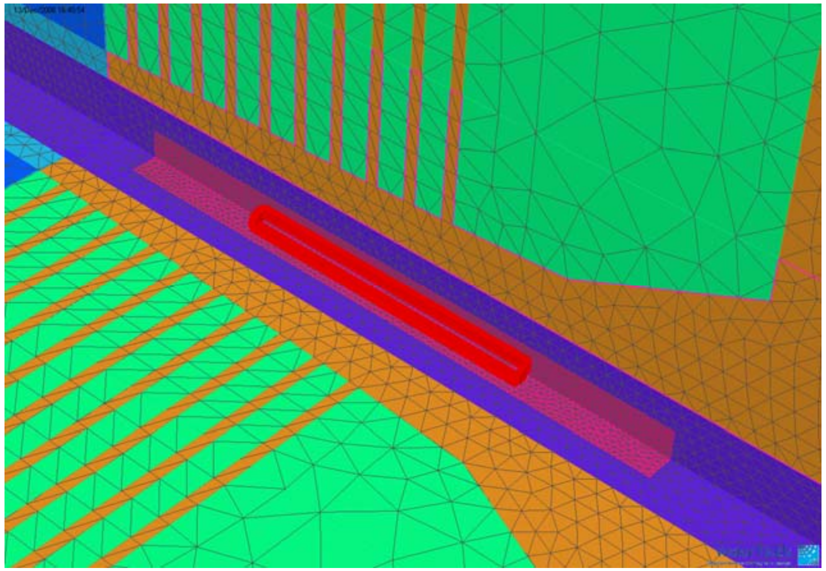
standard NbTi
vs.
high field Nb3Sn



Final Doublet : (Solenoid + Quad) 3D Map

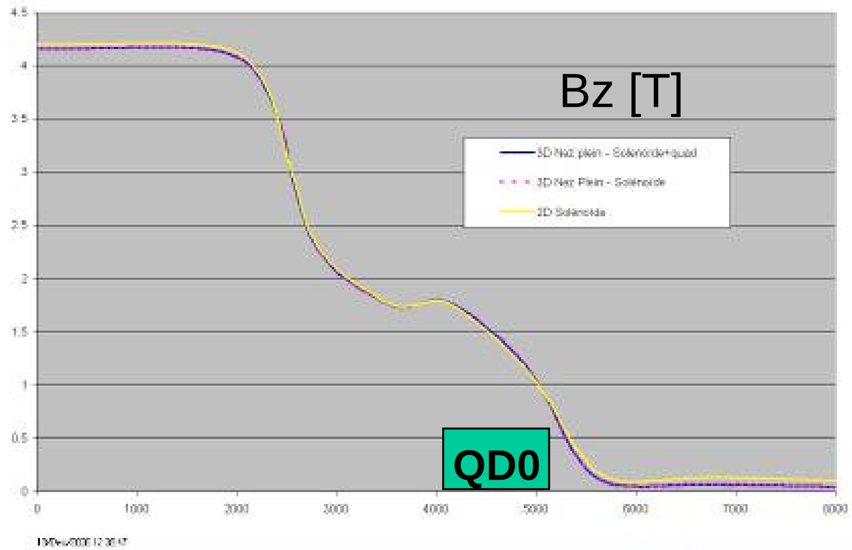


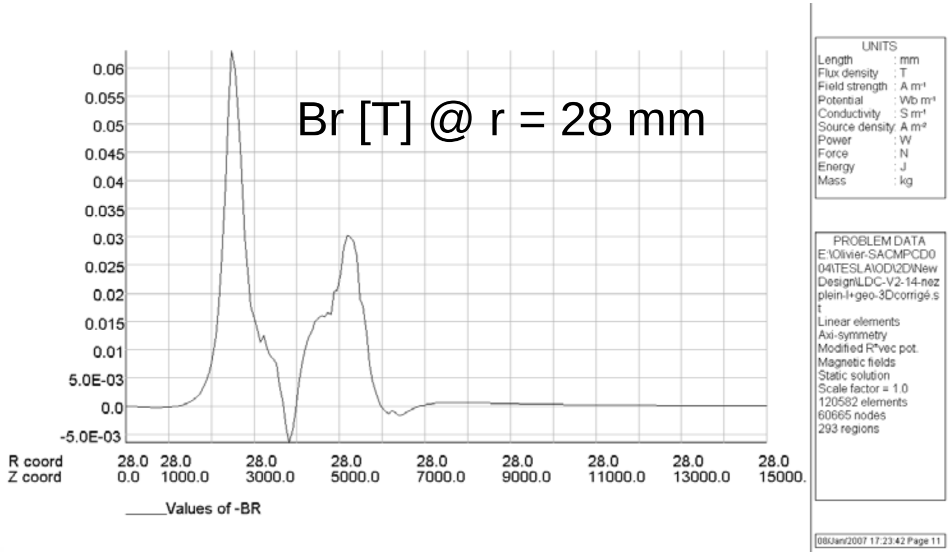


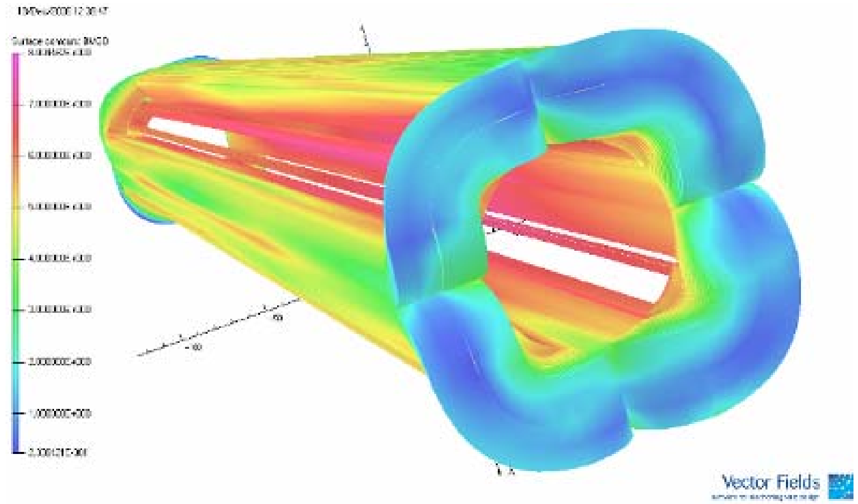


OPERA 3D modelling of QDO imbedded in LDC 4T Solenoid

Final Doublet : (Solenoid + Quad) 3D Map







Preliminary analysis:

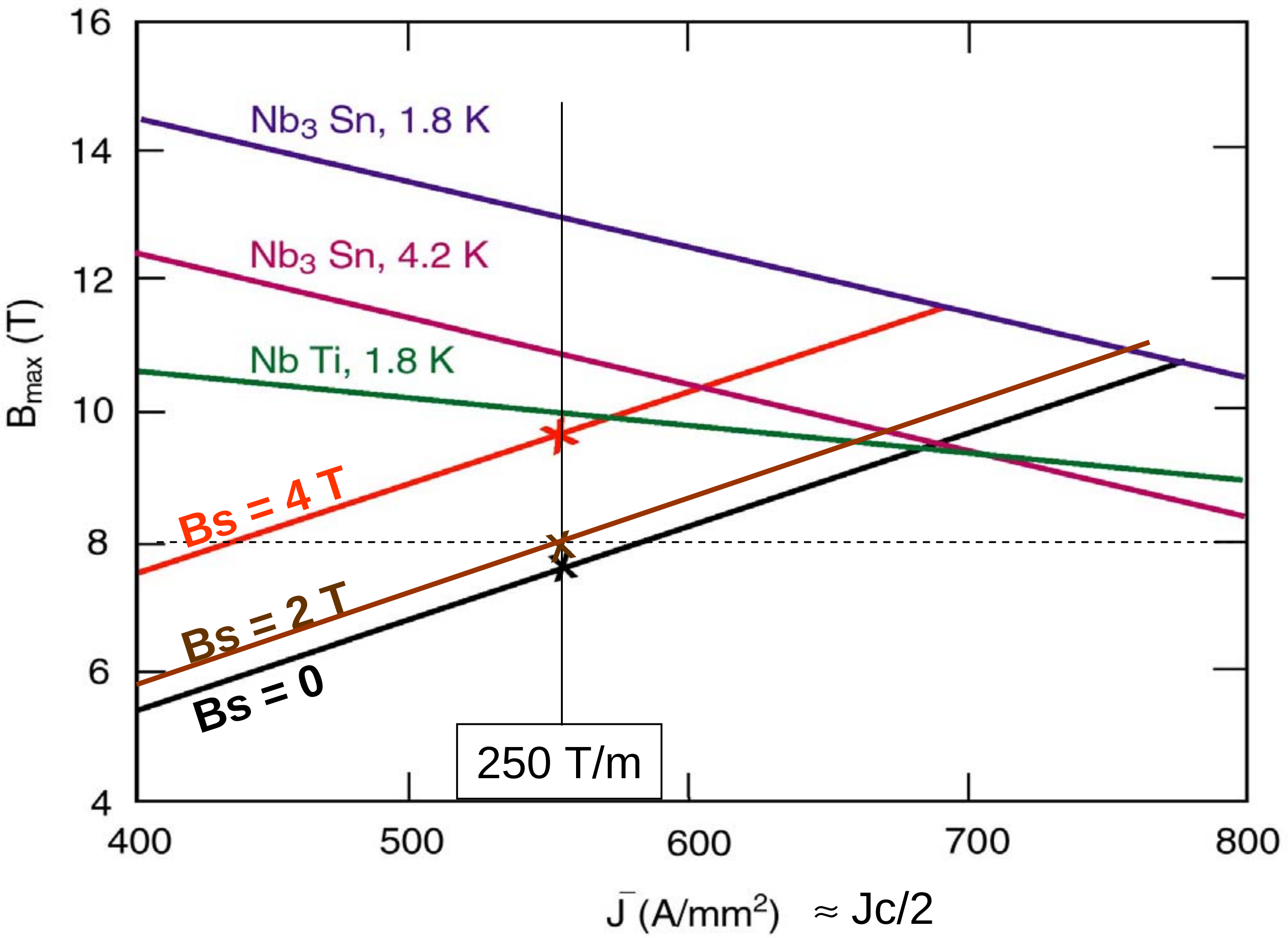
- Solenoid Br component is negligible
- Solenoid Bz < 2 T @ QD0

⇒ Bmax = 7.65 T ⊕ 2 T in quadrature

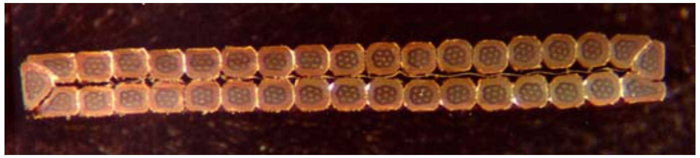
⇒ Bmax ≈ 8 T on QD0

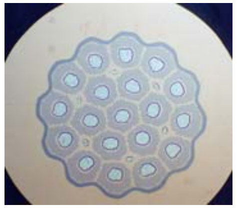
⇒ Standard NbTi doublet seems feasible for 500 GeV cm energy

Final Doublet : 500 GeV cm energy



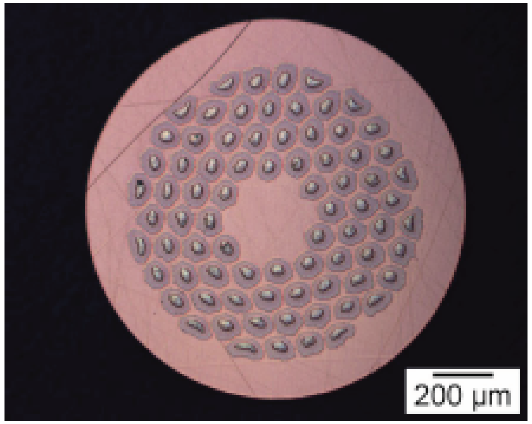
Assumes Nb_3Sn ITER conductor :
Jc = 750 A/mm^2 @ 12 T and 4.2 K



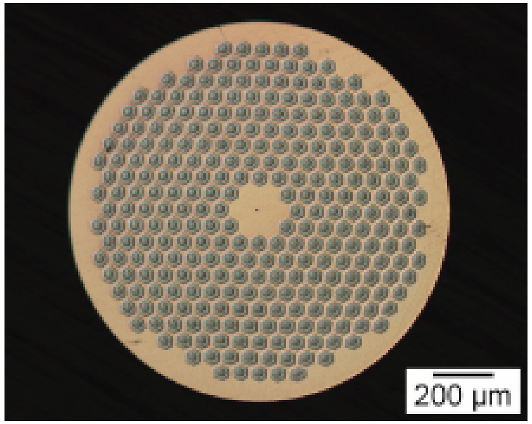


Final Doublet : 1 TeV upgrade

NED Nb3Sn conductors achieve **Jc > 1500 A/mm²**

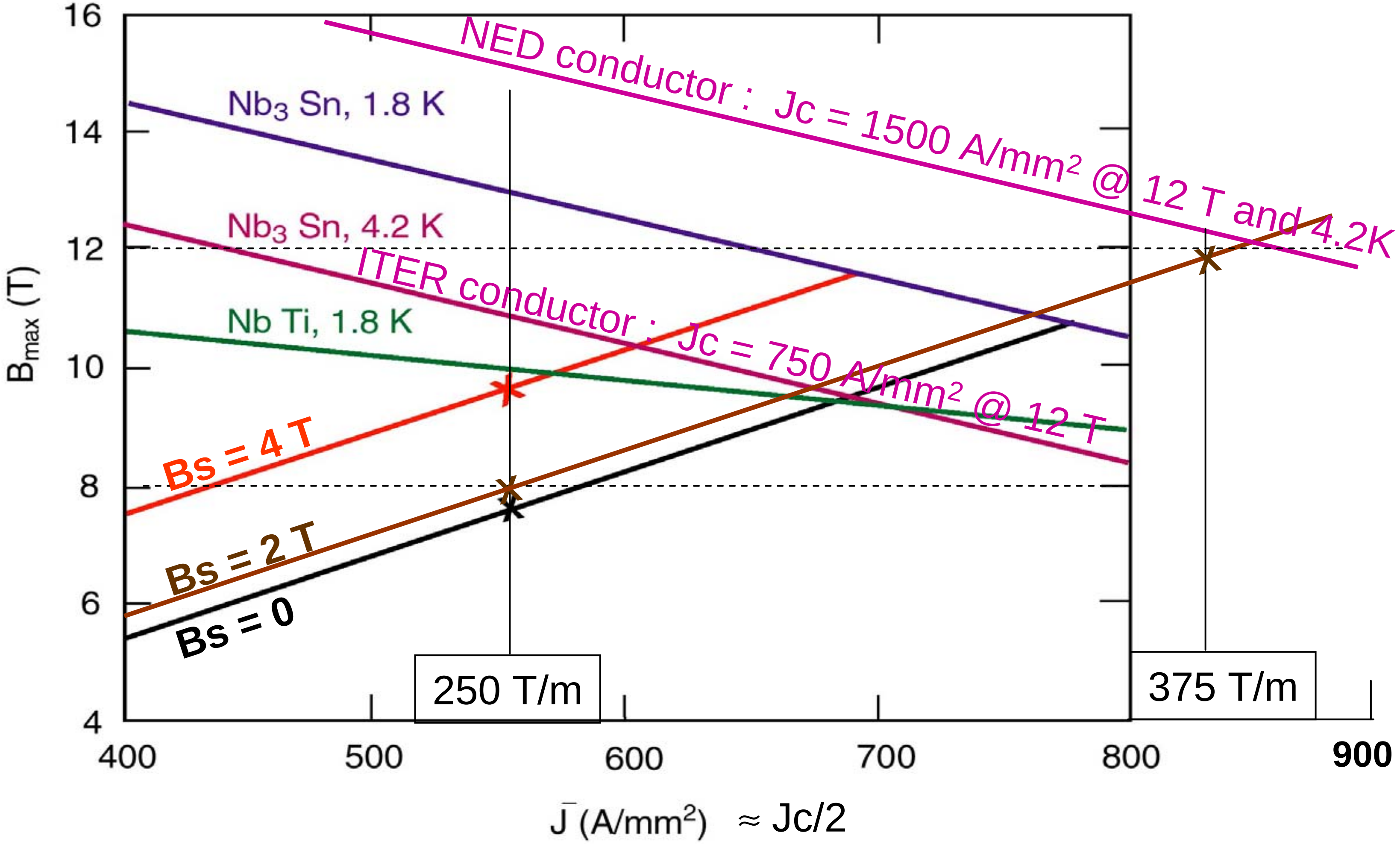


Alstom/NED
(workability program milestone)
1.25 mm ; 78x85 μm sub-element
740 A (~1500 A/mm²)
@4.2 K & 12T
(measured at CERN & INFN-Mi)



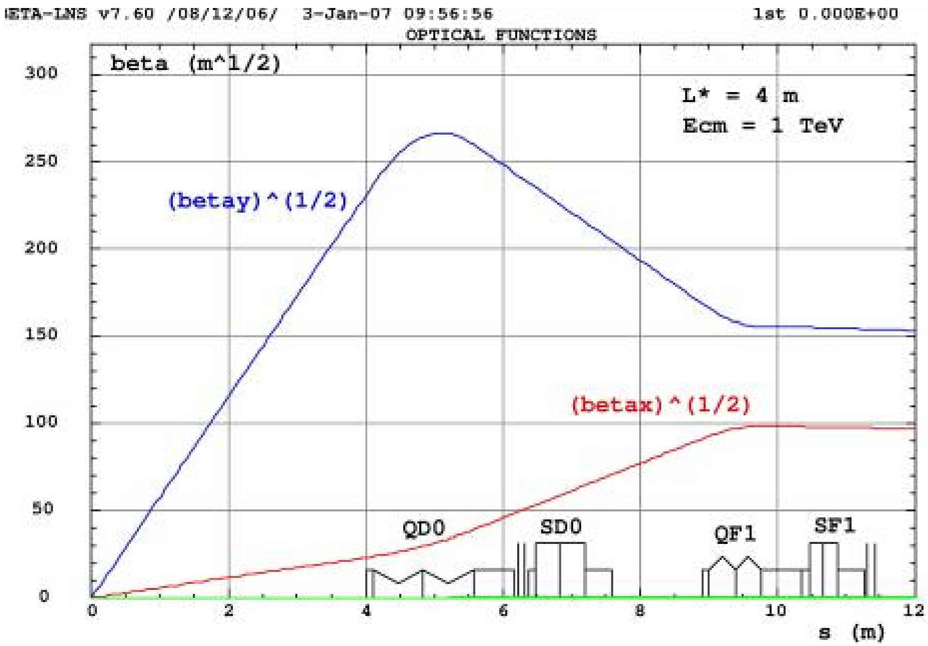
SMI/NED
(step II iteration)
1.26 mm ; 288 x 50 μm tube
1400 A (~2500 A/mm²)
@4.2 K & 12T
(measured at TEU & INFN-Mi)

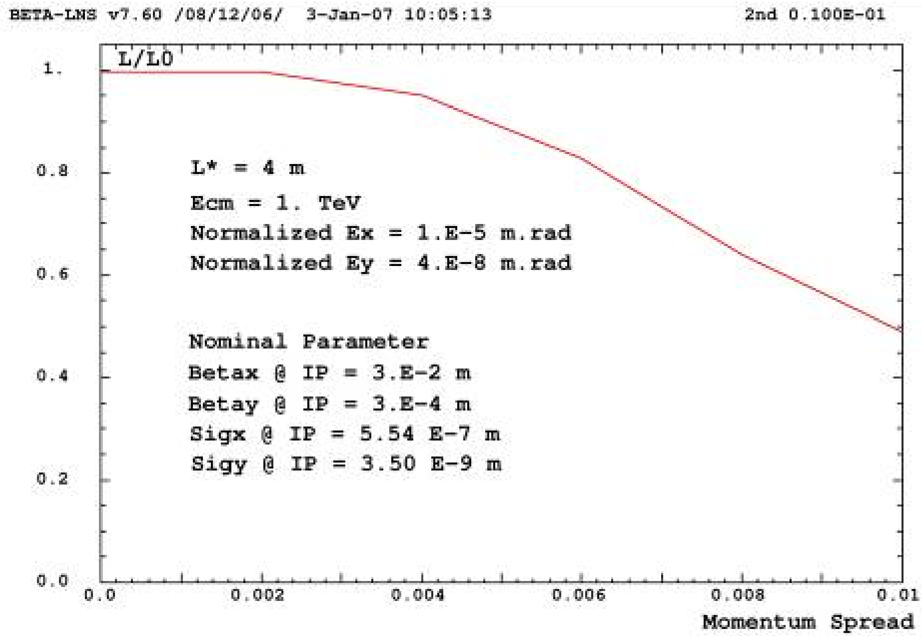
Final Doublet : 1 TeV upgrade



NED Nb3Sn conductor seems to allow safely a 50 % increase of the gradient

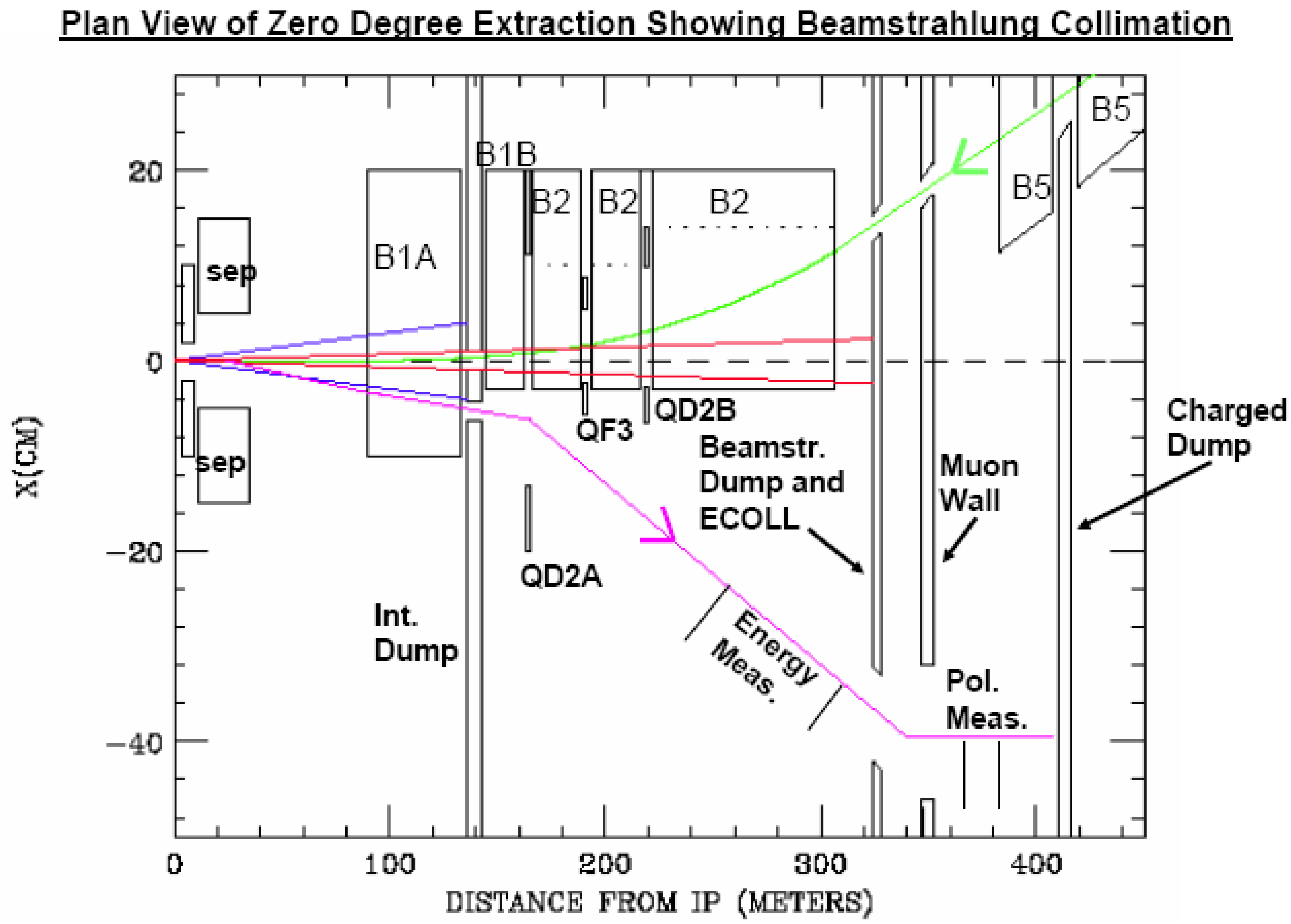
Final Doublet : 1 TeV upgrade



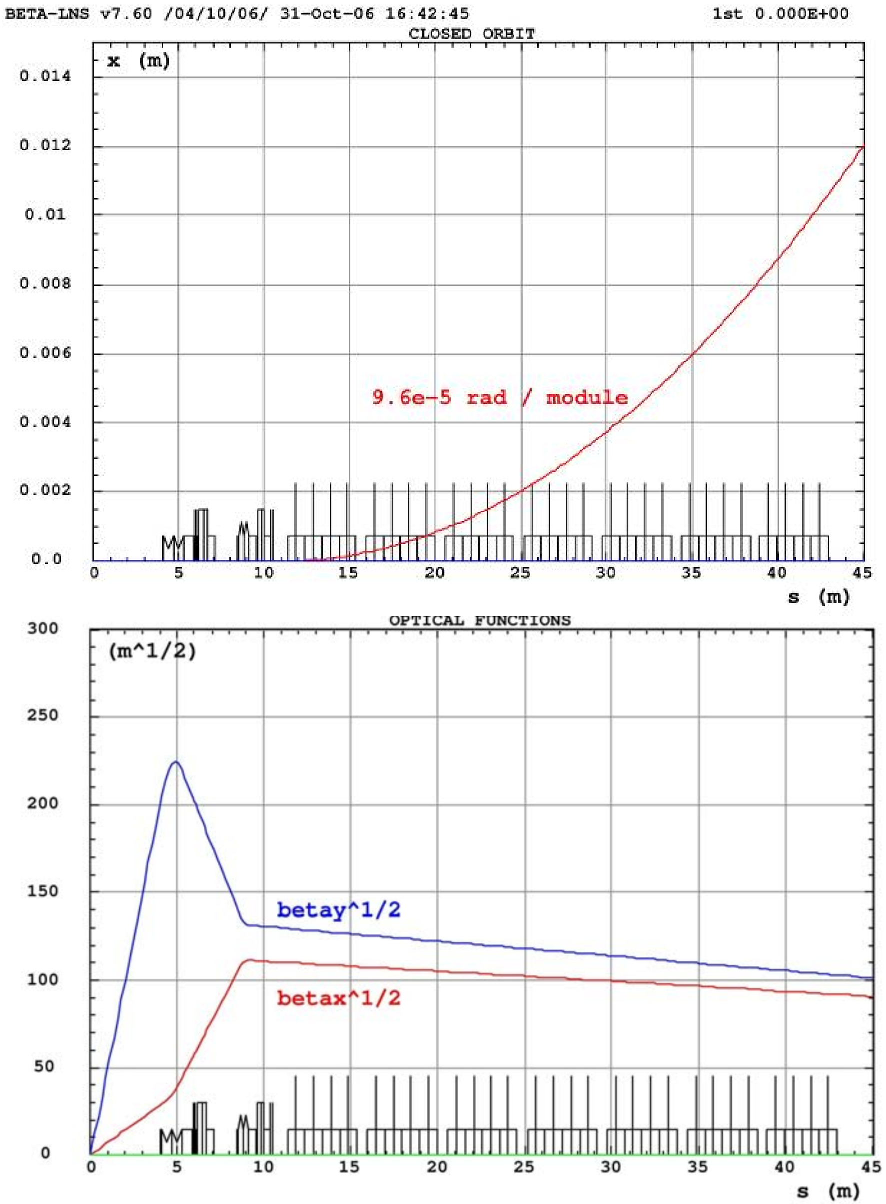


	QD0	QF1	SD0	SF1
Length [m]	1.374	0.746	0.7	0.4
Gradient	373 T/m	370 T/m	5243 T/m2	4873 T/m2
Field @ bore	10.5 T	10.5 T	4.11 T	3.82 T

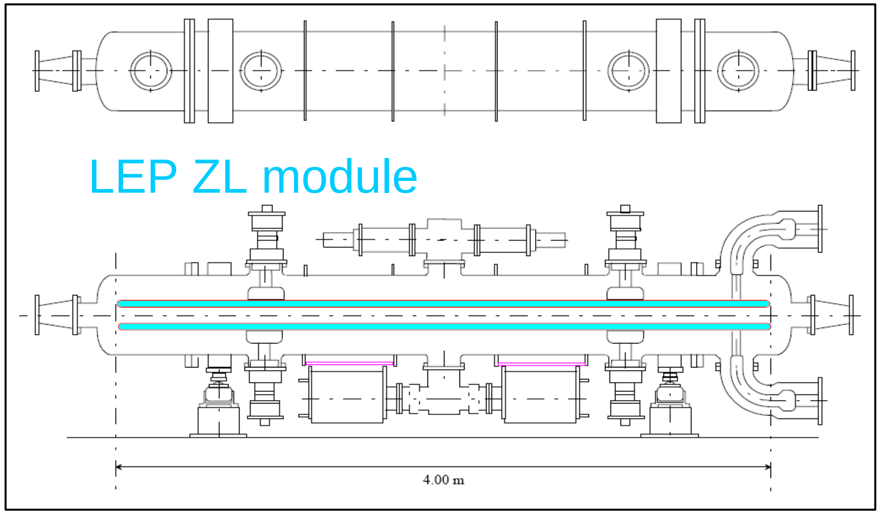
Beam Extraction Scheme



Extraction Scheme : Parasitic Crossing



First stage separation is provided by seven 4 m long Electrostatic Separator modules with Es = 30 kV/cm
+ 100 Gauss compensating dipoles



Beam-beam instability from parasitic crossings is under control when :

- Horizontal transverse separation is larger than 11 mm
- R_{34}(IP $\rightarrow$ 1st PIP) < $\beta^{*1/2}$ x 100 $m^{1/2}$

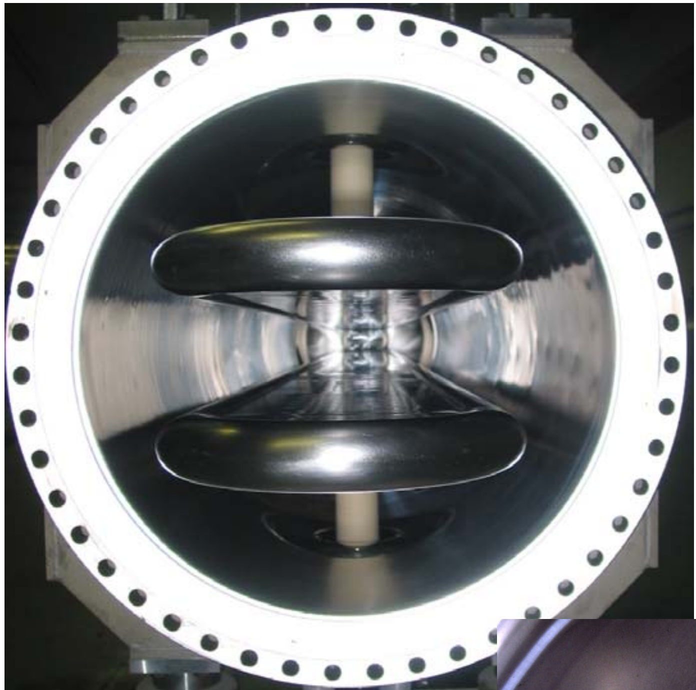
(cf. J. Brossard's talk)

Electrostatic Separators Experience

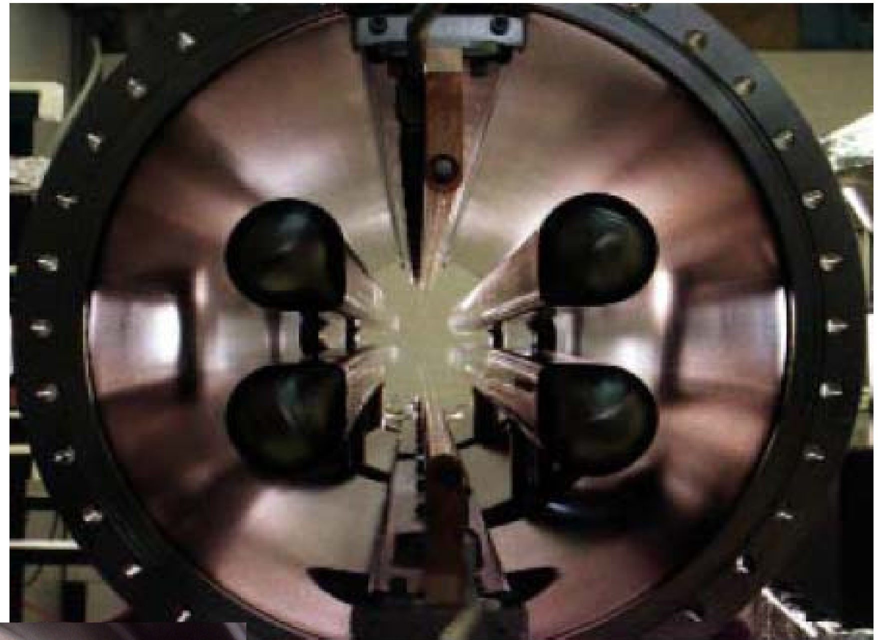
From Jan Borburgh	LESB II (1979) [1]	Tristan (1989) [2]	Tevatron (1992) [3]	SPS ZX (1982) [4]	LEP ZL (1996)	CESR (1999) [5]	BEPC II (2001) [6]
Nominal gap (mm)	150	80	50	40 (20 – 160)	100 (60 – 160)	85	100
Operational field strength (MV/m)	< 5.2	3.0	5.0 max.	5.0	2.5 (tested to 5.0)	2.0	2.2
HV supply (kV)	+/-390	+/- 120	+/- 125	0/-200	+/- 150	+/- 85	+/- 110
Electrode dimension (mm x mm)	n.a.	4600 x 150		3000 x 160	4000 x 260	2700	
Electrode material	Glass	Ti		Ti	SS		
Device length (mm)	n.a.	5105	3000	3380	4500		
Working pressure (mbar)	10^{-6}			10^{-10}	10^{-10}		
Operational spark rate (#/h)	<1	<0.02		< 0.03	0.2	0.04	
Particle beam	p-	e- e+ 9mA 15GeV	p p-	p p- (270 GeV)	e- e+ (100 GeV)	e- e+ 150 mA	e- 576 mA

Electrostatic Separators Experience

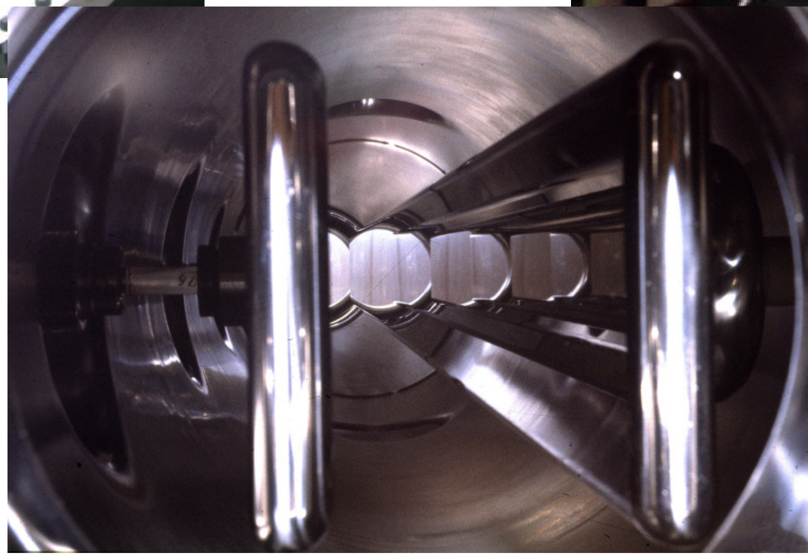
Electrode layouts



LEP ZL separator



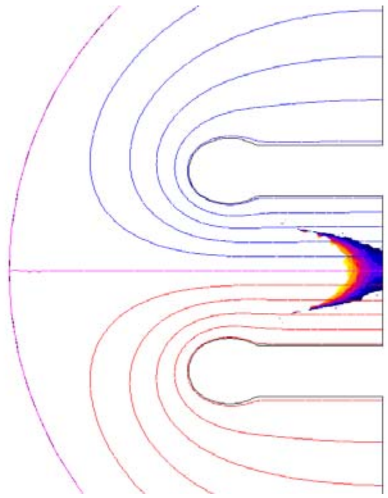
CESR separator



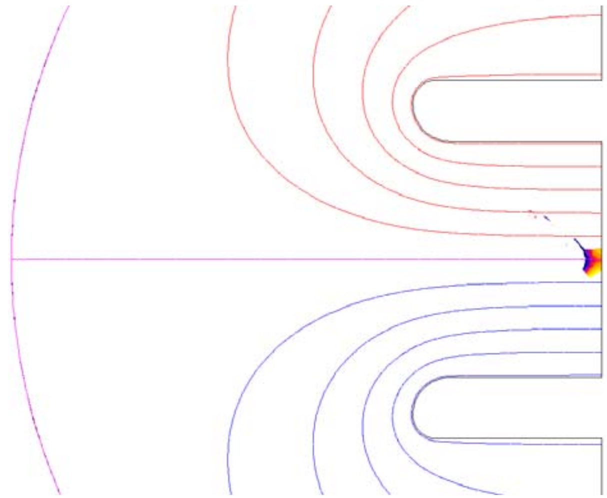
SPS ZX separator

Electrostatic Separators Modelling

- Field homogeneity is being calculated at CERN *(B. Balhan)*



ZL: 1‰ for 25 x 13 mm

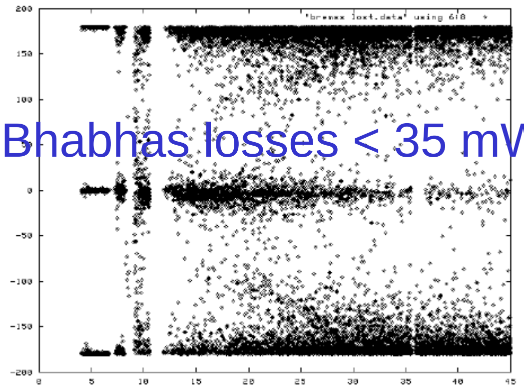


ZX: 1‰ for 14 x 10 mm

- Beam transport through inhomogeneous ES field is being modelled at Saclal

Electrostatic Separators

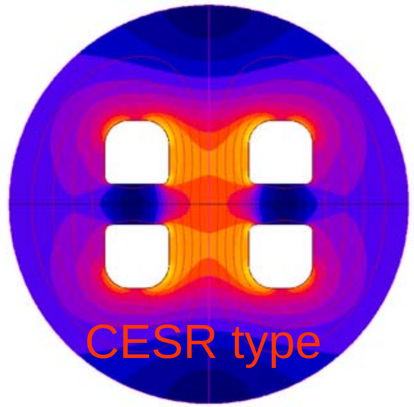
Remaining Questions :



R^{ive} Bhabhas losses < 35 mW/m

- Sparking rate vs. Beam loss intensity
  - → no record from LEP
  - → beam test at ESA (or KEK, …)

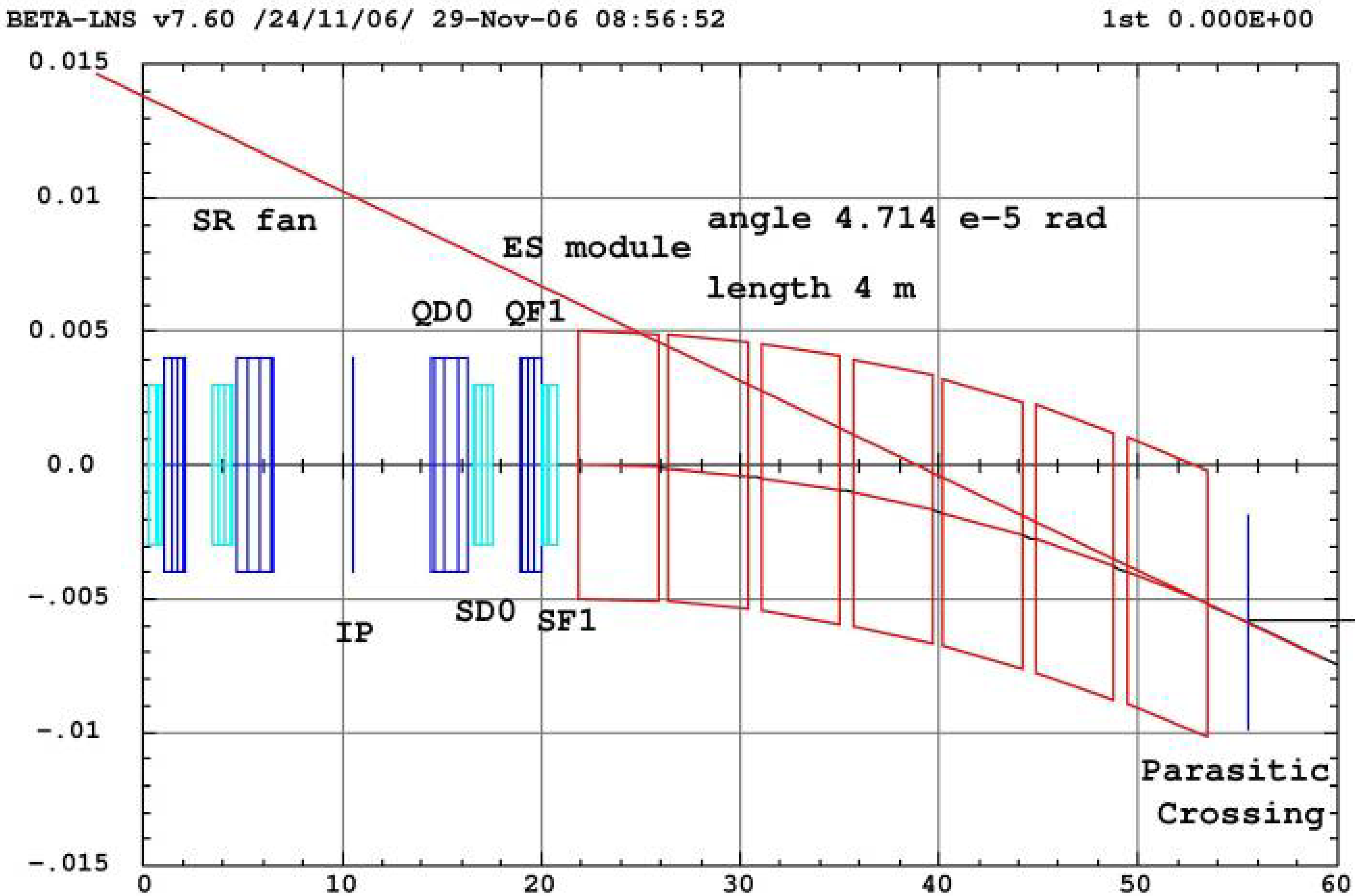
- Field quality in case of slit electrodes



- 1 TeV upgrade requires 50 - 60 kV/cm
  - → Titanium electrodes

- Separator failure handling

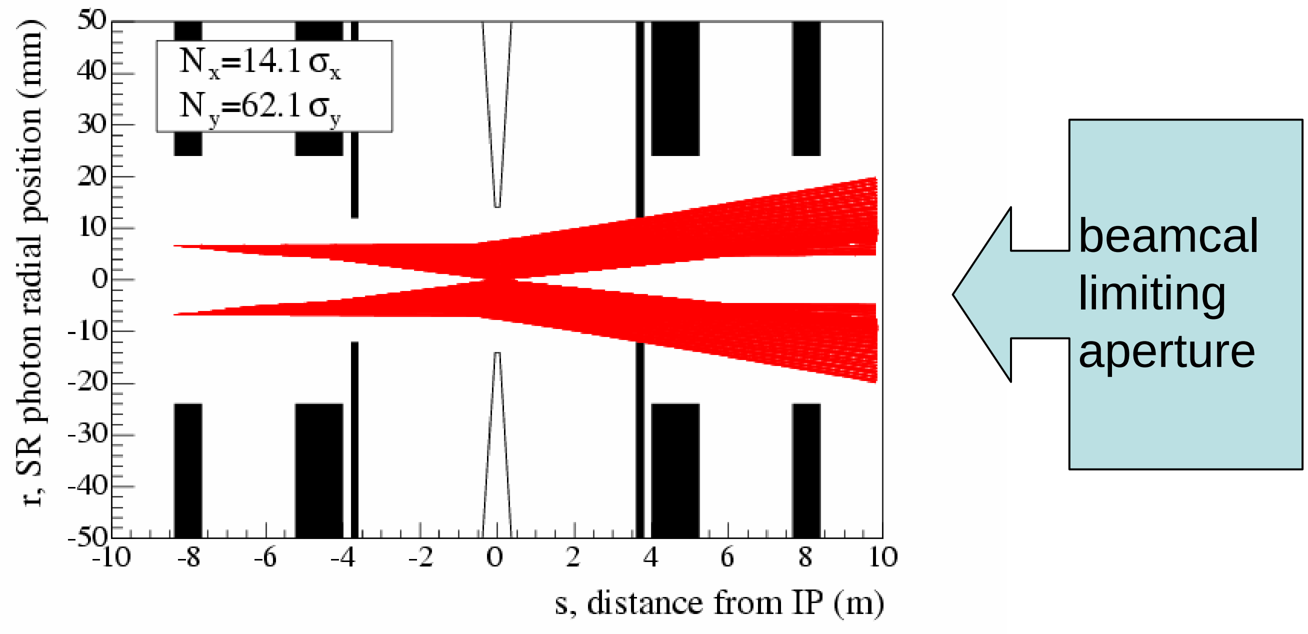
Extraction Scheme : No compensating dipole



This scheme is not fully checked :
beamstrahlung collimation seems a problem because of the small transerse separation w.r.t. the spent beam *(L. Keller)*

Collimation and Beam Losses

- Collimation depths are limited by BeamCal



- Extraction optics is currently been studied with the primary goals to **minimize the spent beam losses** and **reduce the tunnel length**.

- Spent beam intermediate collimation is proposed.

Prospects

• **Head-on IR** has the potential to be a **Luminosity** and **Cost** effective option for 500 GeV and 1 TeV ILC

• **Head-on IR** has the potential to make full profit from the high-field superconducting magnet technological developments driven by SLHC

• I am optimistic that a **spent beam extraction system** can be found with tolerable beam and beamstrahlung losses.

• **Post-IP instrumentation** will be challenging

• Beam test of an existing LEP ZL **separator module** is necessary. I hope GDE R&D Board could help.

Parameter Space for E=250 GeV L=2 10^{34} $cm^{-2}s^{-1}$

		Nominal	Large Y	Low P	High L	TESLA	Med Q P
N	x 10^{10}	2	2	2	2	2	1.3
n_b		2820	2820	1330	2820	2820	2820
$\varepsilon_{x,y}$	µm,nm	9.6, 40	12, 80	10, 35	10, 30	10, 30	9.6, 30
$\beta_{x,y}$	cm,mm	2, 0.4	1, 0.4	1, 0.2	1, 0.2	1.5, 0.4	1, 0.2
$\sigma_{x,y}$	nm	626.5, 5.7	495.3, 8.1	452.1, 3.8	452.1, 3.5	553.7, 5	443, 3.5
σ_z	µm	300	500	200	150	300	200
Bunch space	ns	308.5	308.5	462.4	308.5	308.5	308.5
D_y		19.12	28.30	26.72	21.66	24.98	19.16
δ_{BS}	%	2.2	2.2	5.1	6.2	2.7	2.5
P	MW	11.3	11.3	5.3	11.3	11.3	7.3