IP Stabilization issues

T. Tauchi

ILC Tokusui Workshop, KEK, 17 -19 Dec. 2013

ILC TDR : IR Engineering Specifications (3)

Engineering Specifications (3) : QD0 Issues	unit	value	
Mover : number of degrees of freedom		5	horizontal x, vertical y, pitch φ, yaw ψ, roll α
Mover : Range per x,y degree of freedom	mm	± 2	
Mover : Range per φ, ψ degree of freedom	mrad	± 1	
Mover : Range per α degree of freedom	mrad	± 30	
Mover : Step size per degree of freedom of motion	μm	± 0.05	
Before BBA : Accuracy per x,y degree of freedom	μm	± 50	
Before BBA : Accuracy per φ, ψ degree of freedom	μrad	± 20	
Before BBA : Accuracy per α degree of freedom	mrad	± 20	
BBA : alignment accuracy per x,y	nm	± 200	from a line determined by QF1s for 200ms
BBA : Accuracy per α degree of freedom	μrad	± 0.1	from a line determined by QF1s for 200ms
Vibration stability : $\Delta(QD0(e^+)-QD0(e^-))$	nm	50	within 1ms long bunch train
Engineering Specifications (4) : Radiation shield	unit	value	
Self shielding		must	
Normal operation : anywhere beyond the 15m zone housing the off-beamline detector	μSv/hour	0.5	
Accidental beam loss : dose for occupational workers	mSv/hour	250	The acident is defined as the simultaneous loss of both e^+ and e^- beams at 250 GeV/beam anywhere, at maximum beam power.
Accidental beam loss : integrated doze for occupational workers	mSv/accident	1	
Accidental beam loss : beam shut-off time after the accident	beam-train	1	
Engineering Specifications (5) : Vacuum	unit	value	
in the 200m upstream of the IP	Pa	1	=1.3 x 10^{-7} Pa
in the remainder of the BDS system	Pa	10	=1.3 x 10^{-6} Pa
in the 18m zone of the detector			not specified in the IR document

ILC TDR Parameters

Crossing scheme : crab crossing with 14mr, and also waist scan with 0.6 σ_z at IP

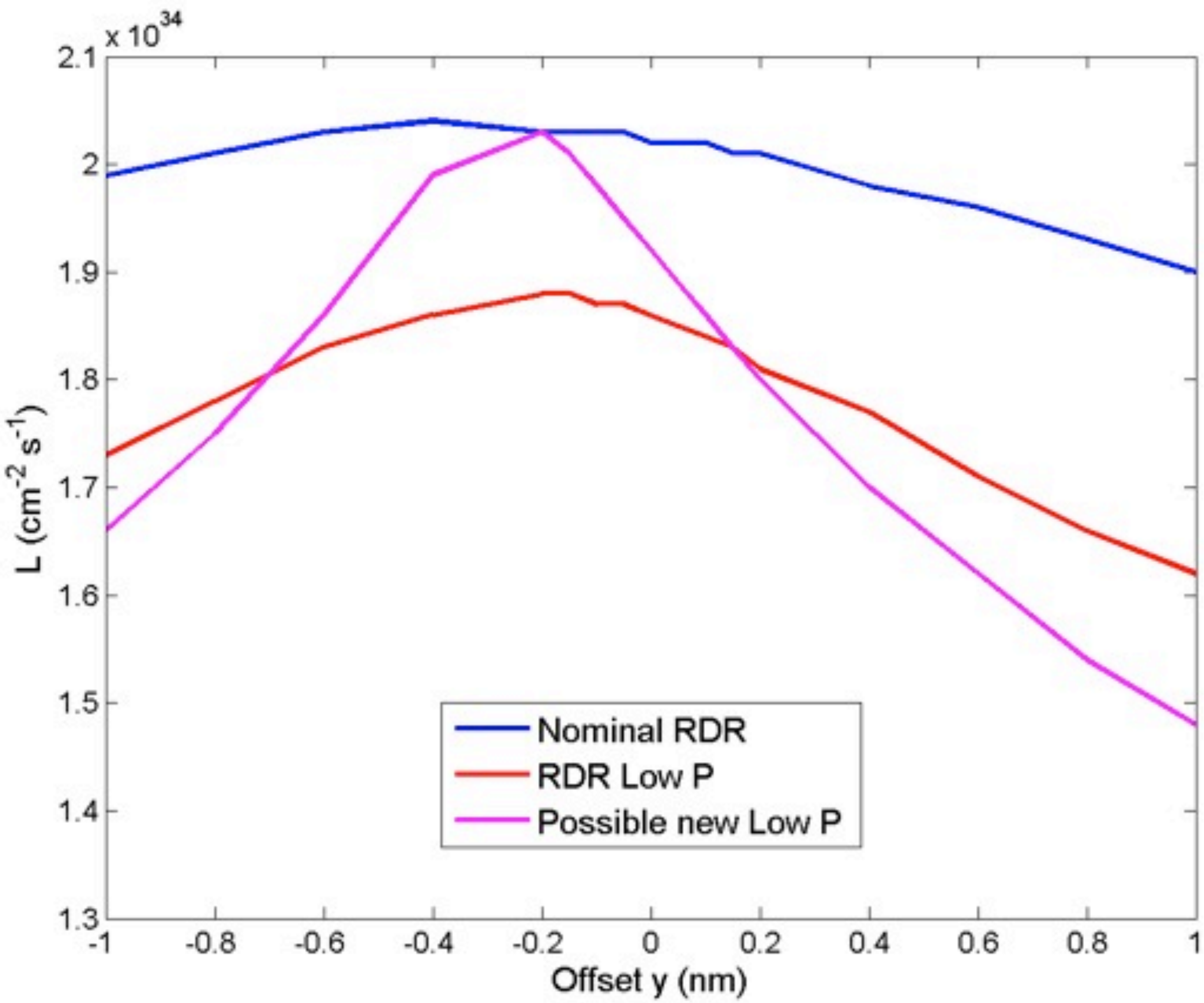
Table 3.1. Summary table of the 250–500 GeV baseline and luminosity and energy upgrade parameters. Also included is a possible 1st stage 250 GeV parameter set (half the original main linac length)

			Baseline 500 GeV Machine			1st Stage	L Upgrade	E_{CM} Upgrade	
								A	B
Centre-of-mass energy	E_{CM}	GeV	250	350	500	250	500	1000	1000
Collision rate	f_{rep}	Hz	5	5	5	5	5	4	4
Electron linac rate	f_{linac}	Hz	10	5	5	10	5	4	4
Number of bunches	n_b		1312	1312	1312	1312	2625	2450	2450
Bunch population	N	$\times 10^{10}$	2.0	2.0	2.0	2.0	2.0	1.74	1.74
Bunch separation	Δt_b	ns	554	554	554	554	366	366	366
Pulse current	I_{beam}	mA	5.8	5.8	5.8	5.8	8.8	7.6	7.6
Main linac average gradient	G_a	MV m^{-1}	14.7	21.4	31.5	31.5	31.5	38.2	39.2
Average total beam power	P_{beam}	MW	5.9	7.3	10.5	5.9	21.0	27.2	27.2
Estimated AC power	P_{AC}	MW	122	121	163	129	204	300	300
RMS bunch length	σ_z	mm	0.3	0.3	0.3	0.3	0.3	0.250	0.225
Electron RMS energy spread	$\Delta p/p$	%	0.190	0.158	0.124	0.190	0.124	0.083	0.085
Positron RMS energy spread	$\Delta p/p$	%	0.152	0.100	0.070	0.152	0.070	0.043	0.047
Electron polarisation	P_-	%	80	80	80	80	80	80	80
Positron polarisation	P_+	%	30	30	30	30	30	20	20
Horizontal emittance	$\gamma\epsilon_x$	μm	10	10	10	10	10	10	10
Vertical emittance	$\gamma\epsilon_y$	nm	35	35	35	35	35	30	30
IP horizontal beta function	β^*_x	mm	13.0	16.0	11.0	13.0	11.0	22.6	11.0
IP vertical beta function	β^*_y	mm	0.41	0.34	0.48	0.41	0.48	0.25	0.23
IP RMS horizontal beam size	σ^*_x	nm	729.0	683.5	474	729	474	481	335
IP RMS veritcal beam size	σ^*_y	nm	7.7	5.9	5.9	7.7	5.9	2.8	2.7
Luminosity	L	$\times 10^{34}$ cm^{-2}s^{-1}	0.75	1.0	1.8	0.75	3.6	3.6	4.9
Fraction of luminosity in top 1%	$L_{0.01}/L$		87.1%	77.4%	58.3%	87.1%	58.3%	59.2%	44.5%
Average energy loss	δ_{BS}		0.97%	1.9%	4.5%	0.97%	4.5%	5.6%	10.5%
Number of pairs per bunch crossing	N_{pairs}	$\times 10^3$	62.4	93.6	139.0	62.4	139.0	200.5	382.6
Total pair energy per bunch crossing	E_{pairs}	TeV	46.5	115.0	344.1	46.5	344.1	1338.0	3441.0

β^*_x is 1/2 of the RDR and the waist scan is assumed in the TDR to compensate the half number of bunches.

SB2009 beam offset sensitivity

- Higher Disruption
  - **Higher sensitivity to Δy**
  - **Intratrain Feedback more challenging**
  - **Vertical bunch-bunch jitter to be <200pm for <5% lumi loss**
  - **However, twice longer bunch separation will help to improve bunch-bunch uniformity & jitter**



Nominal RDR : 95% Lum with the offset of 1nm

Possible new low P :90(75)% Lum with the offset of 0.2(1)nm

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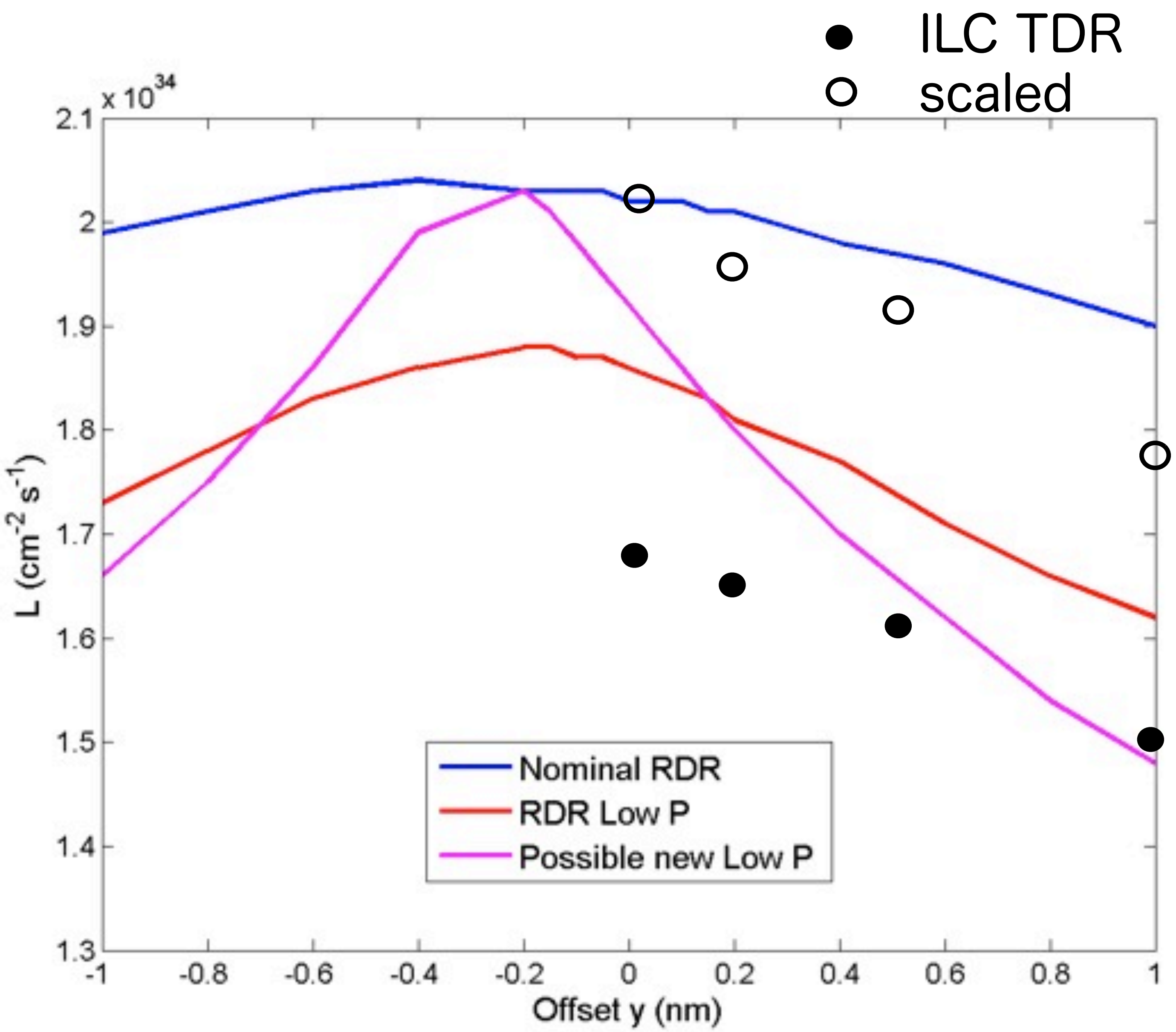

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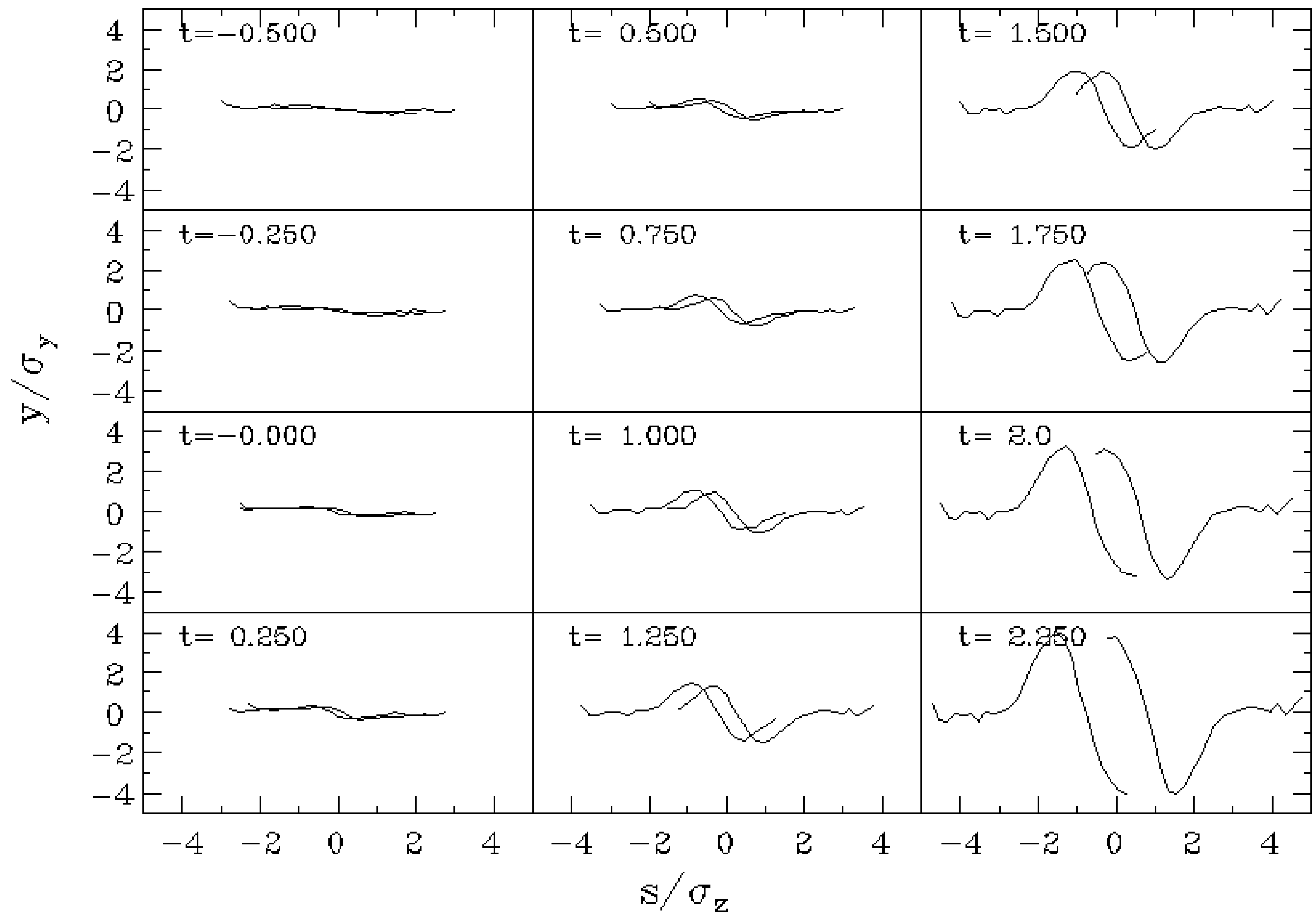
Kink Instability in the flat beam with D_y=20

Figure 3: Evolution of the kink instability. The beams collide with initial vertical offset Δ_y=0.2σ_y. The time range, -0.5< t < 2.25 (t in units of σ_z), is shown with time mesh 0.25. In each plot the vertical center-of-mass y/σ_y is shown as a function of the longitudinal position s/σ_z. Flat beam with D_y=20.



Center-of-Mass Deflection

$$A_y \equiv \frac{\sigma_z}{\beta_y^*} = \frac{300 \times 10^{-6}}{480 \times 10^{-6}} = 0.625$$

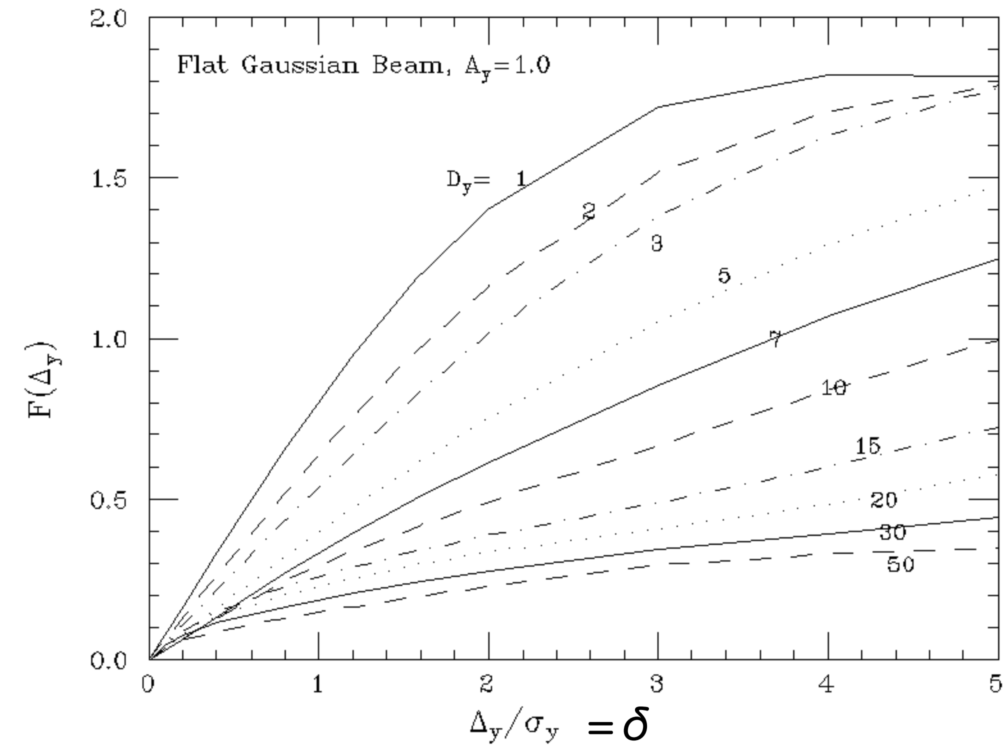
$$\theta_0 \equiv \frac{2Nr_e}{\gamma(\sigma_x + \sigma_y)} = \frac{D_x \sigma_x}{\sigma_z} = \frac{D_y \sigma_y}{\sigma_z} = 4.86 \times 10^{-4}$$

$$\theta_0 \to \frac{2Nr_e}{\gamma \sigma_x} \quad \text{at} \quad \frac{\sigma_x}{\sigma_y} \gg 1$$

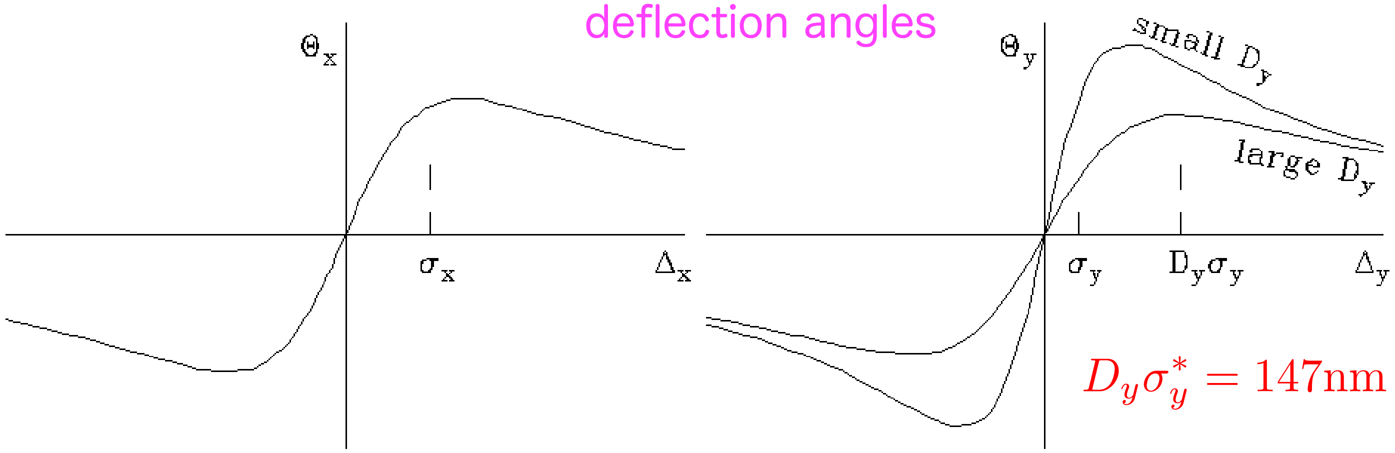
larger by √2 than the RDR for σ_x

$$D_{x(y)} \equiv \frac{2Nr_e}{\gamma} \frac{\sigma_z}{\sigma_{x(y)}(\sigma_x + \sigma_y)} = 0.3(24.9)$$

$$\Theta_{x,max} = 0.765\theta_0 \qquad \Theta_{y,max} = 1.25\theta_0$$

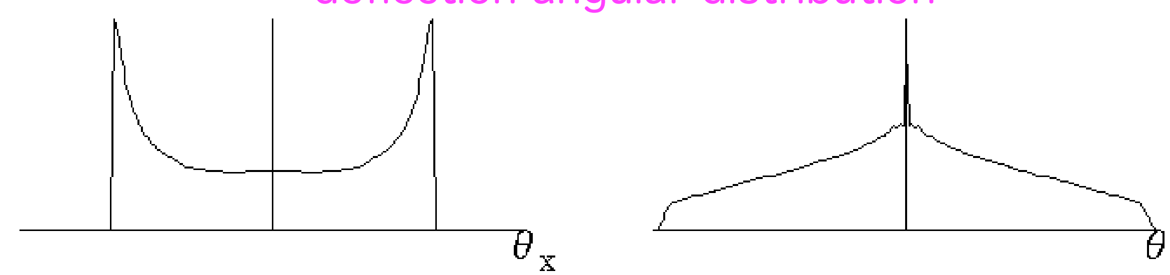


deflection angles



$D_y \sigma_y^* = 147\text{nm}$

deflection angular distribution

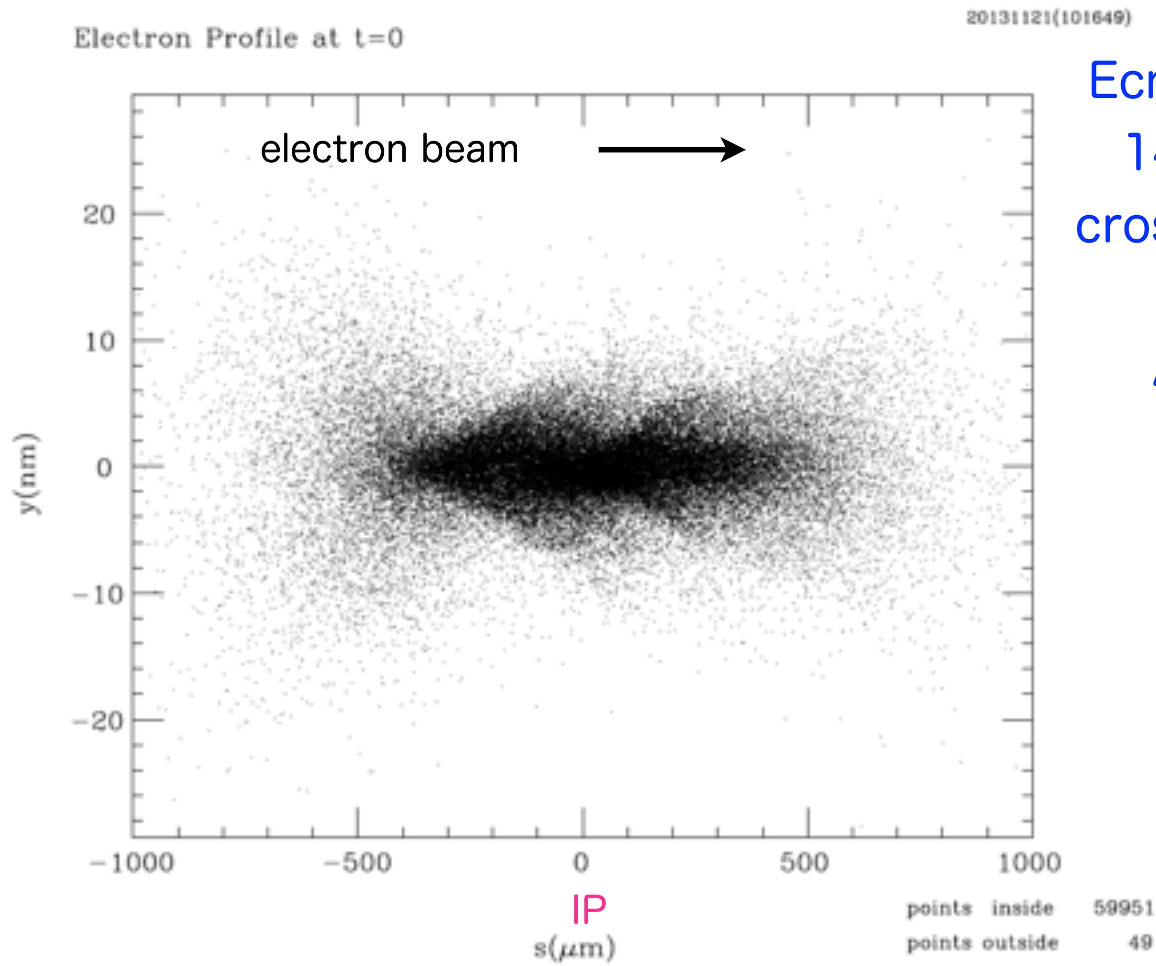


In general, we define the form factor F for the vertical deflection by (analytic calculation)

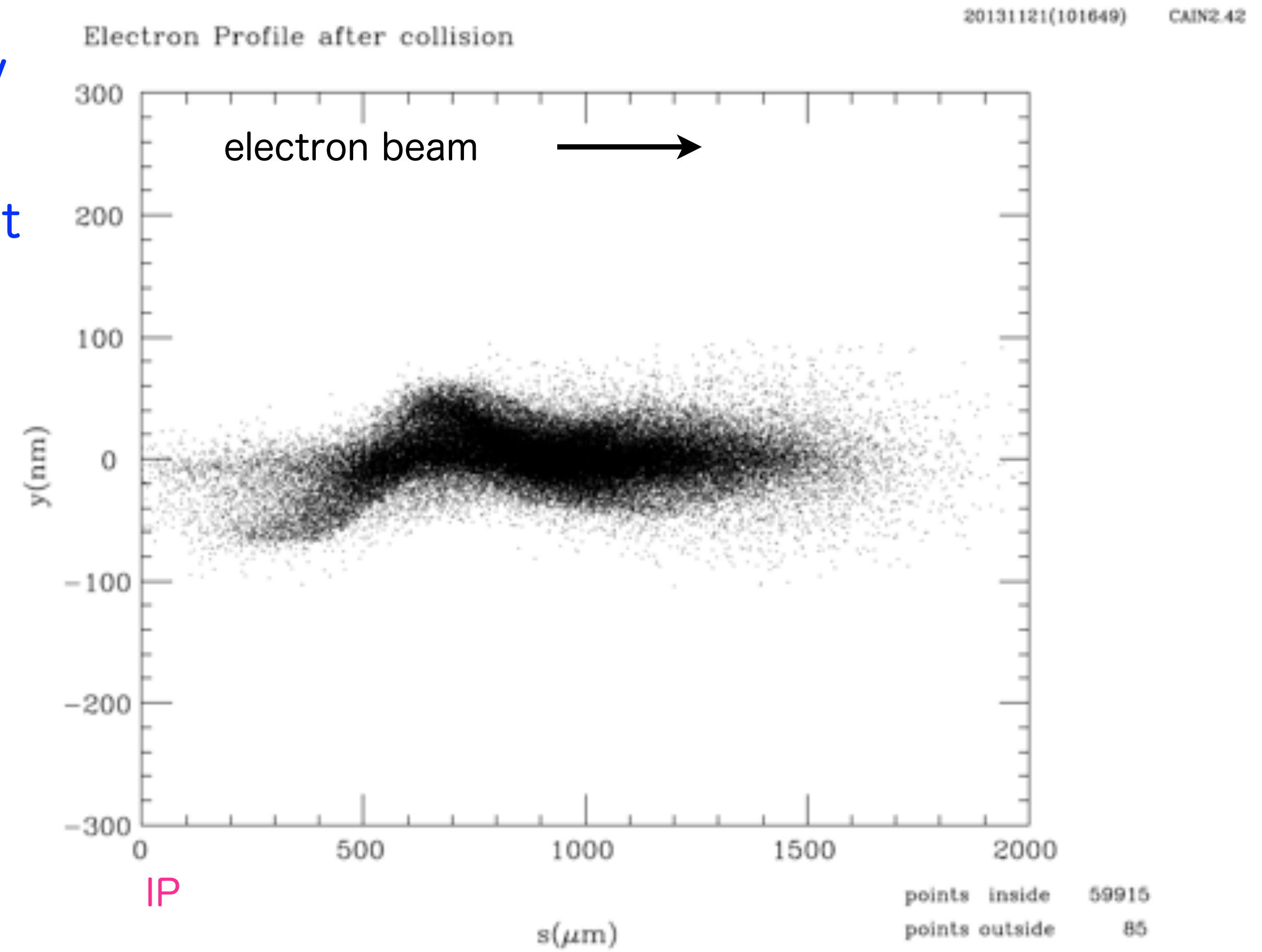
$$\Theta_y = \tfrac{1}{2}\theta_0 F(\Delta_y/\sigma_y). \qquad (2.49)$$

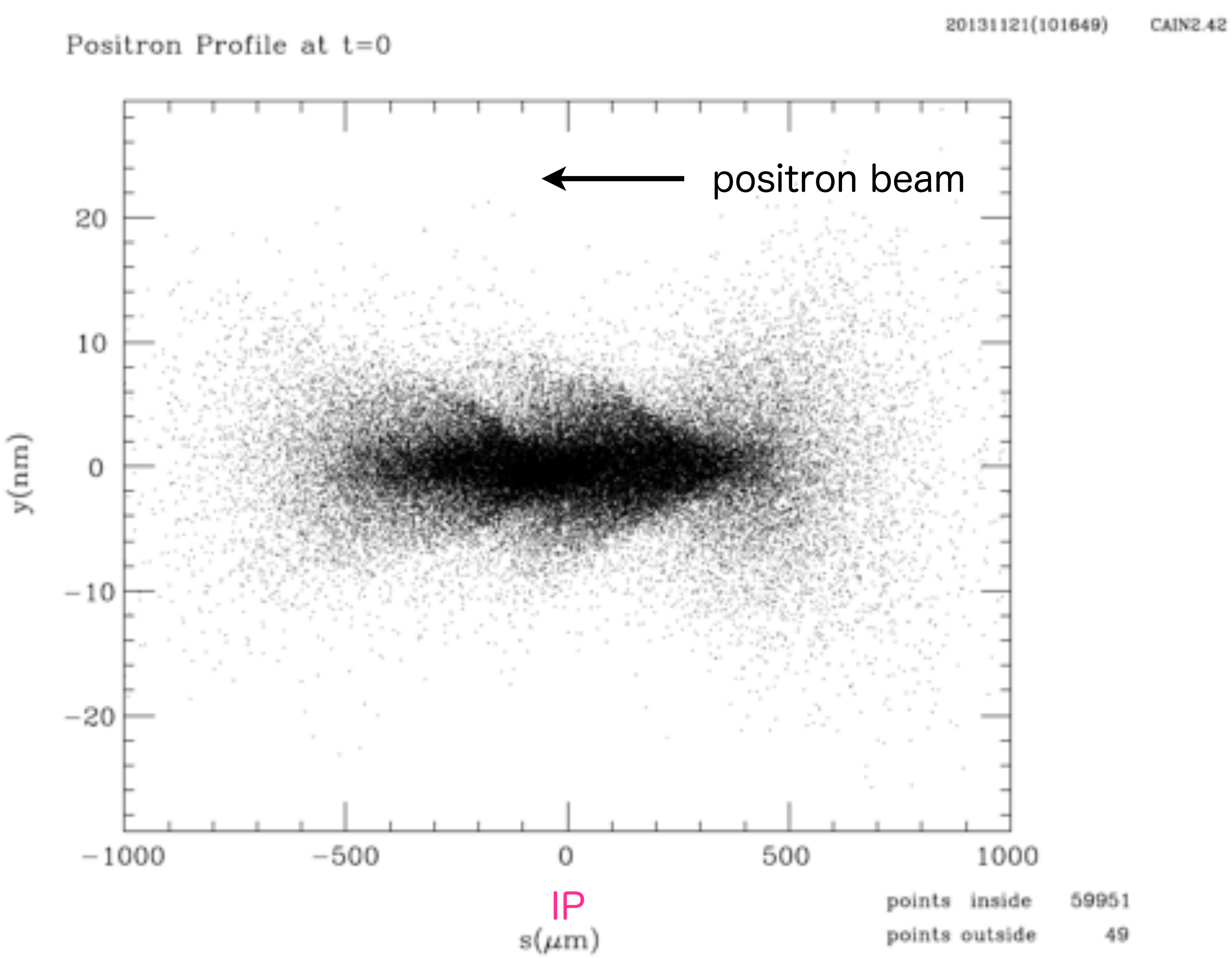
$$F = \delta[C_1 + C_2\delta^2 + \frac{1}{\pi^2}\delta^4]^{-1/4} \qquad (\delta < 3) \qquad \delta \equiv \frac{\Delta_y}{\sigma_y}$$

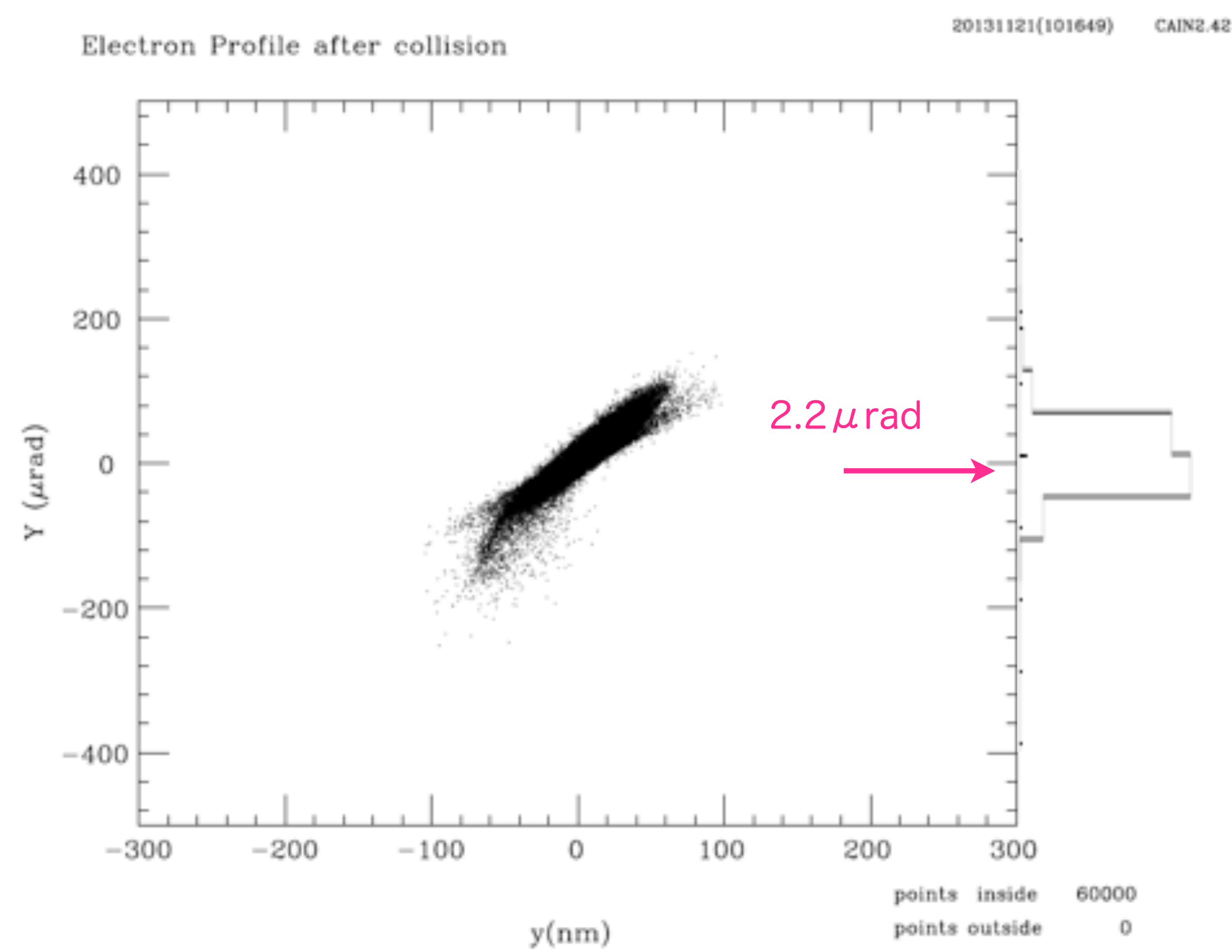
$$C_1 = (1 + A_y^2)[1 + \frac{0.5}{0.6 + (\sqrt{D_y} - 2.5)^2}]^2 = 1.6 \qquad C_2 = [\frac{1.2 D_y^2}{D_y + 10}]^2 = 445$$



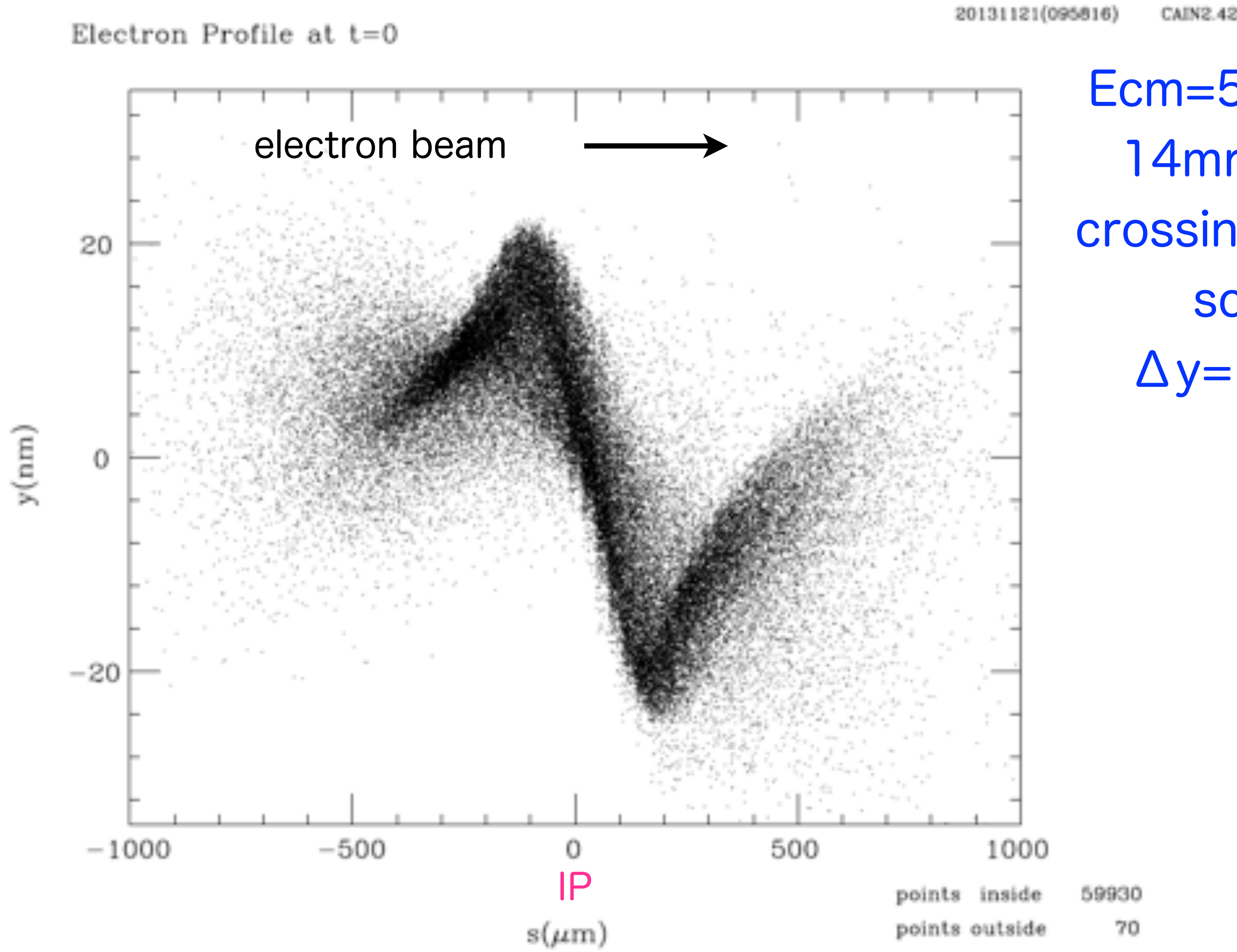
Ecm=500GeV
14mr, crab crossing, waist scan
Δy=0nm

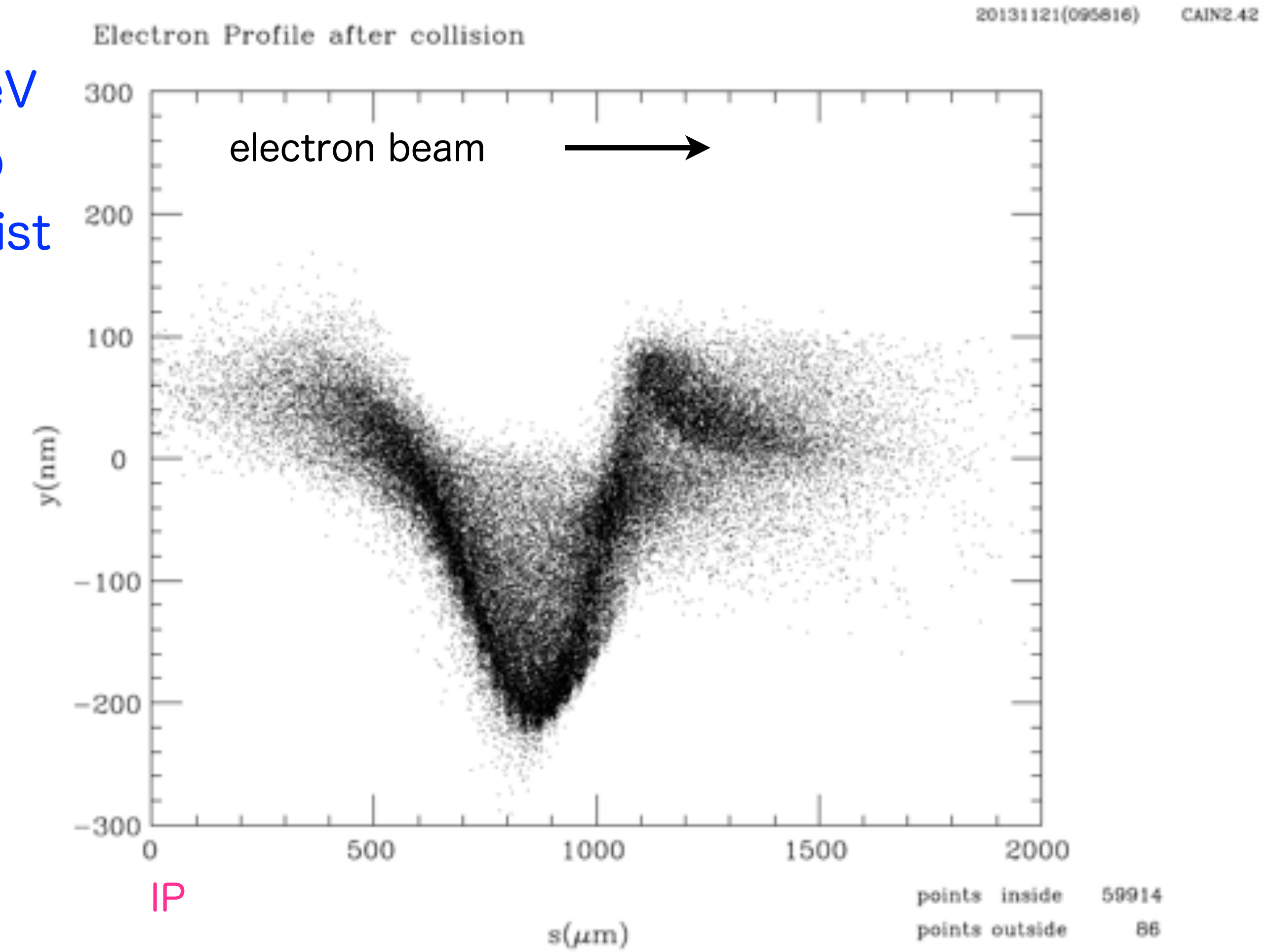


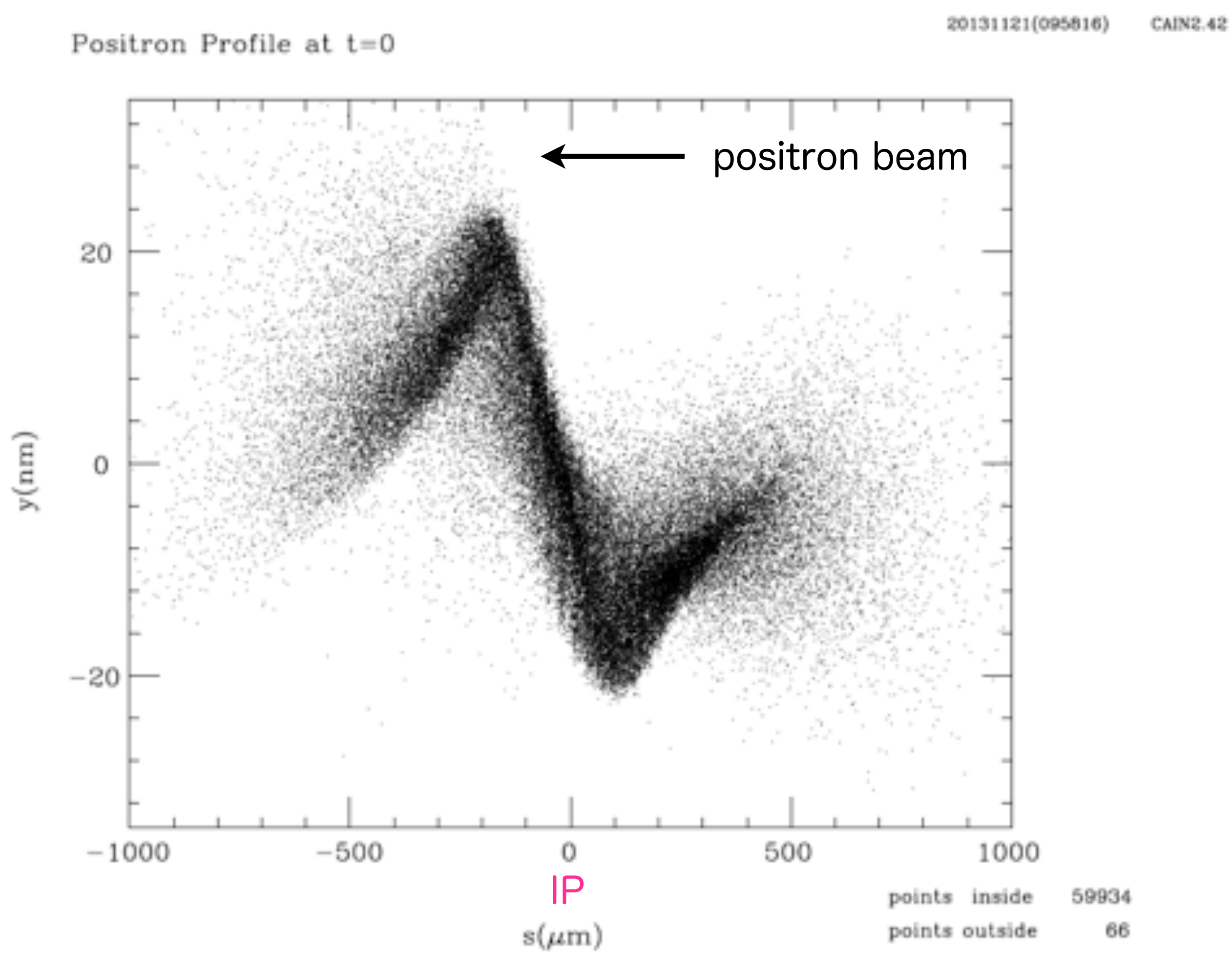


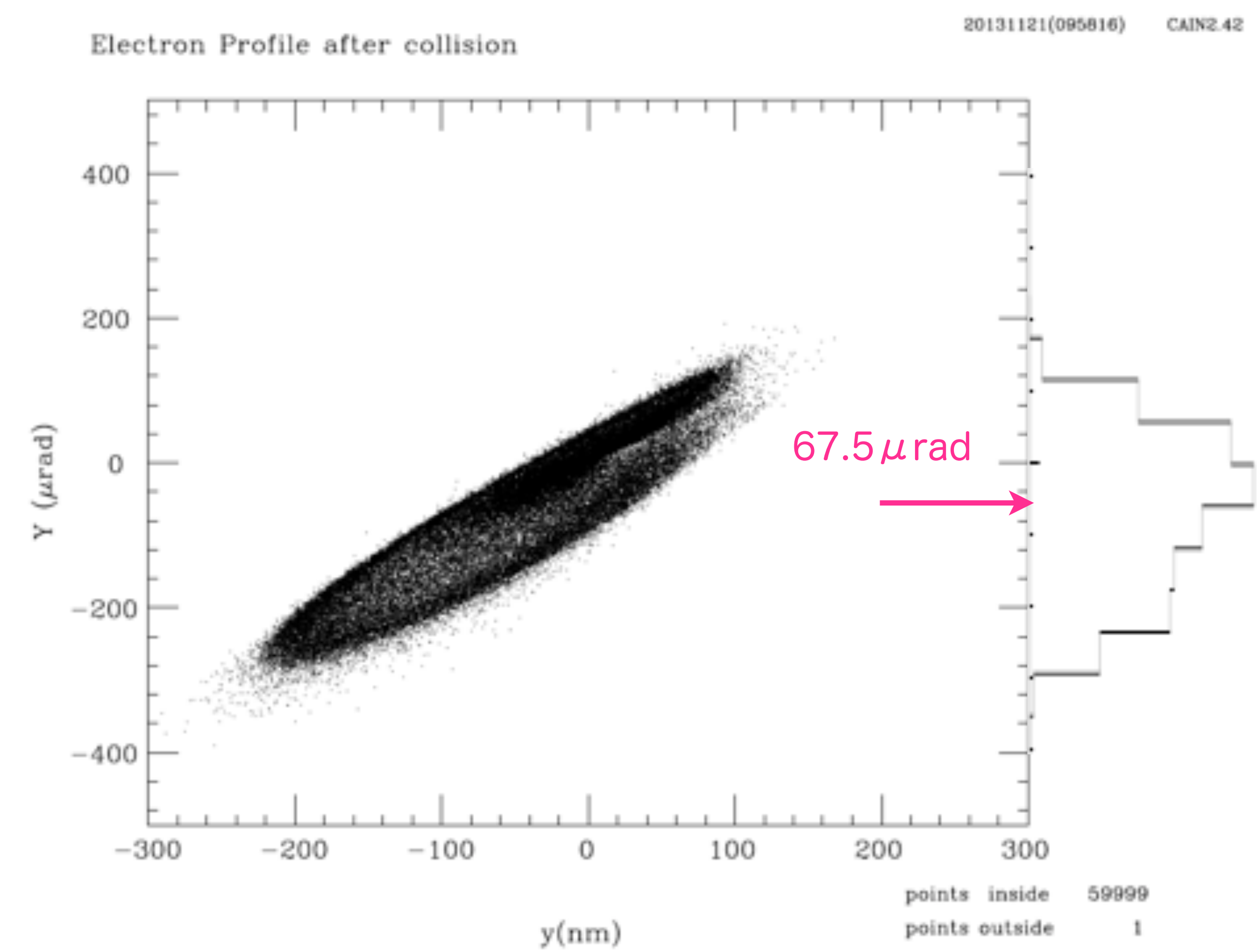


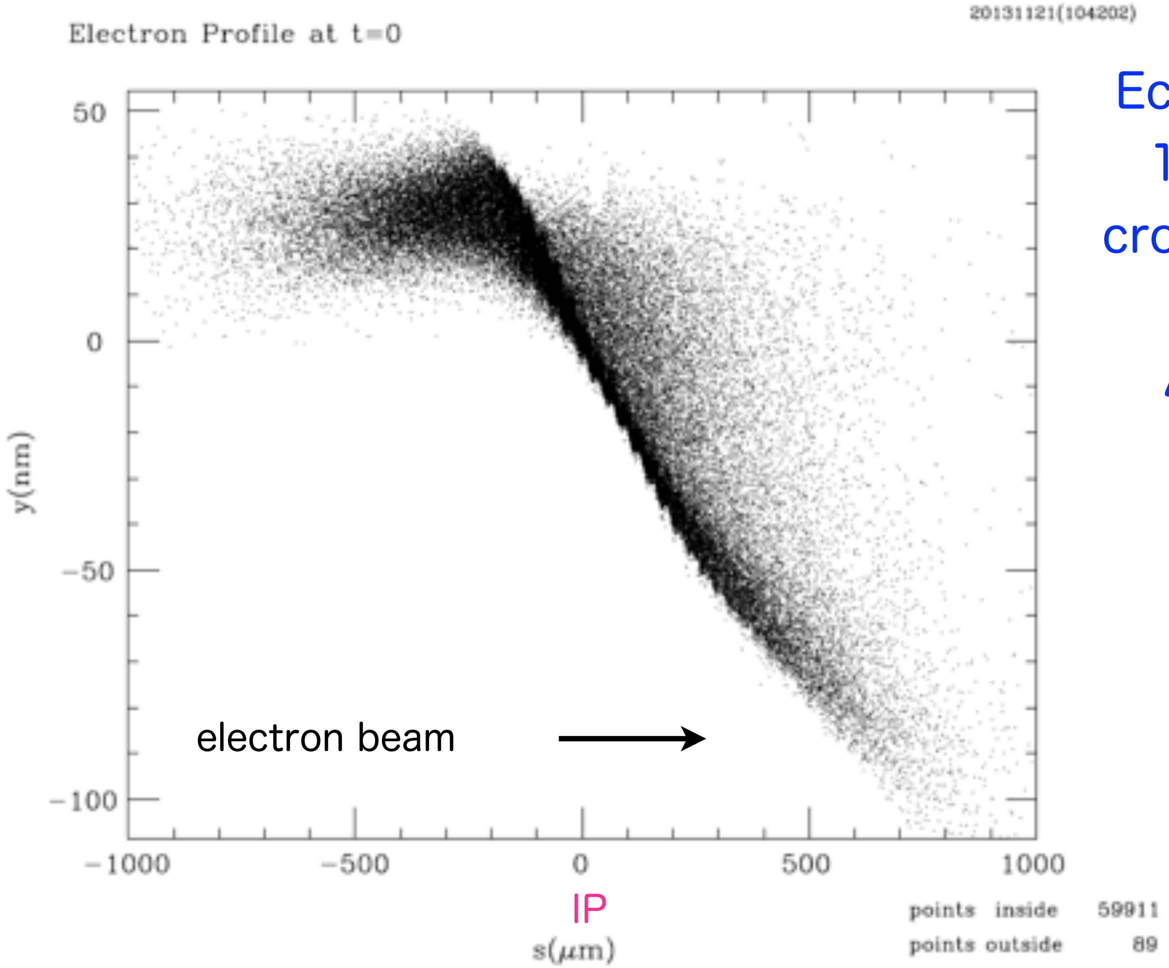
Ecm=500GeV
14mr, crab crossing, waist scan
Δy=10nm



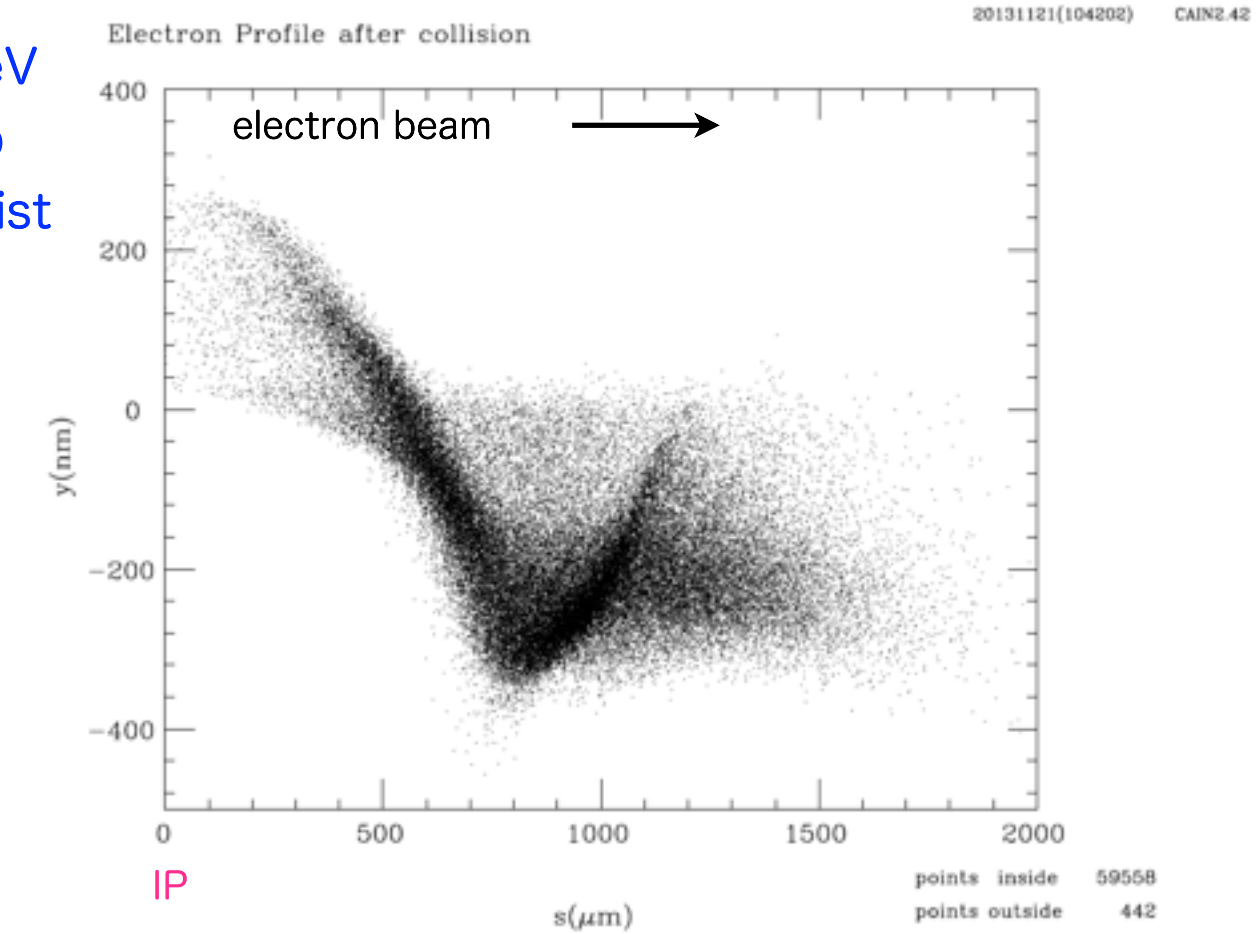


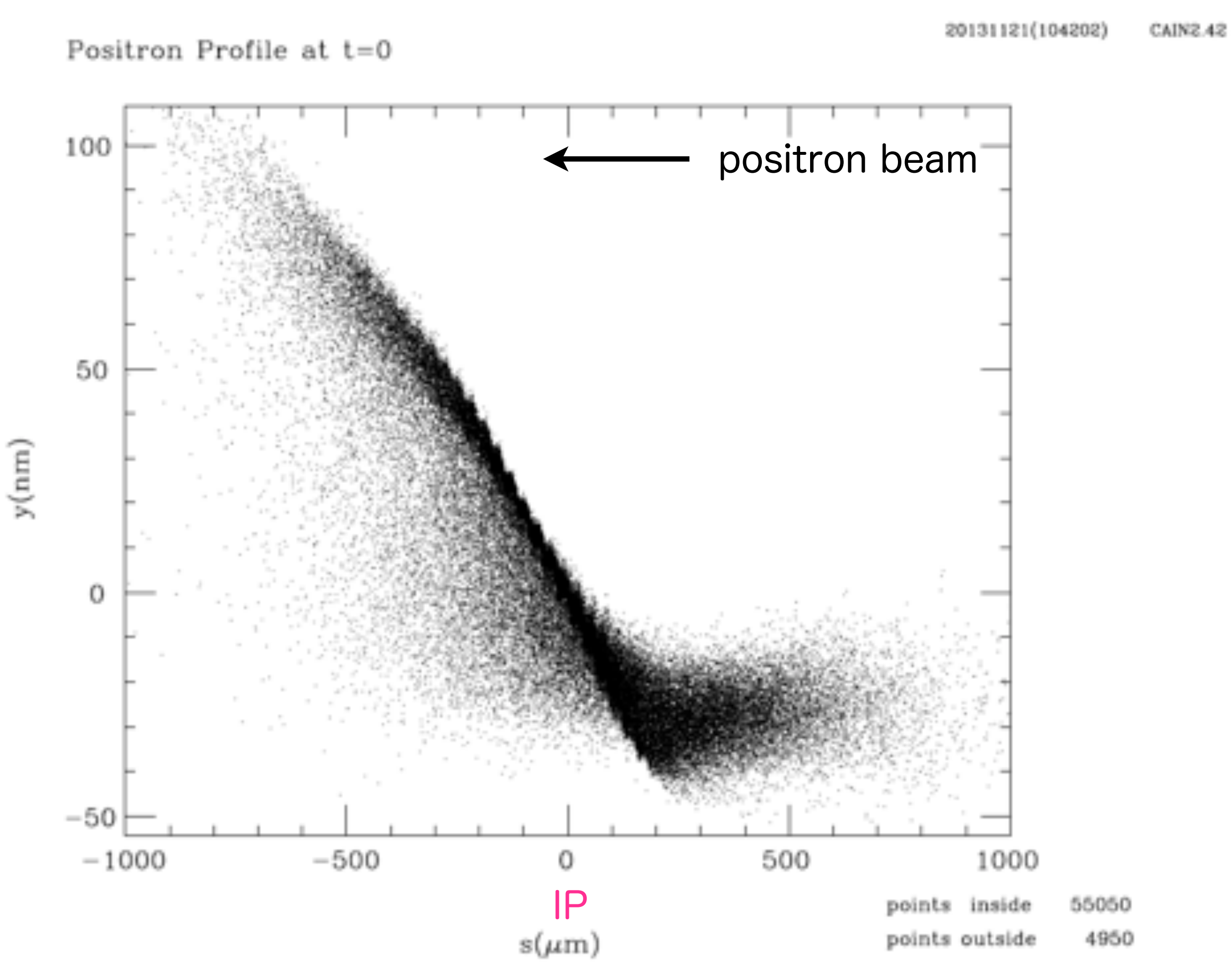


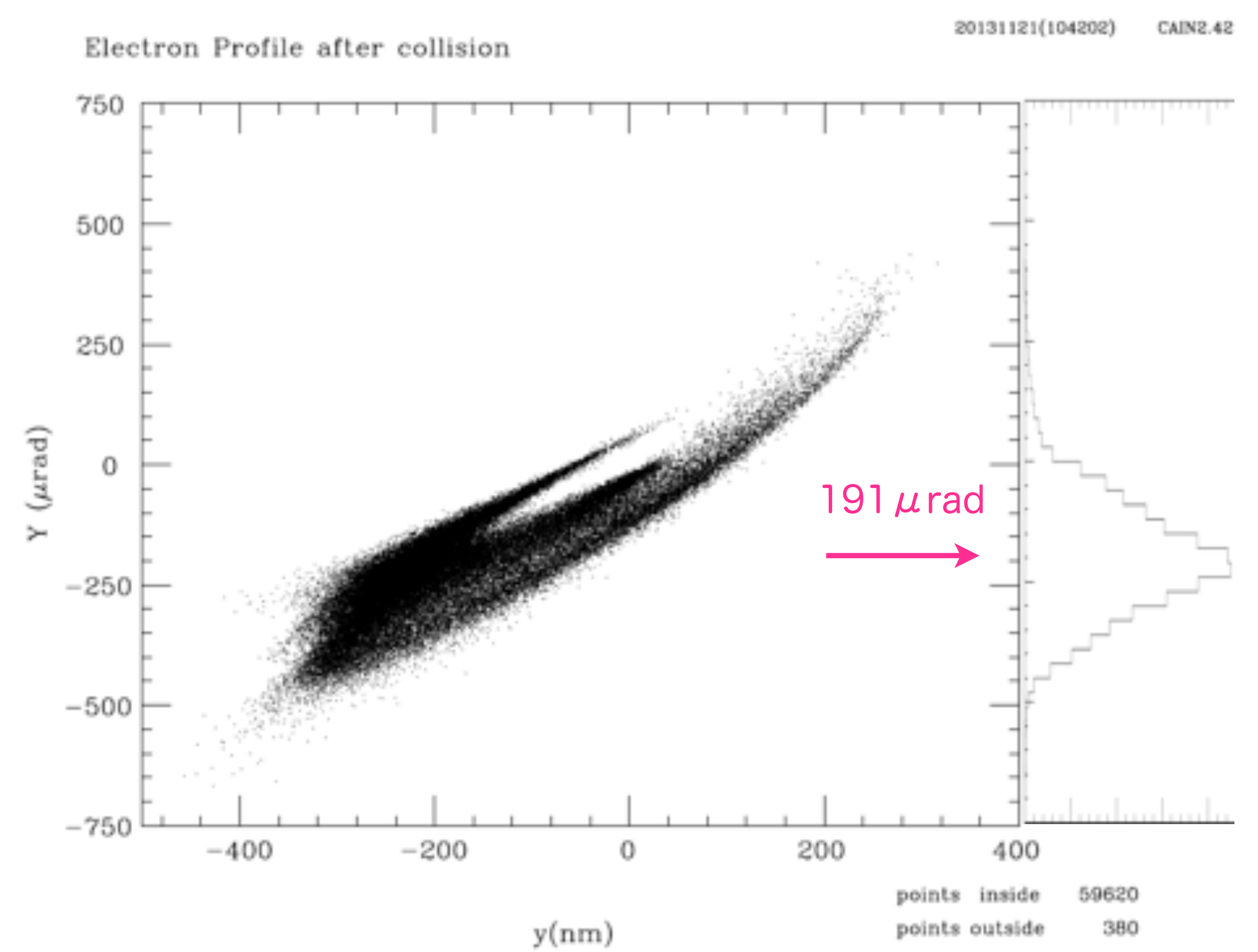




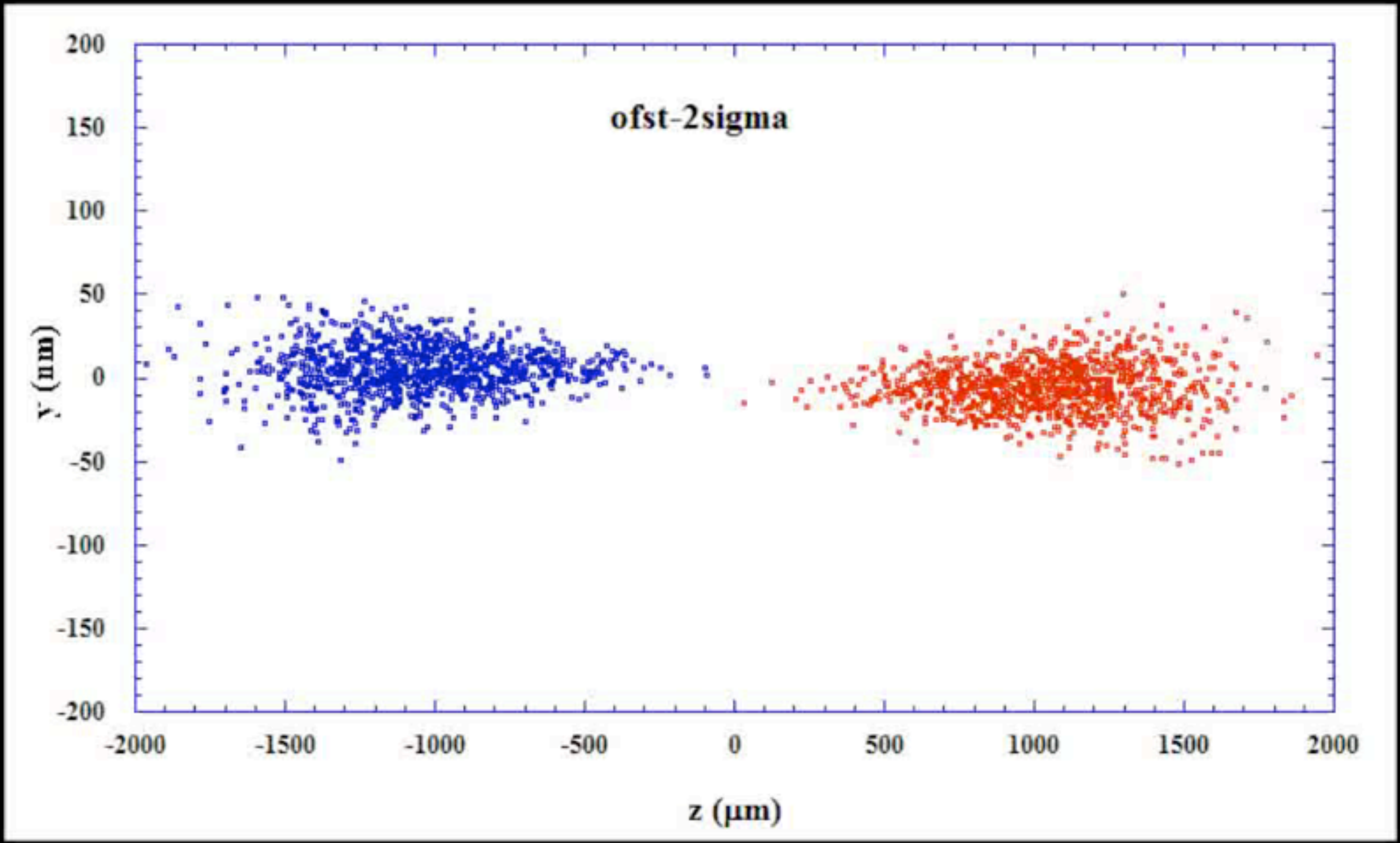
Ecm=500GeV
14mr, crab crossing, waist scan
Δy=50nm







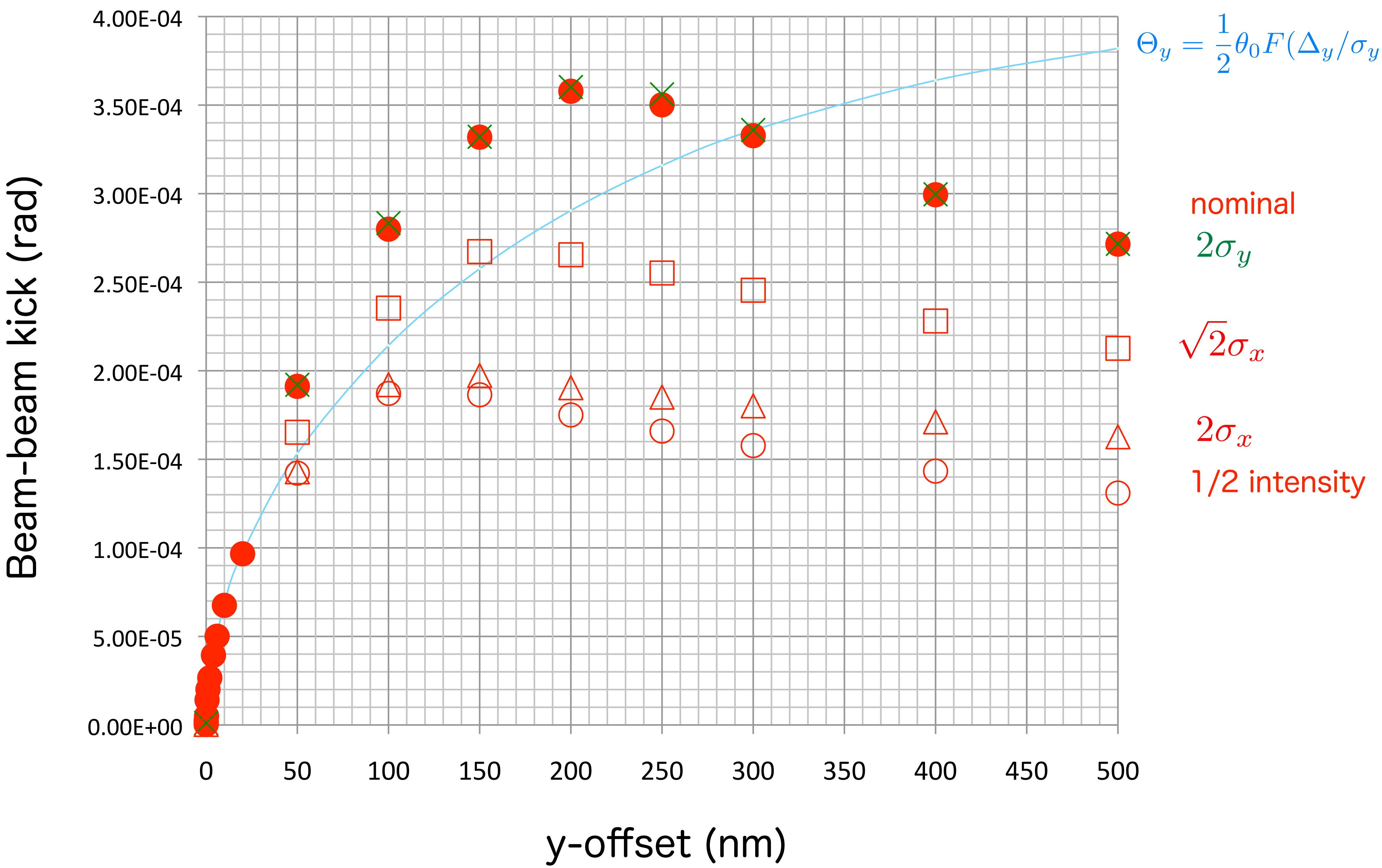
animation of collisions with 2σ*y offset, calculated by CAIN and made by K.Kubo



ILC TDR at E_{cm}=500GeV

14mr crab crossing with the waist scan

calculated by CAIN V2.42



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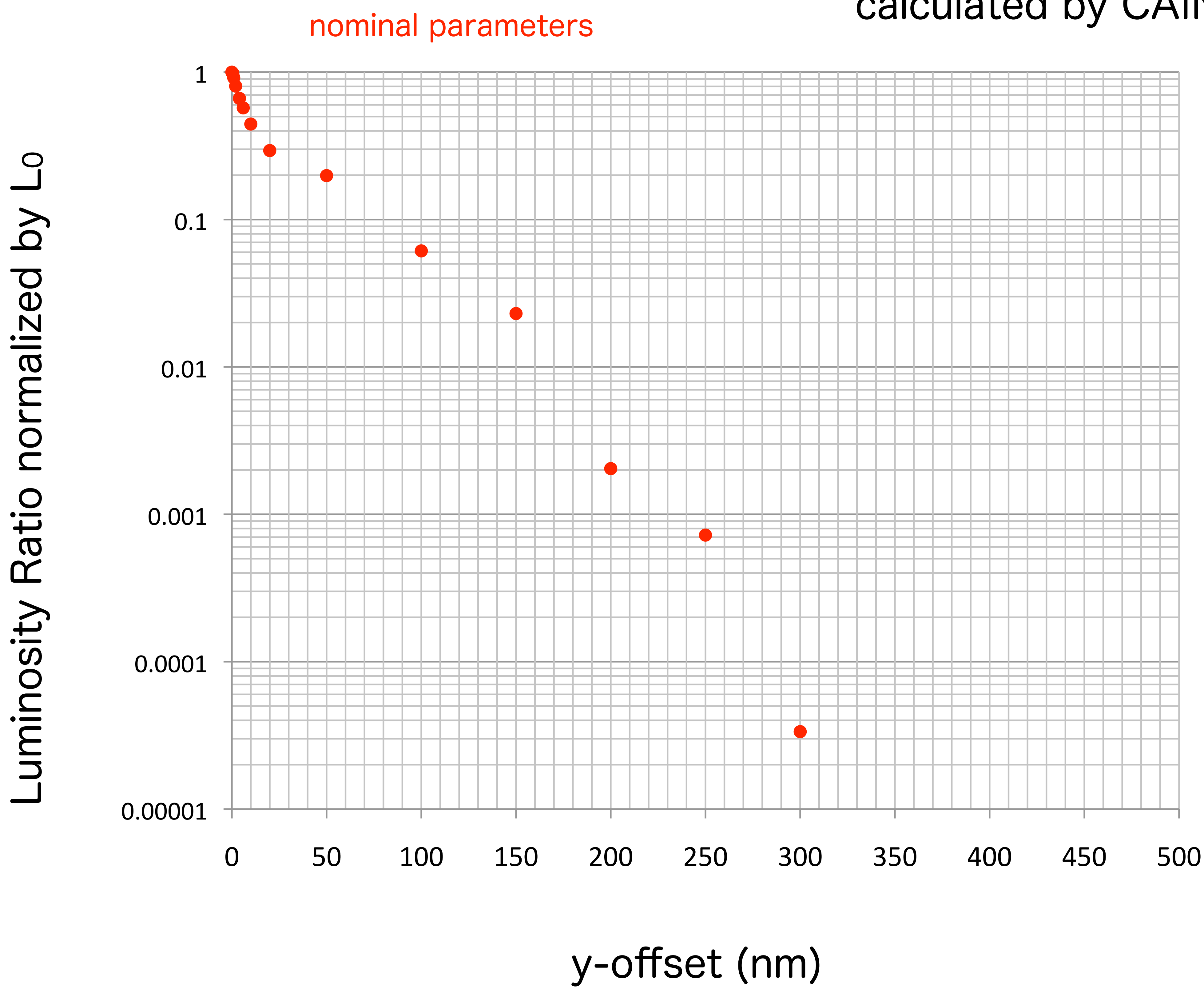
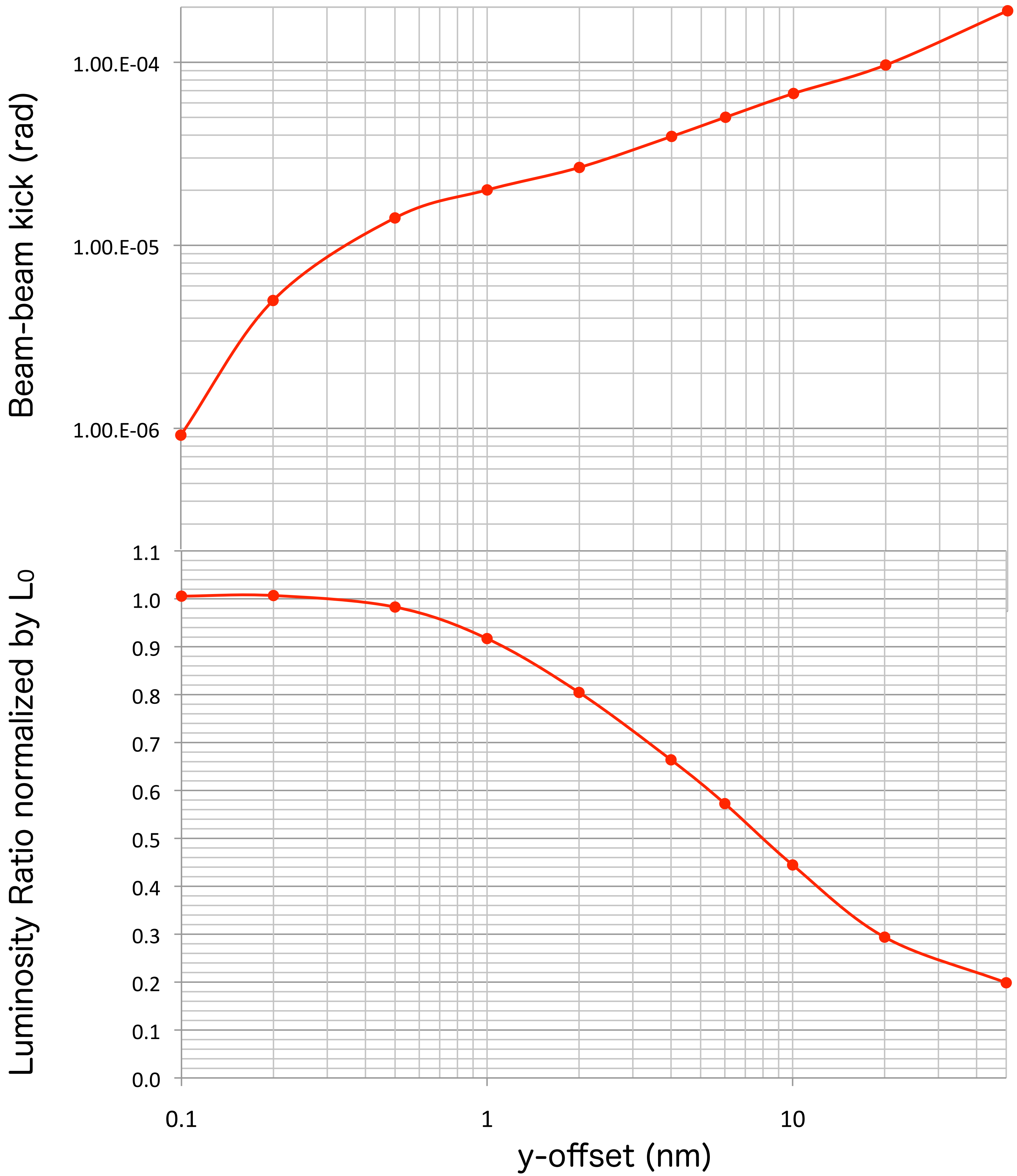


ILC TDR at Ecm=500GeV nominal

calculated by CAIN V2.42

14mr crab crossing with the waist scan



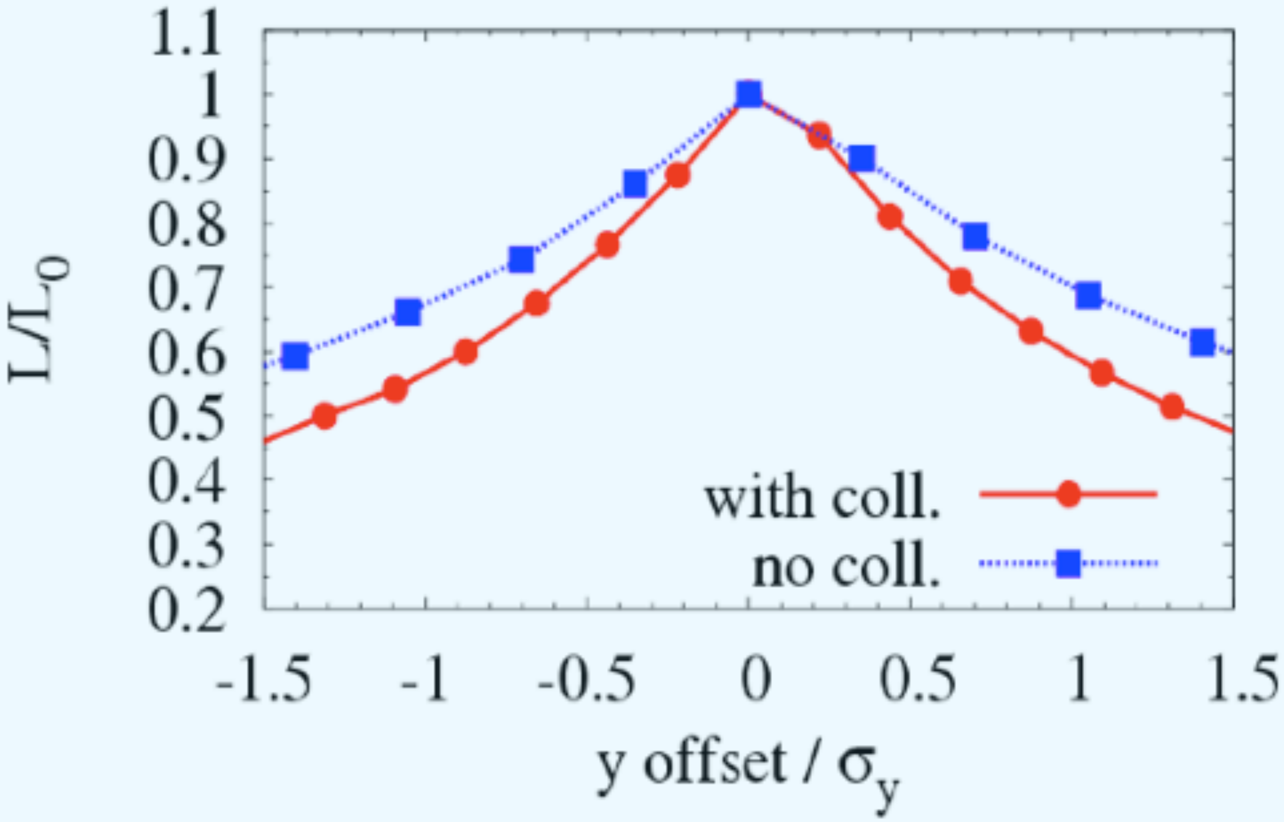
2013年 12月 17日 火曜日

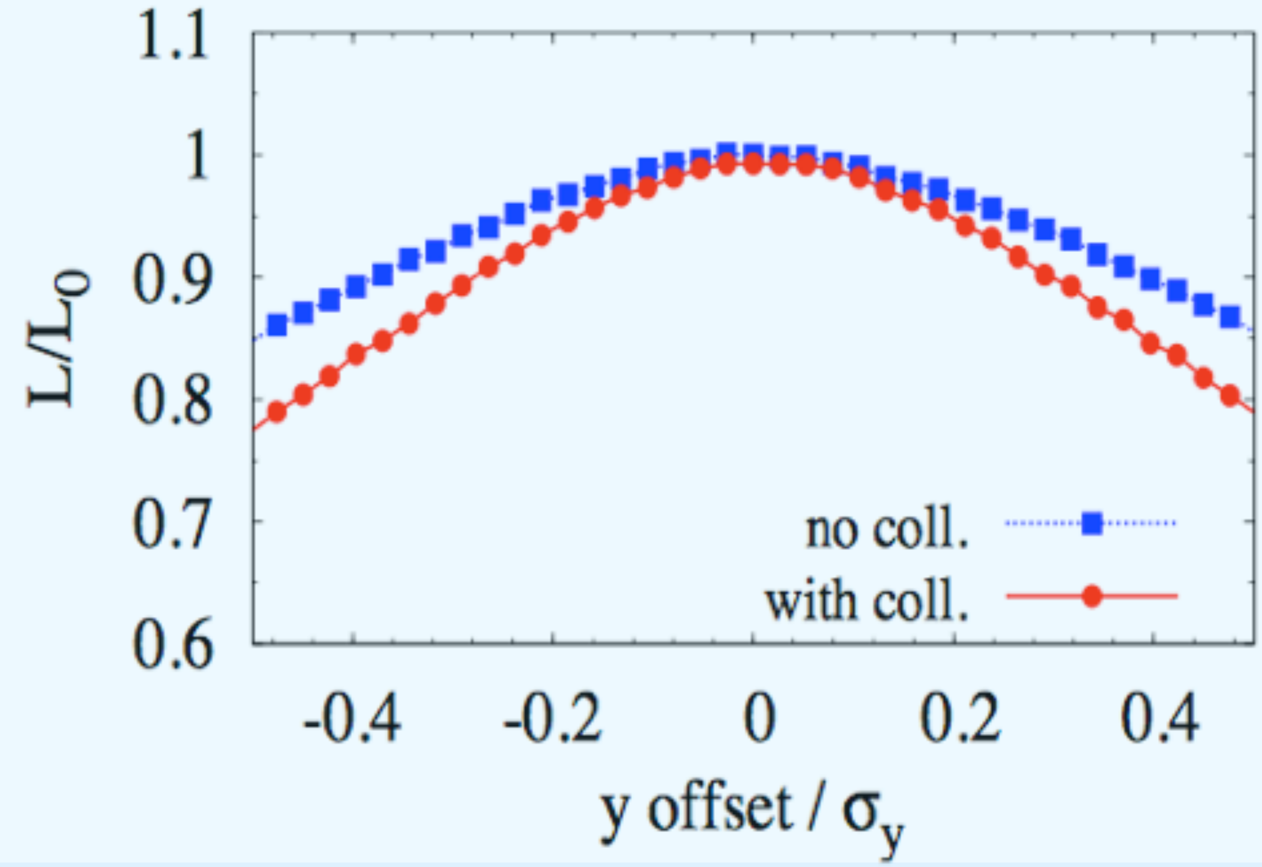
G.White, LCWS2013

ILC (nominal)

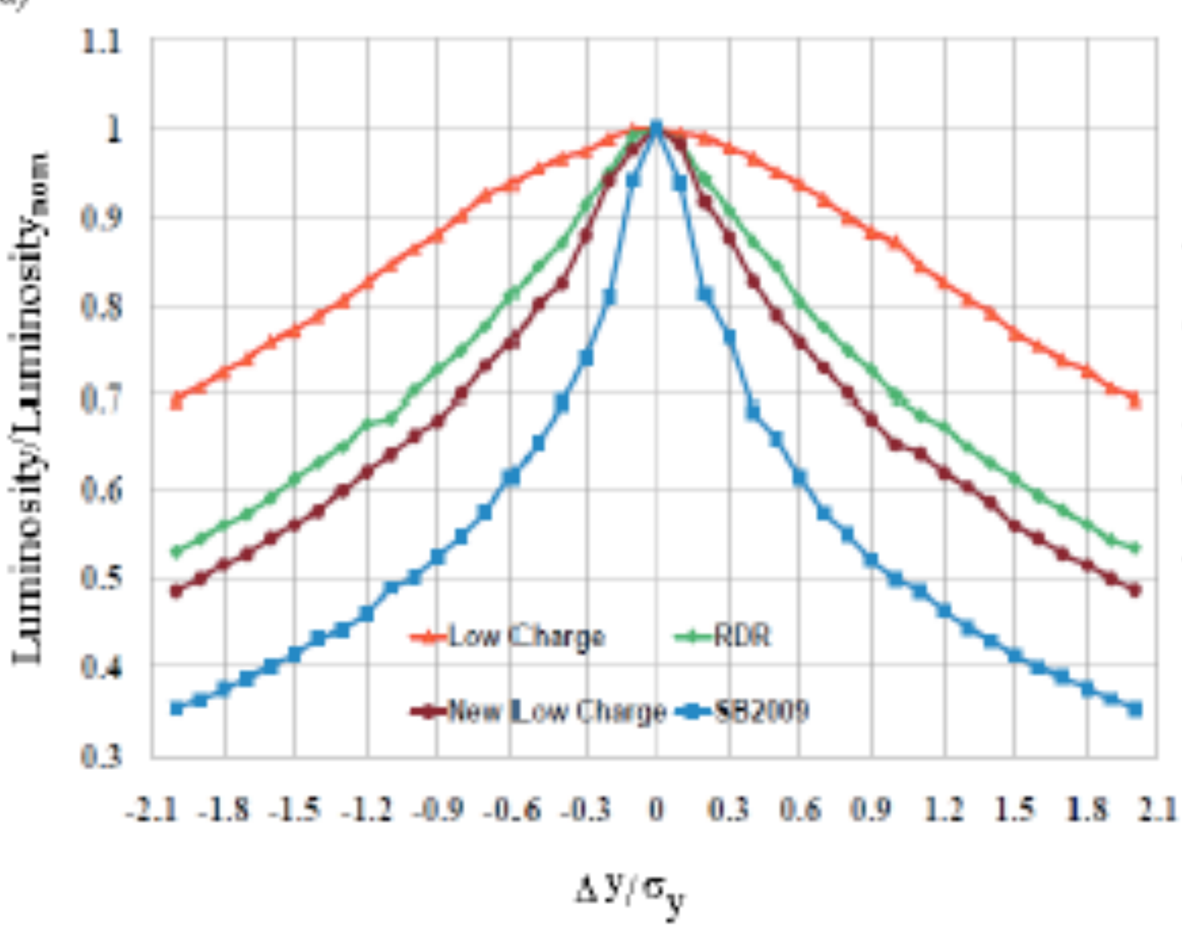
J. R-Lopez et. al. (IFIC) – ILC/CLIC wakefield collaboration

CLIC (nominal)

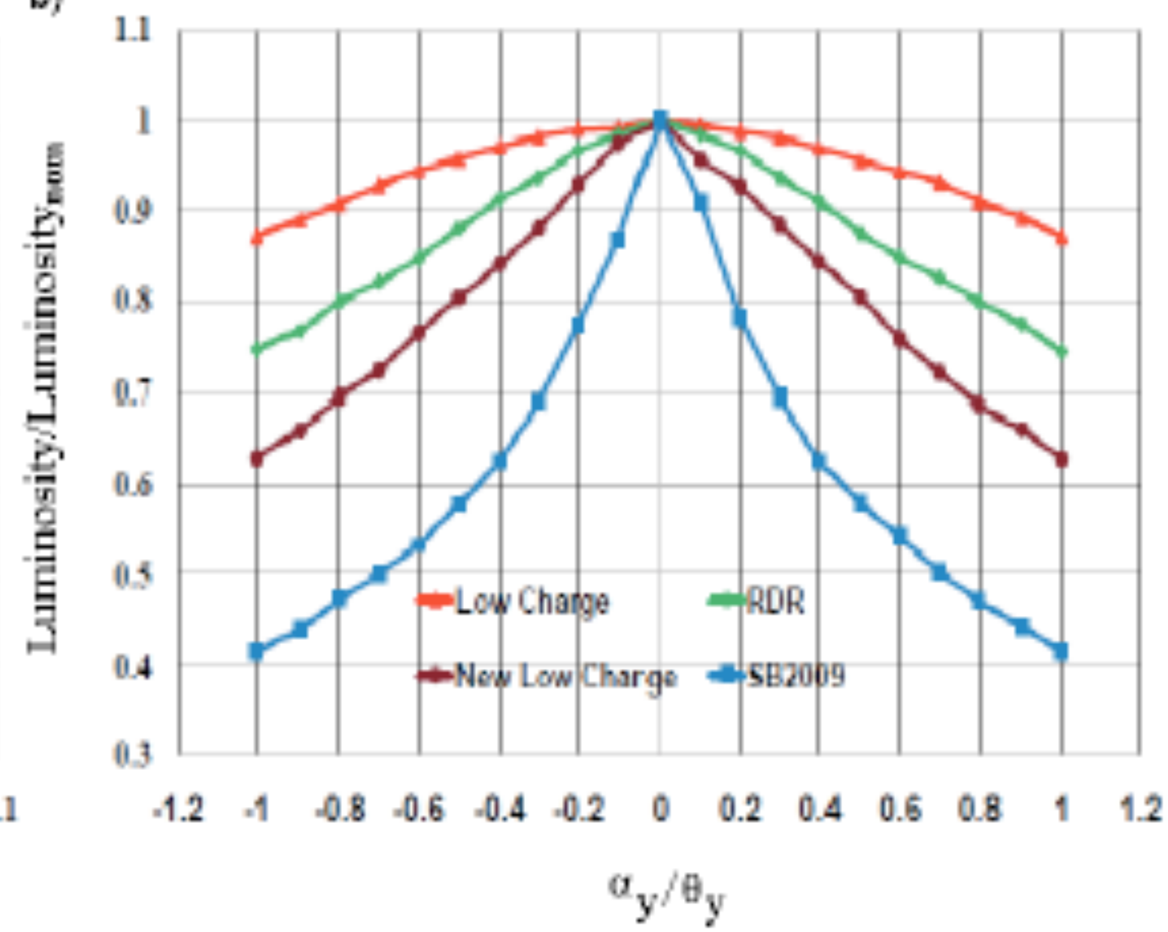




a)



b)



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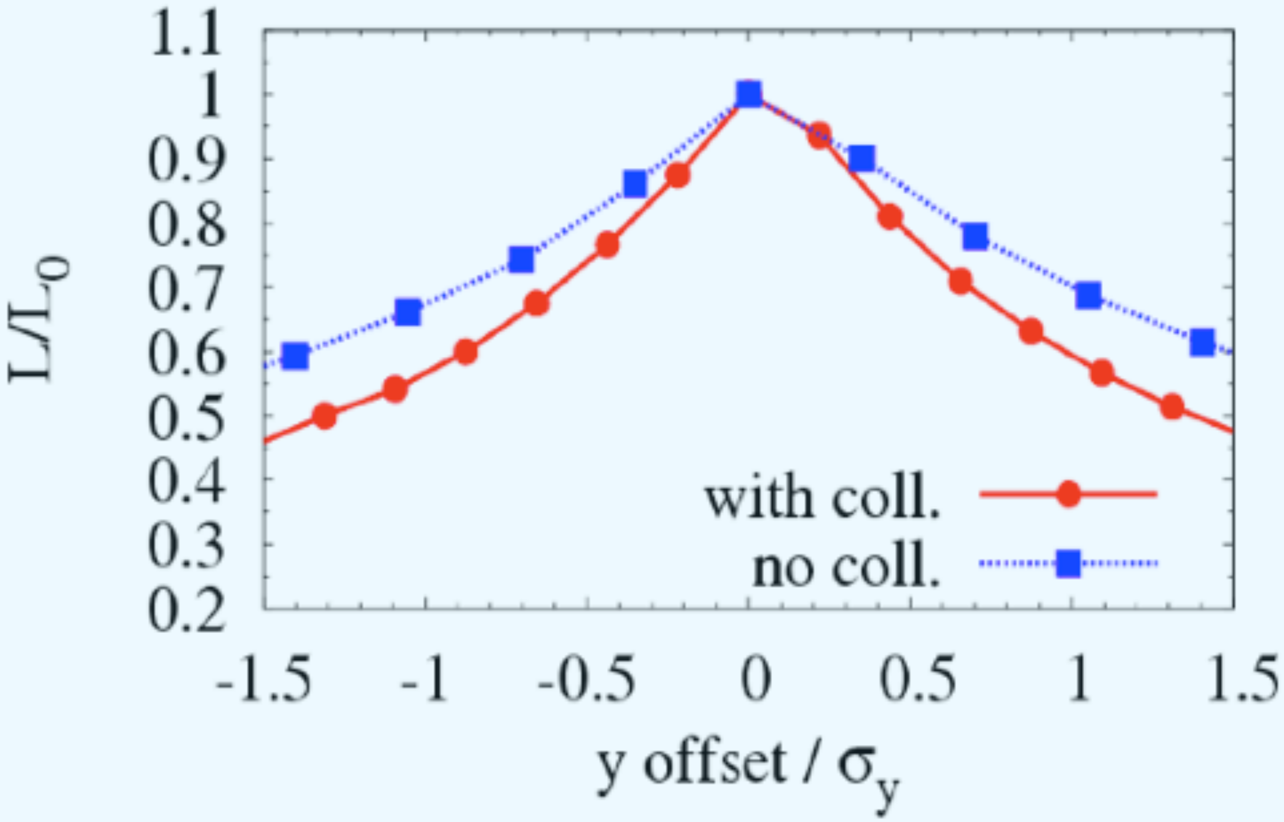
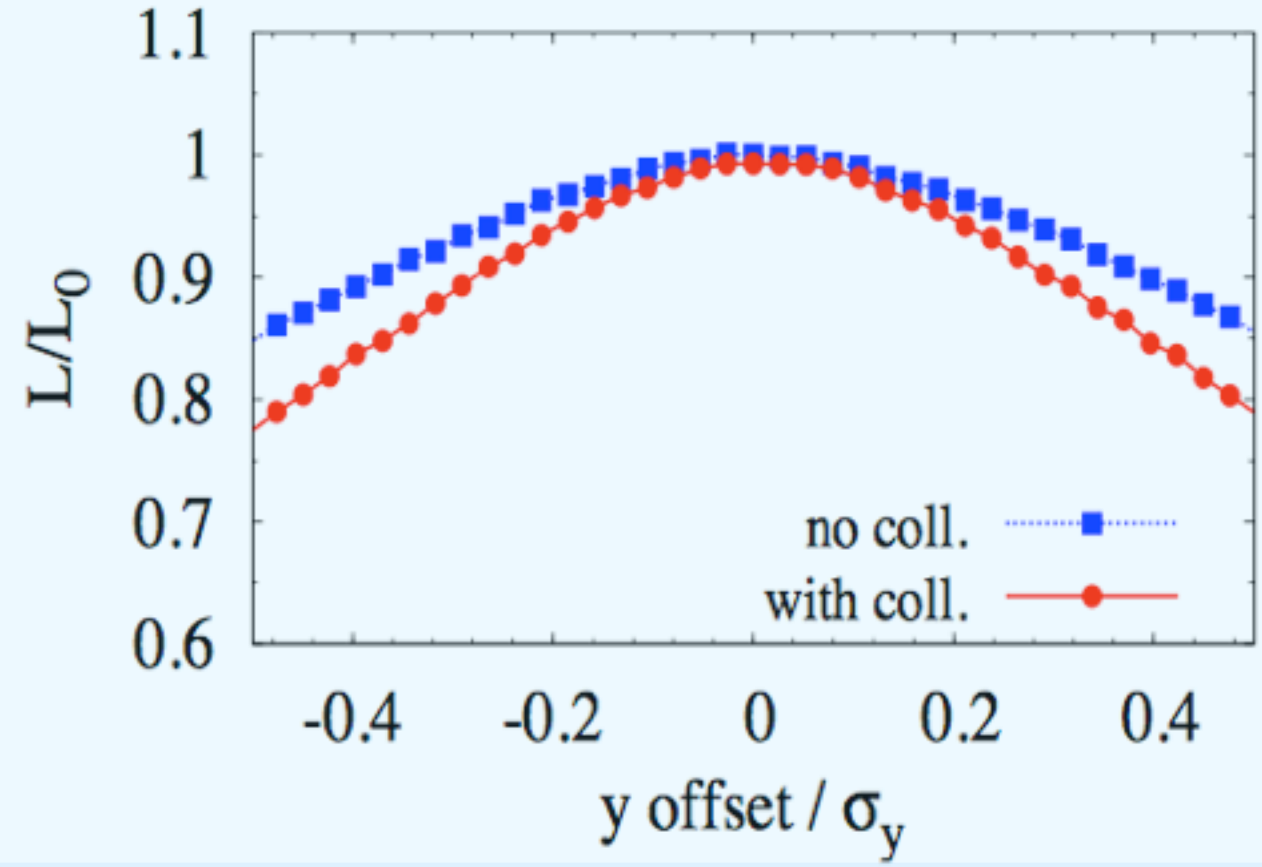
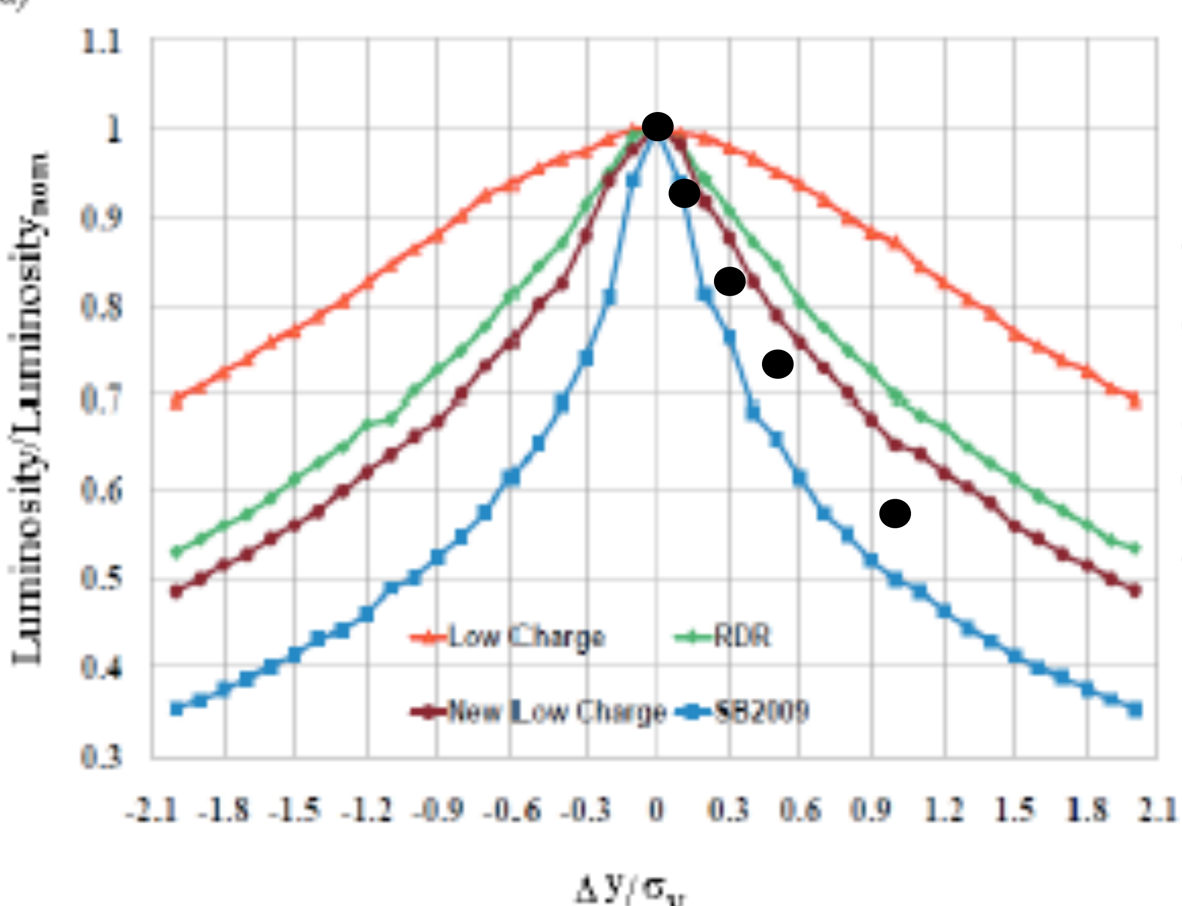
ILC (nominal)



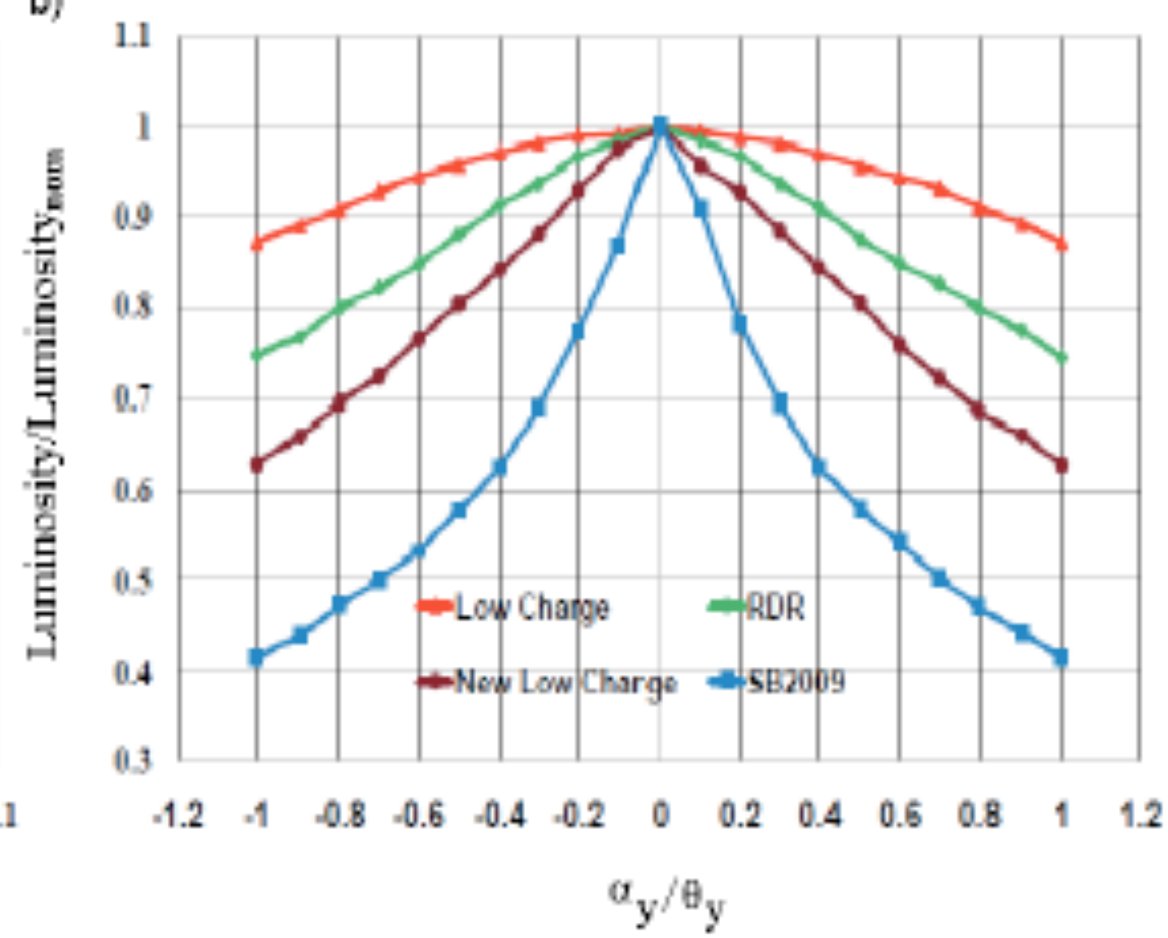
CLIC (nominal)



a)



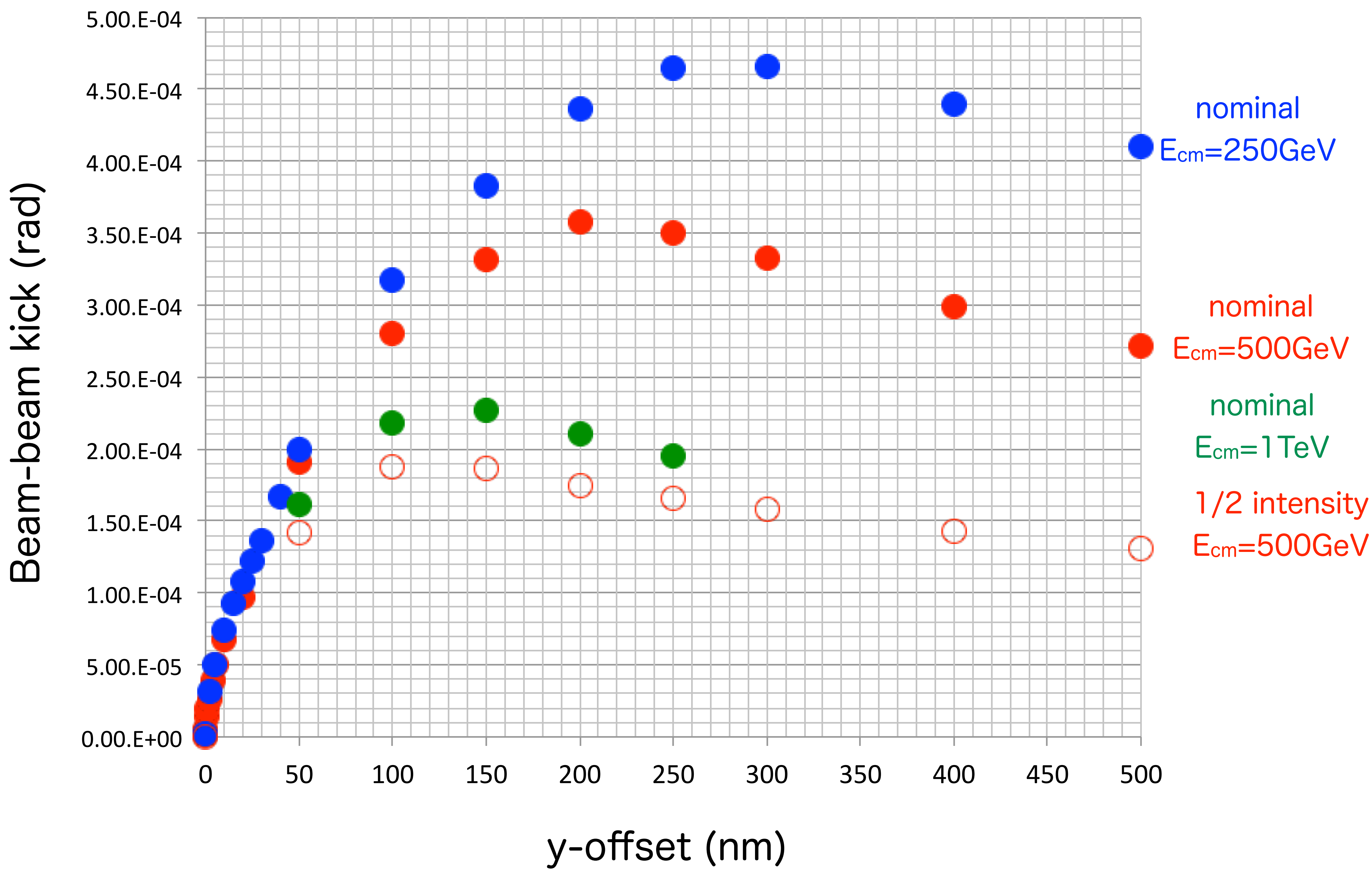
b)



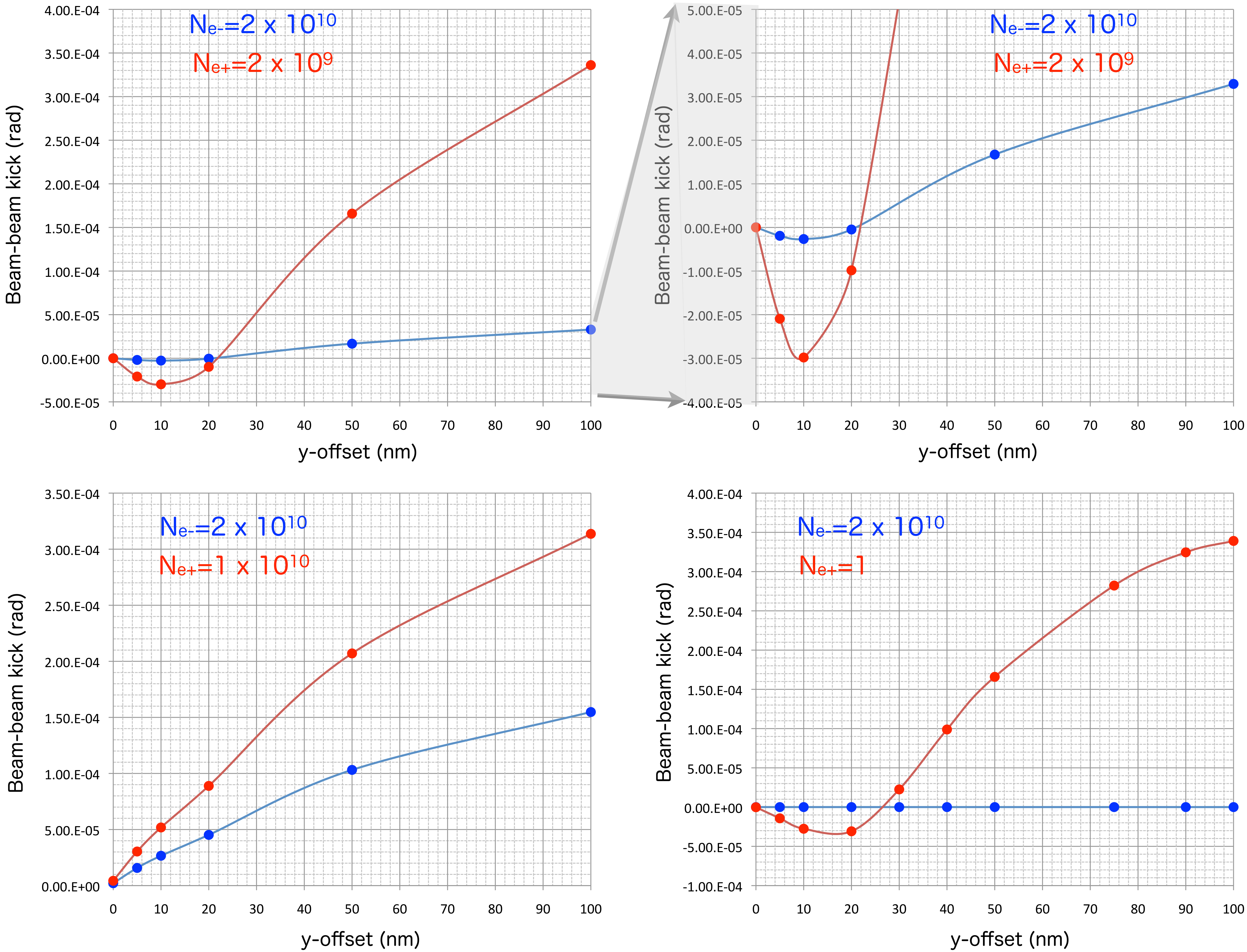
ILC TDR at E_{cm}=500,250GeV and 1TeV

14mr crab crossing with the waist scan

calculated by CAIN V2.42



ILC TDR at E_{cm}=500GeV



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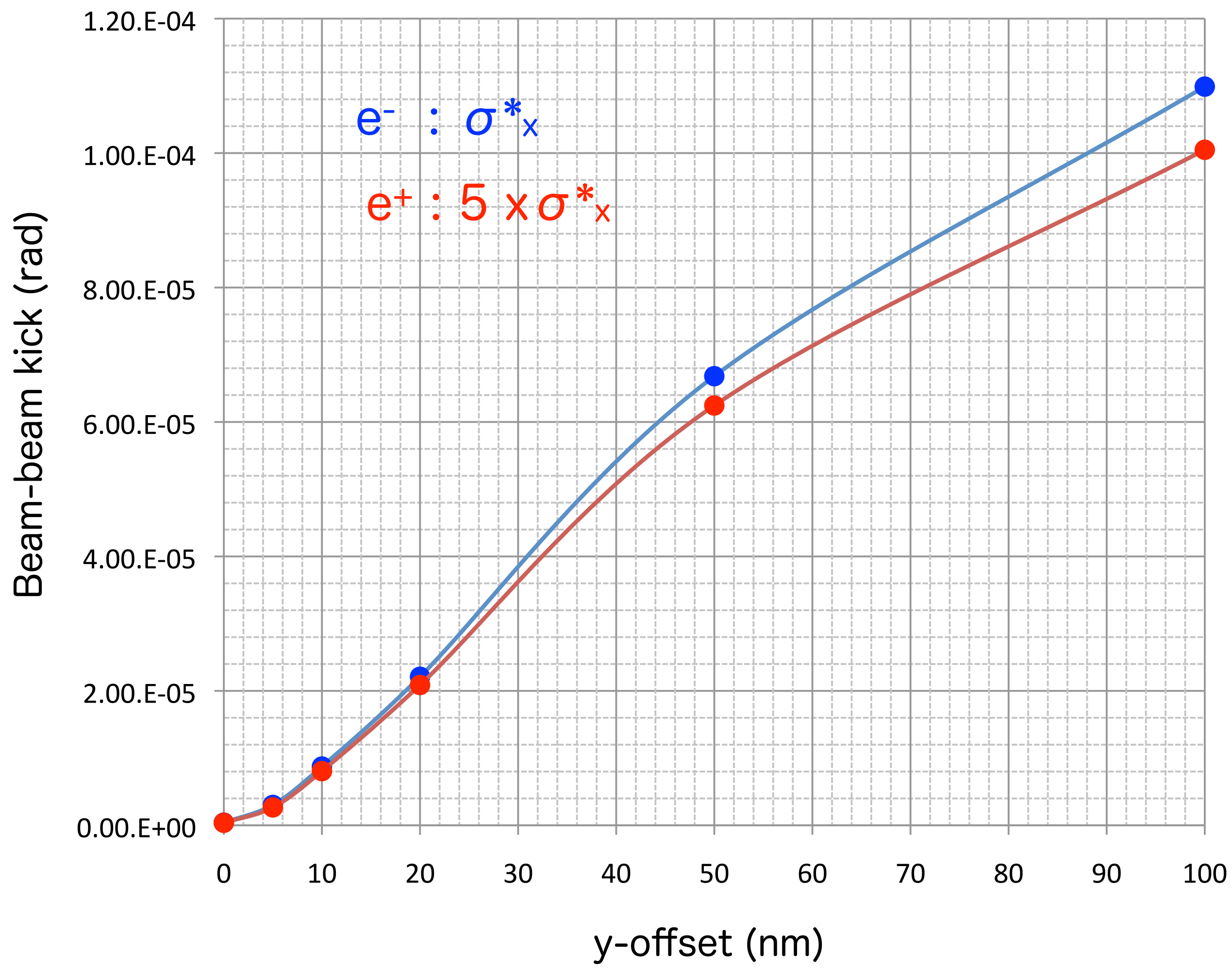
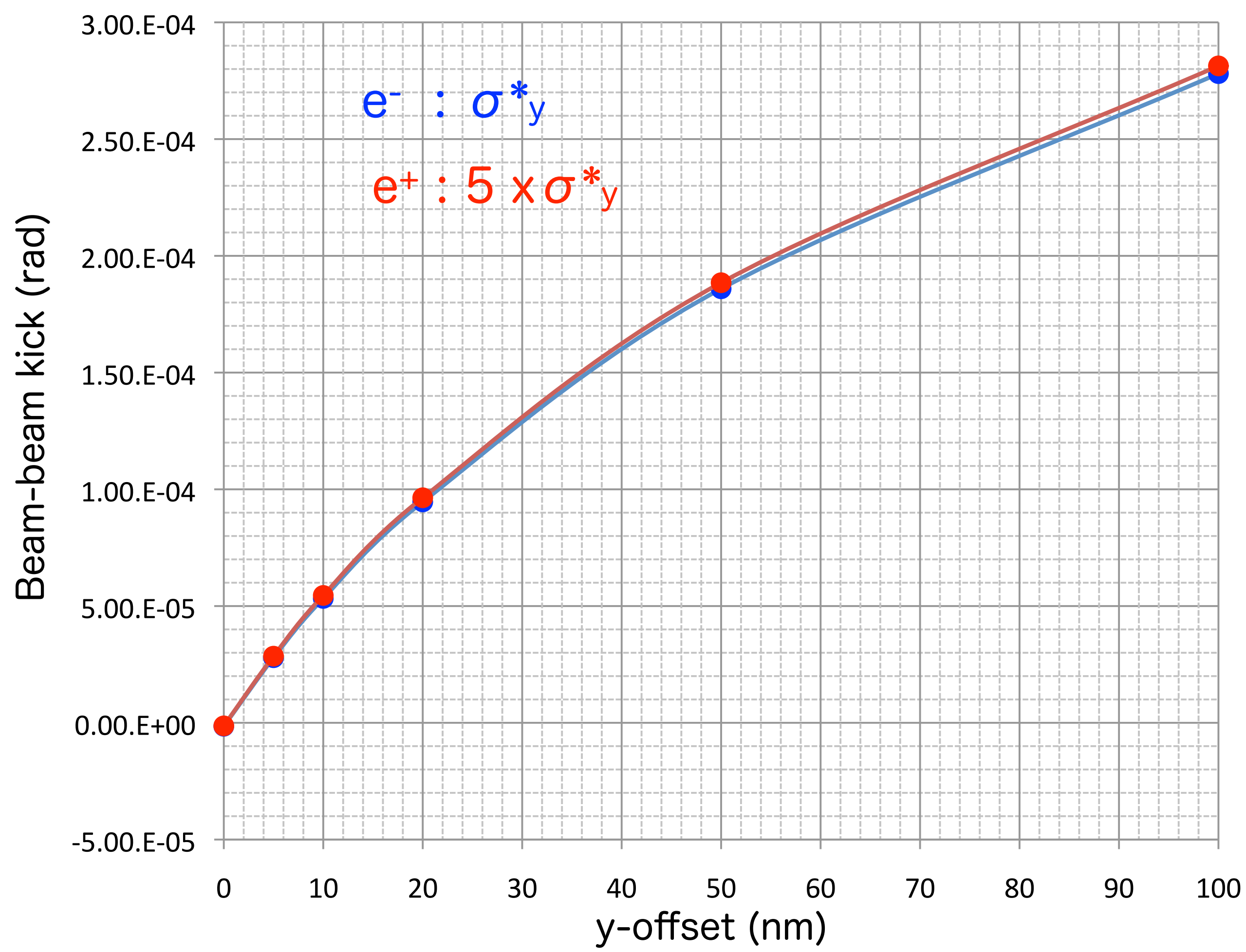
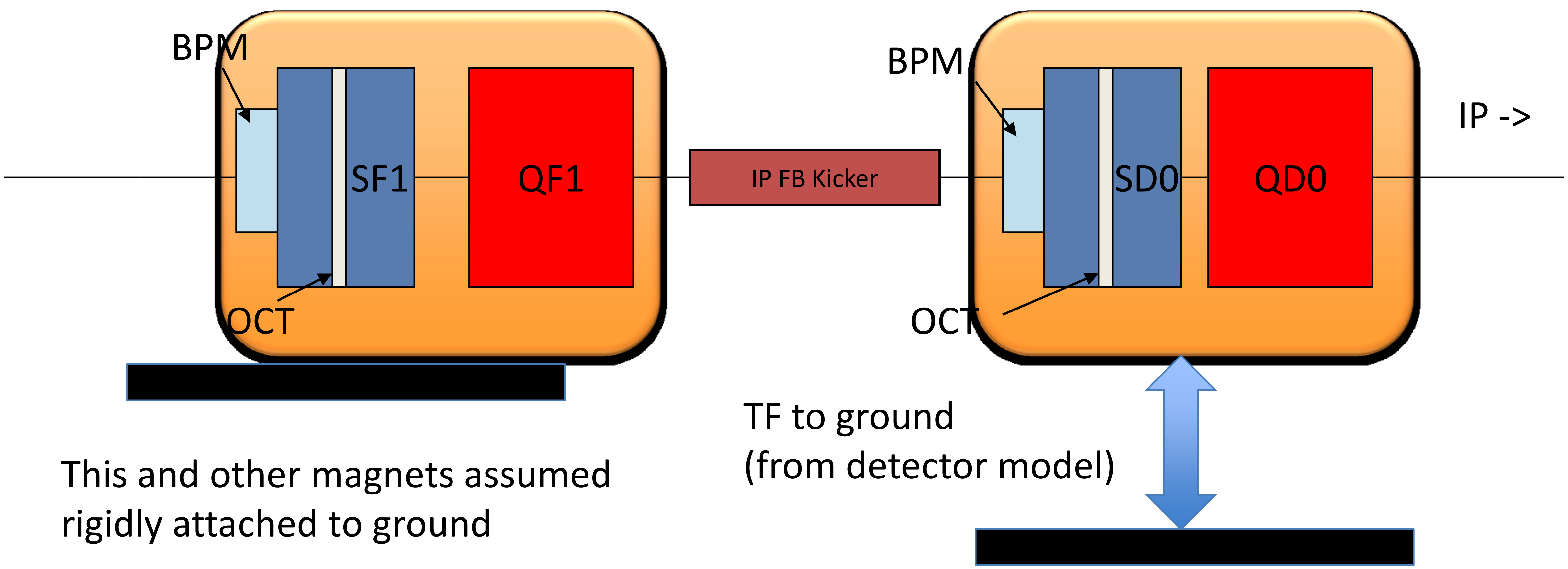


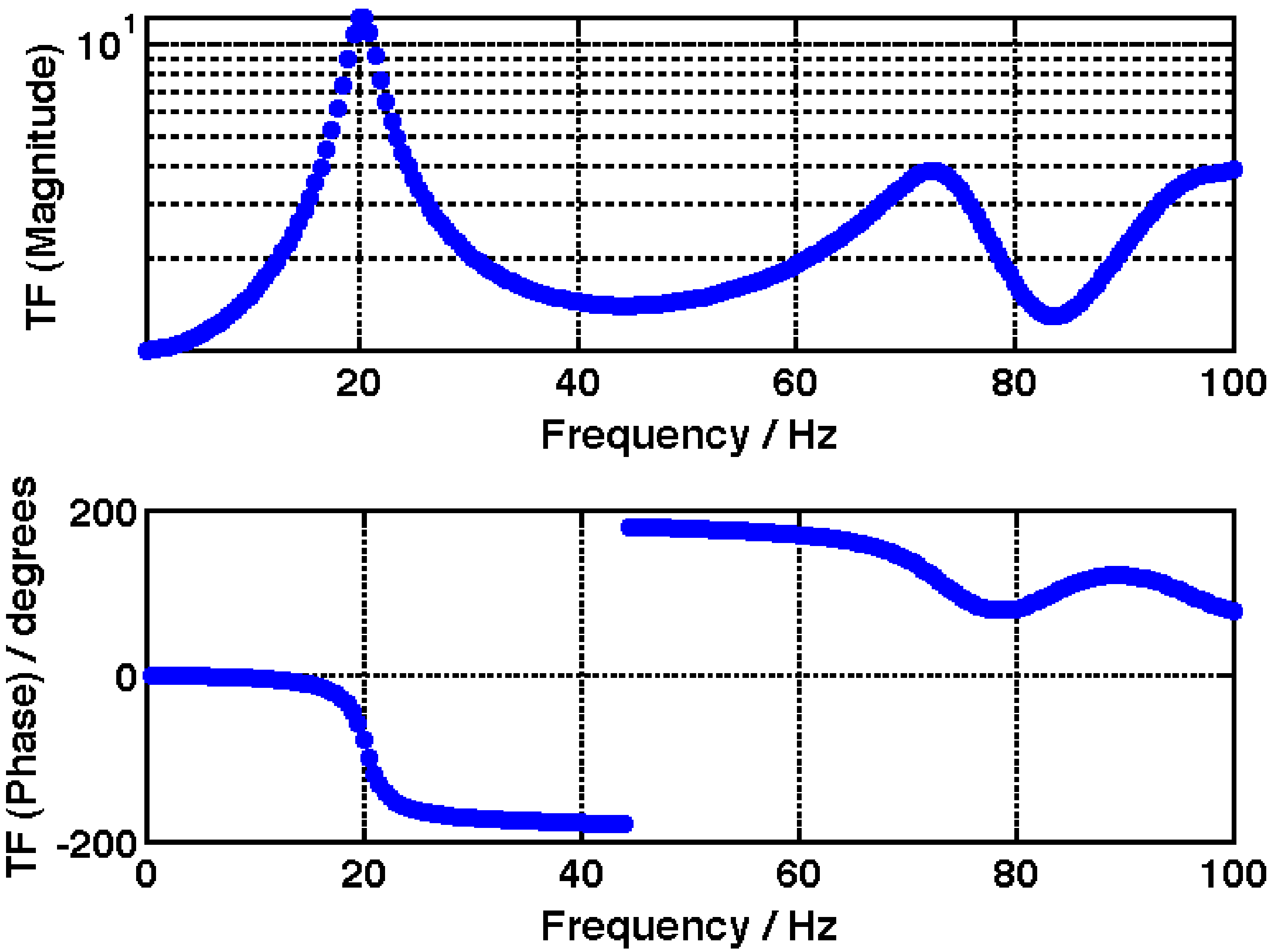


IP Region Final Doublet



This and other magnets assumed rigidly attached to ground

QD0 TF



- "Rigid support structure" model from SiD group (Marco). QD0 rigidly attached to detector platform.
- Apply to simulation girder element attached to SD0/OC0/QD0 cryomodule.

Error Parameters

Initial Quad, Sext, Oct x/y transverse alignment	200 um
Quad, Sext, Oct roll alignment	300 urad
Initial BPM-magnet field center alignment	30 um
dB/B for Quad, Sext, Octs (RMS)	1e-4
Mover resolution (x & y)	50 nm
BPM resolutions (Quads)	1 um
BPM resolutions (Sexts)	100 nm
Power supply resolution	14 - bit
FCMS: Assembly alignment	200 um / 300urad
FCMS: Relative internal magnet alignment	10um / 100 urad
FCMS: BPM-magnet initial alignment (i.e. BPM-FCMS Sext field centers)	30 um
FCMS: Oct – Sext co-wound field center relative offsets and rotations	10um / 100urad
Corrector magnet field stability (x & y)	0.1 %
Luminosity (pairs measurement or x/y IP sigma measurements)	1 % (ATF2 SM ~5%)

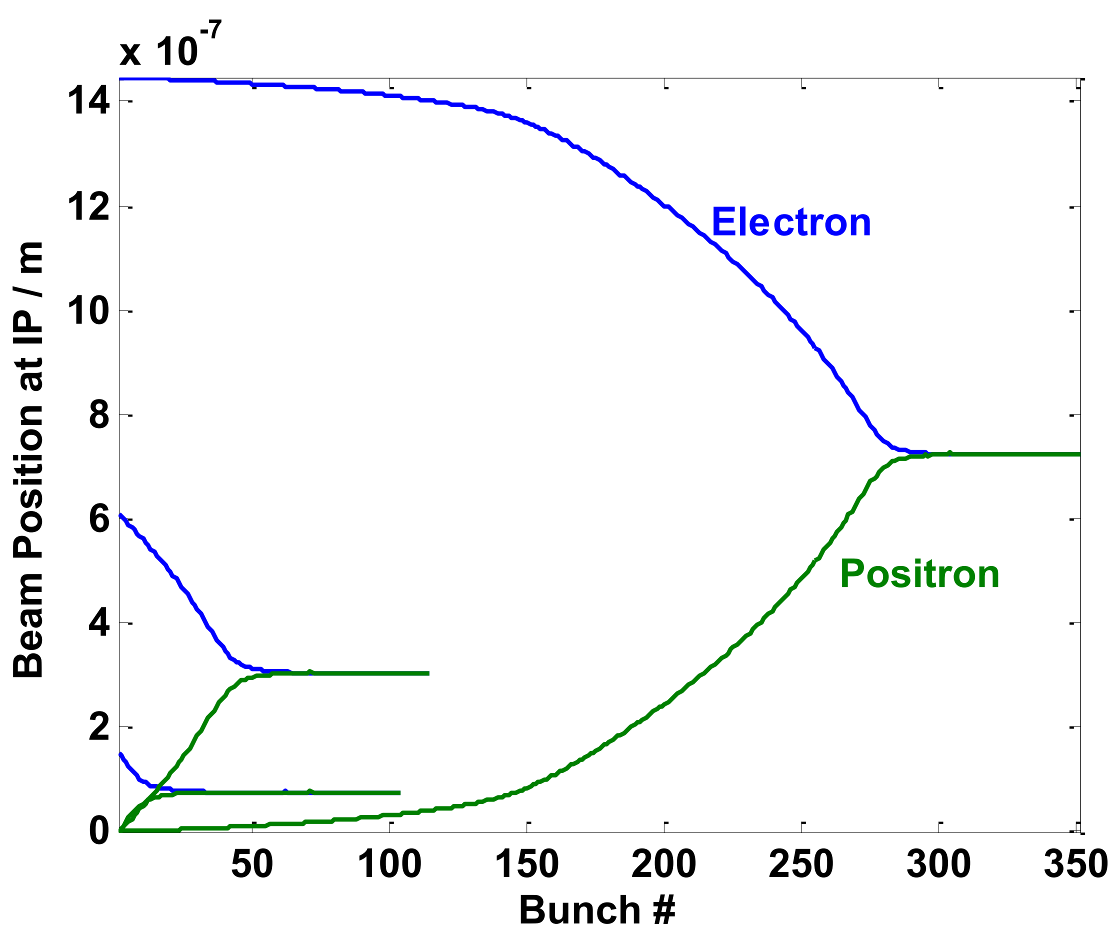
Alignment and Tuning Steps

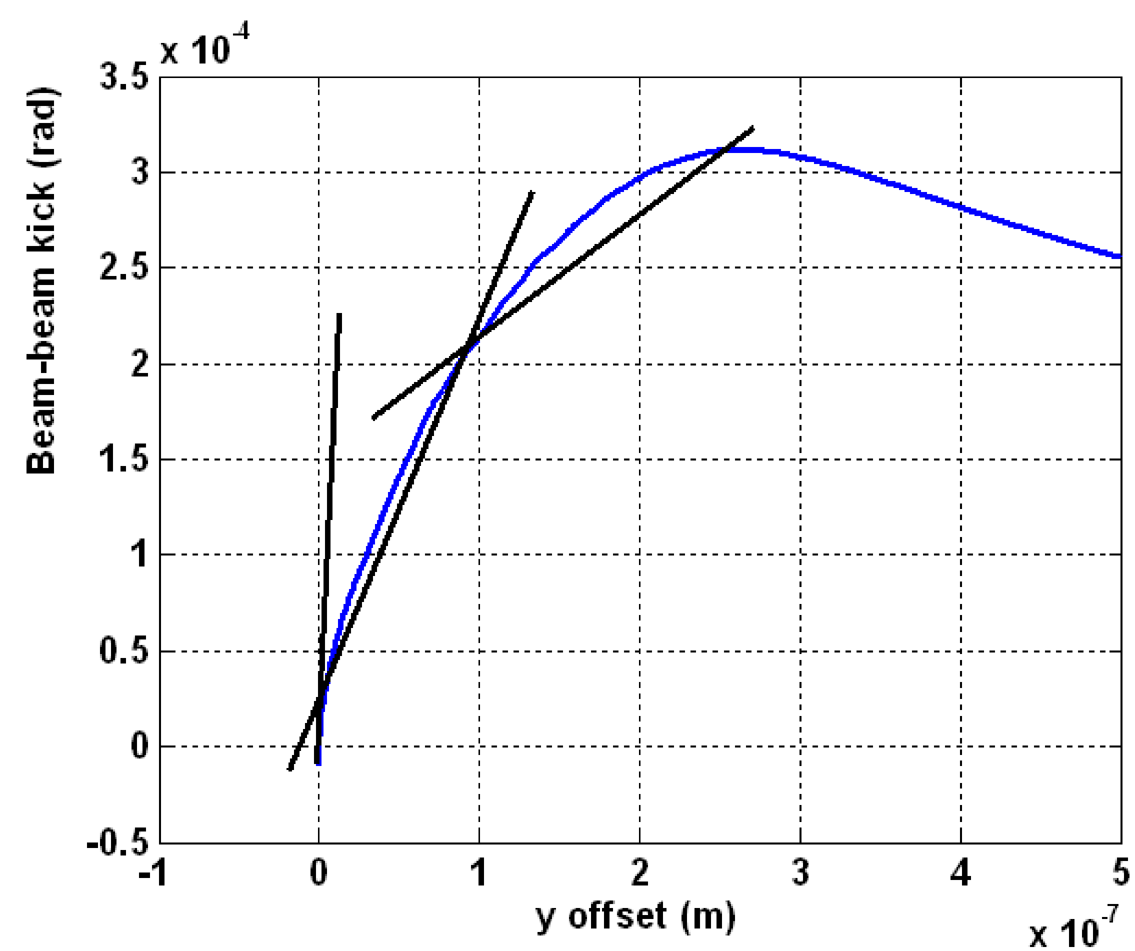
- Switch off Sextupoles and Octupoles.
- Perform initial BBA using Quad movers and BPMs -> beam through to IP.
- Quadrupole BPM alignment.
- Perform Quadrupole BBA (DFS).
- Align Sextupole BPMs.
- Move FCMS to minimize FCMS BPM readings.
- Align tail-folding Octupole BPMs.
- Activate and align sextupole and octupole magnets.
- Rotate whole BDS about first quadrupole to pass beam through nominal IP position.
- Apply sextupole multiknobs to tune-out IP aberrations and maximise luminosity.
- 5-Hz feedback system used throughout to maintain orbit whilst tuning.

Intra-Pulse IP Feedback

G.White, ALCPG11, RDR parameters

- Use ILC IP FFB, tuned for 'noisy' conditions (like those simulated for TESLA)
- Assume BDS-entrance FFB has perfectly flattened beam train (flat trajectory into Final Doublet).
- No systematic or random intra-pulse distortions.
- Calculate Luminosity from measured bunches, with mean of last 50 weighted to account for the rest of the beam train (1320 bunches).





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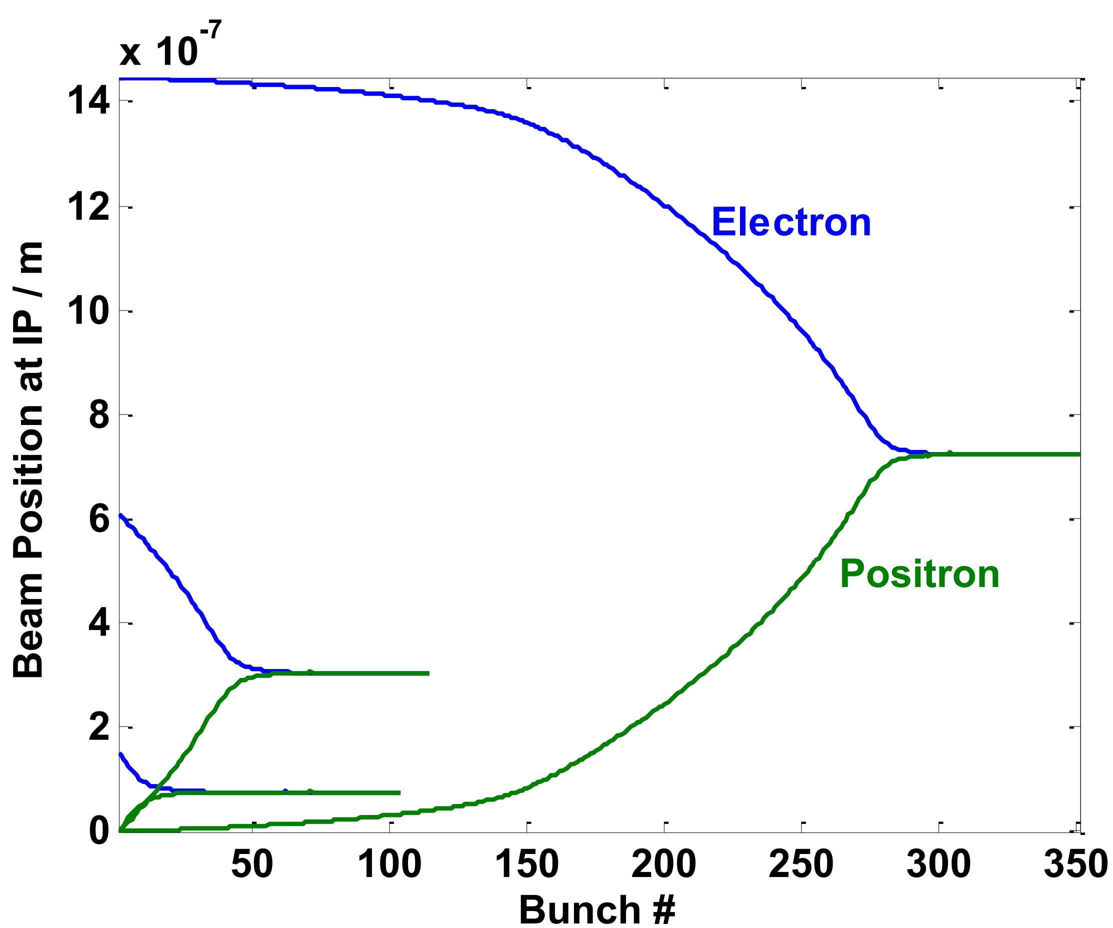
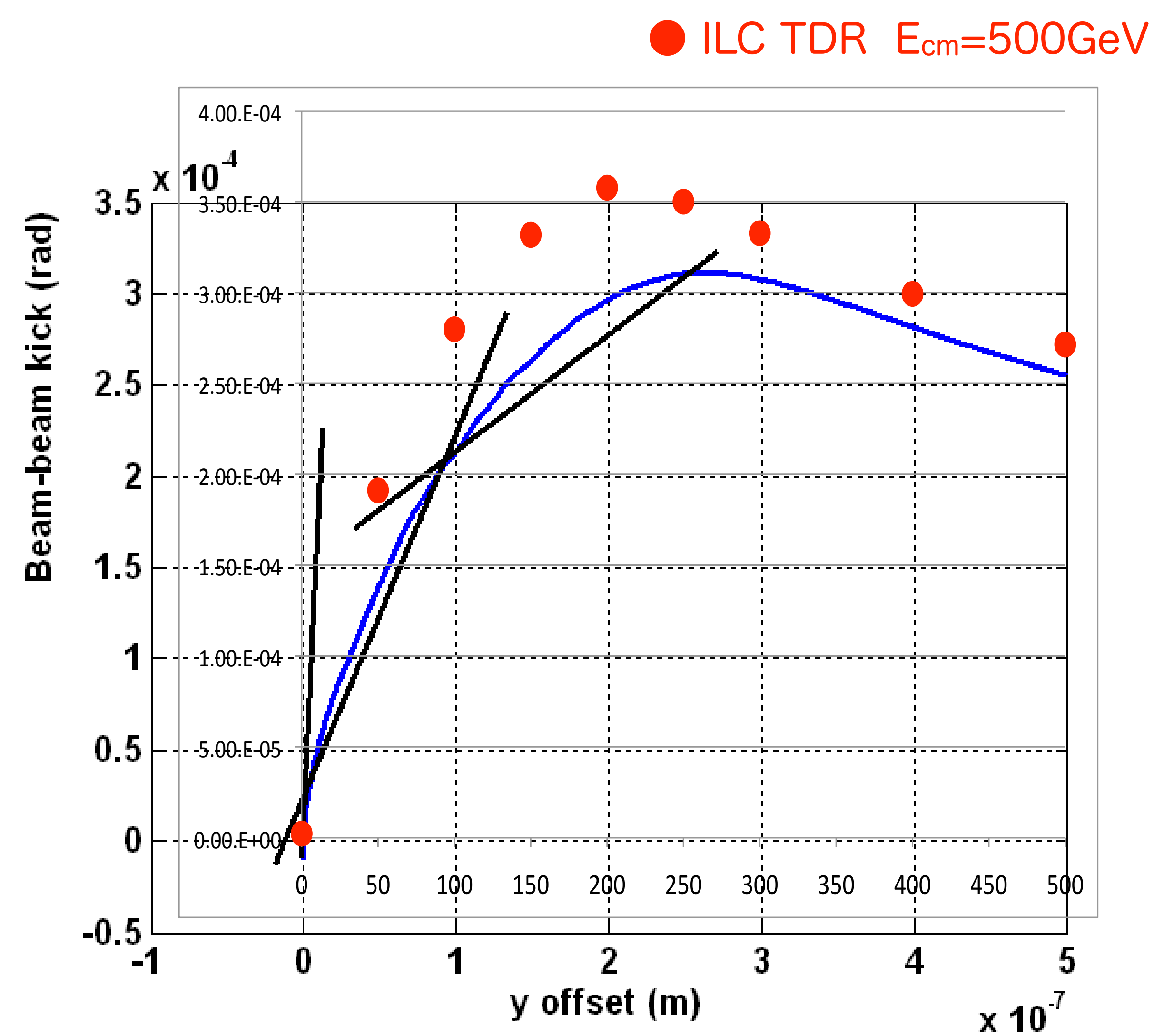
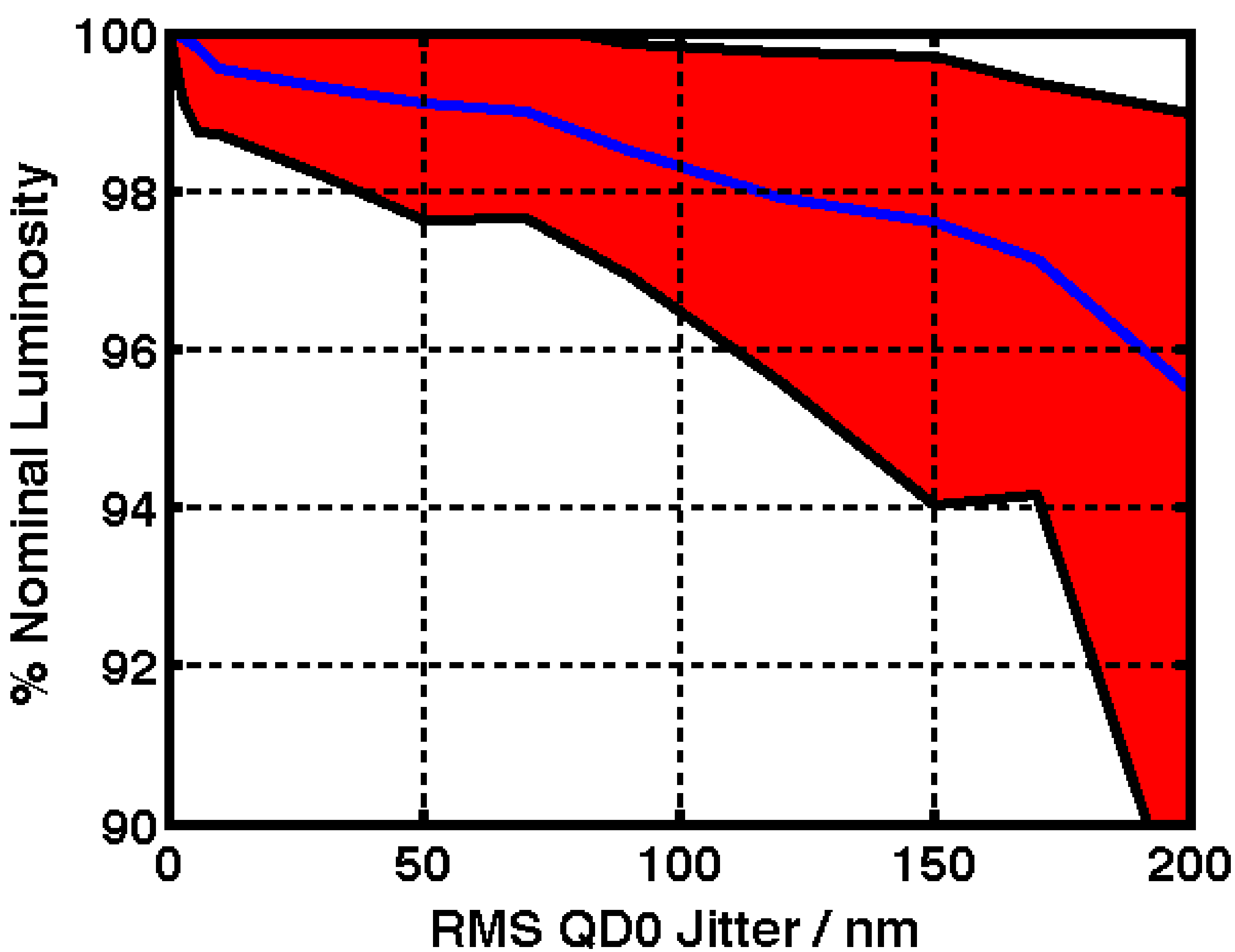




Luminosity Loss vs. QD0 Jitter

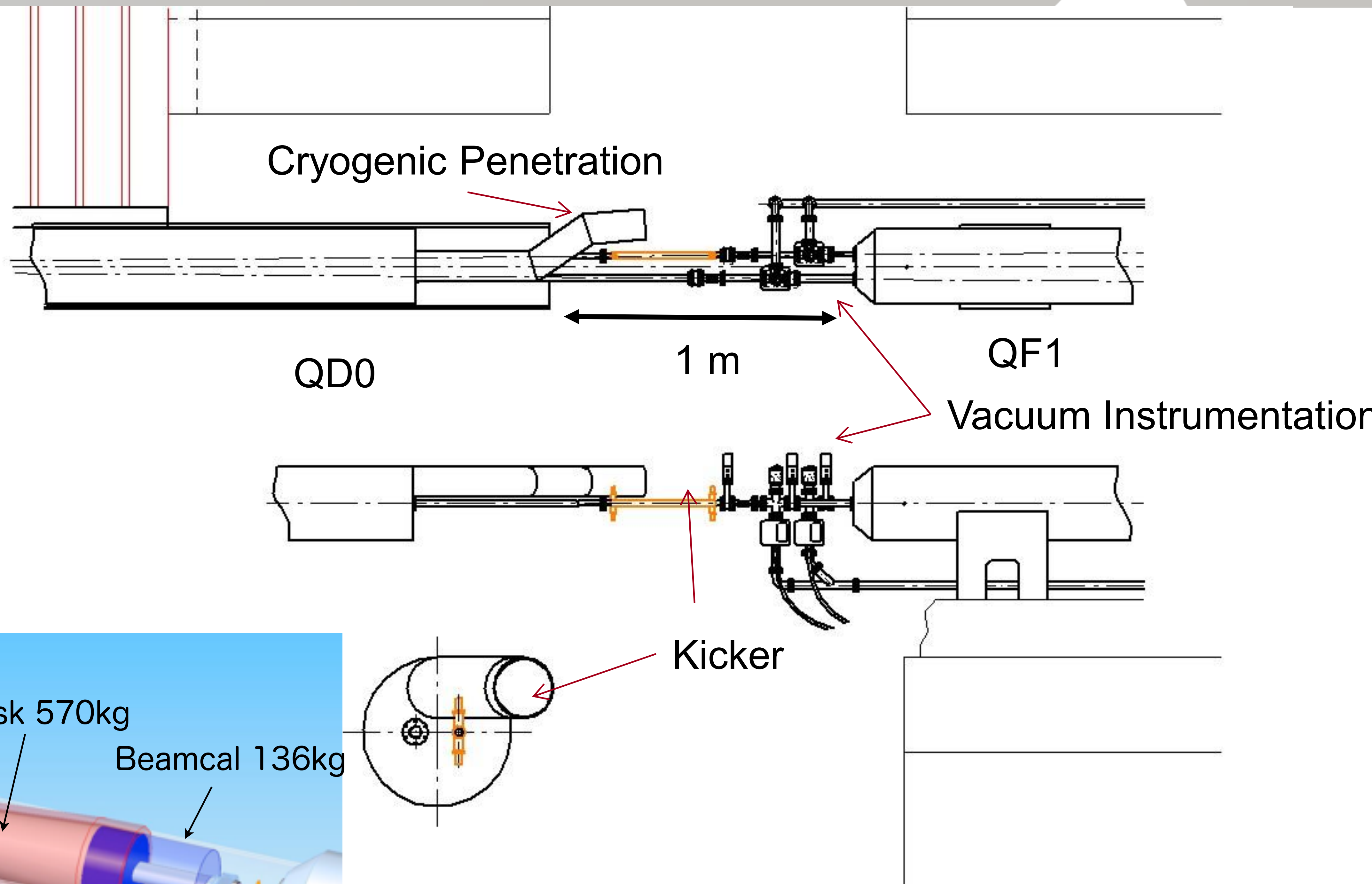
G.White, ALCPG11, RDR parameters

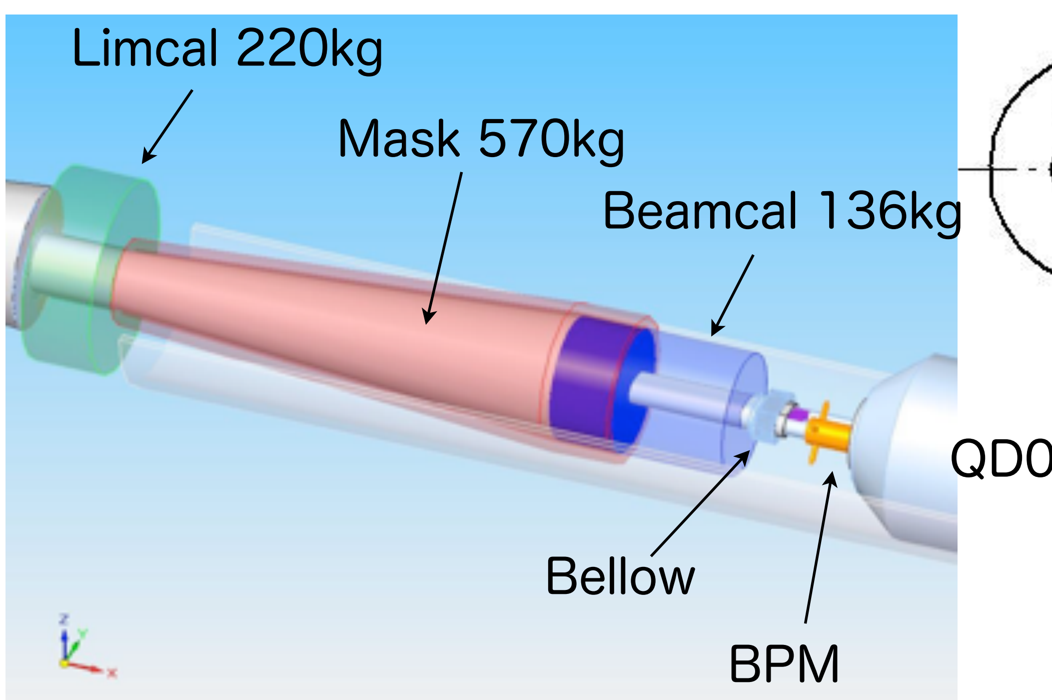


- Data shown gives % nominal luminosity for different levels of uncorrelated QD0 jitter.
  - 100 pulses simulated per jitter cases with FFB
  - Mean, 10% & 90% CL results shown for each jitter point from 100 pulse simulations
- **Tolerance to keep luminosity loss <1% is <50nm RMS QD0 jitter.**

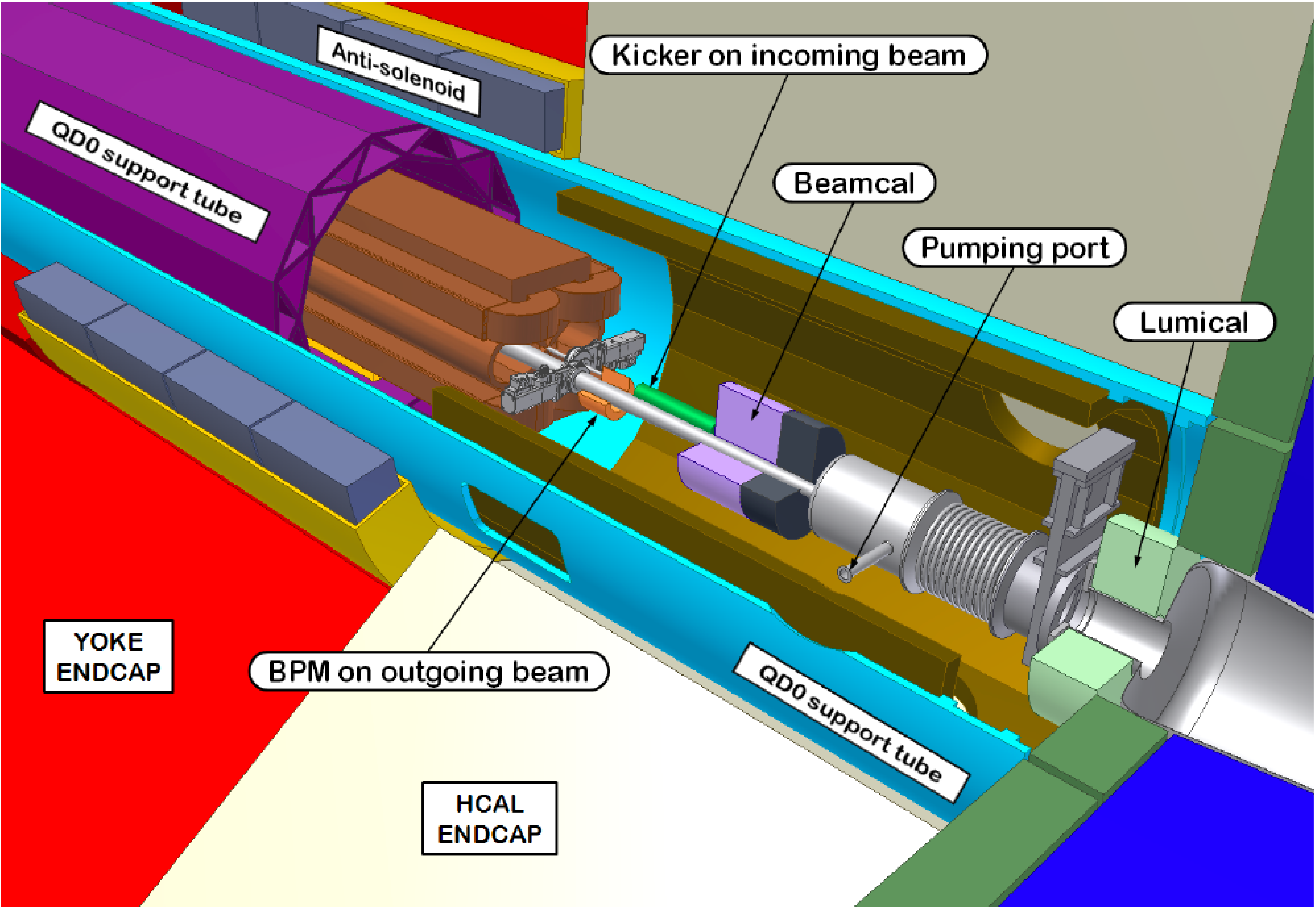
SID MDI, presented by M. Oriunno, LCWS2013

Interface QD0-QF1: Critical for Fast&Reliable Push-Pulls

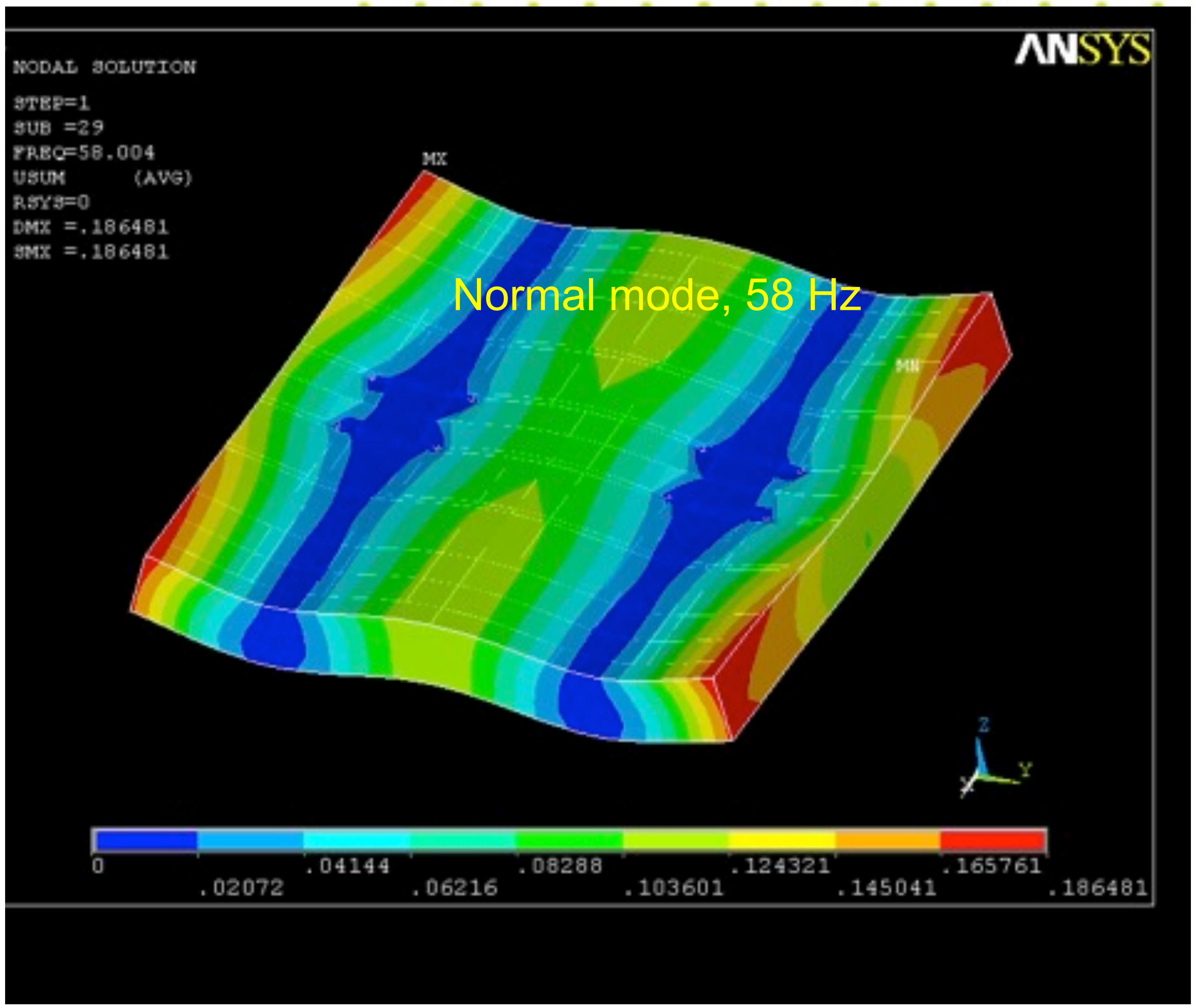


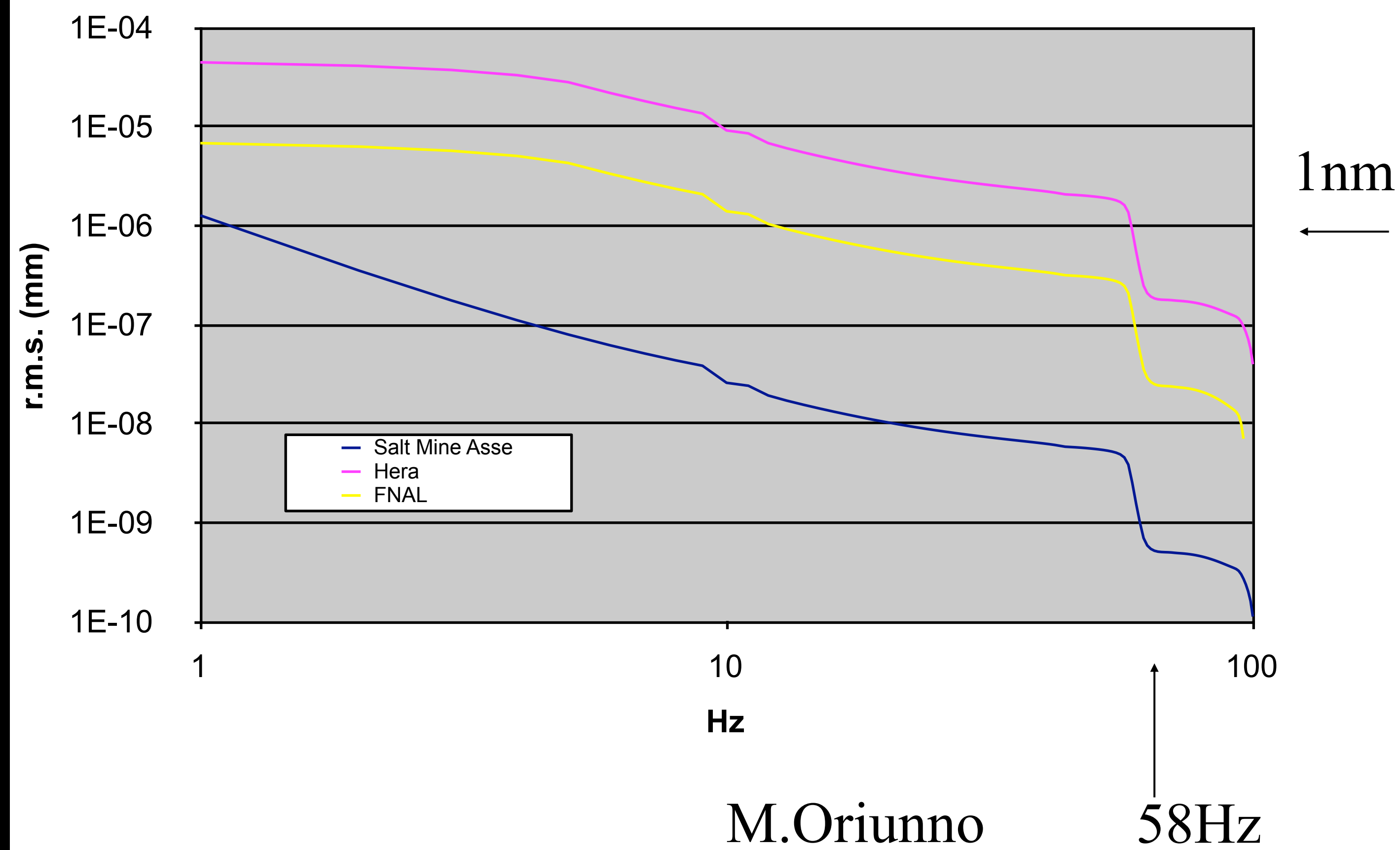


CLIC MDI, presented by L. Gatignon, LCWS2013



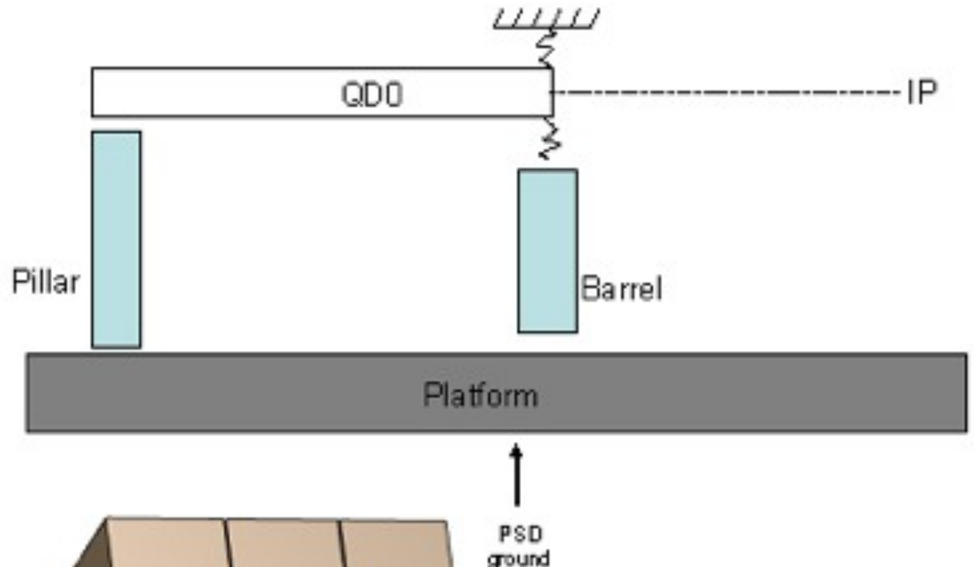
Preliminary
ANSYS analysis of Platform

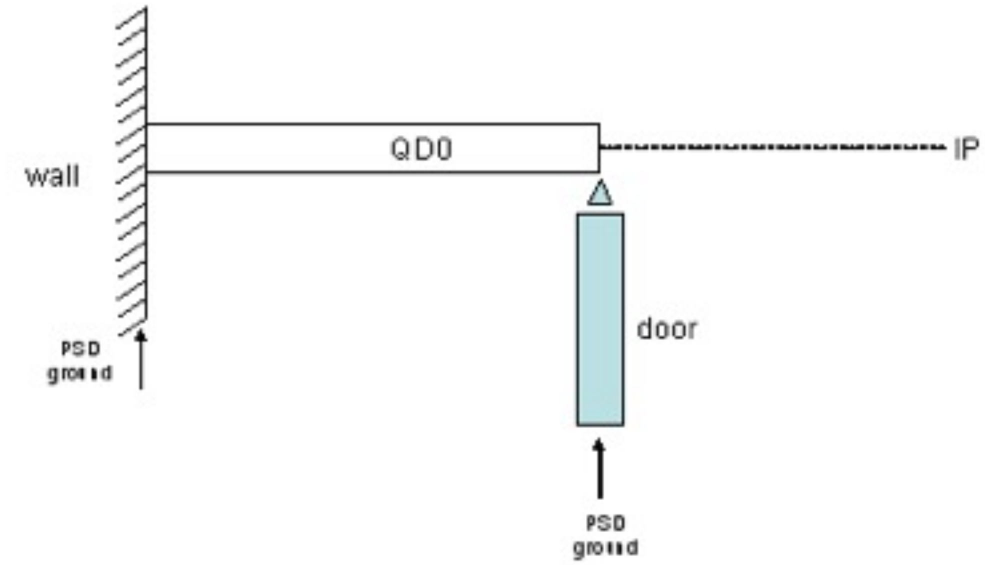


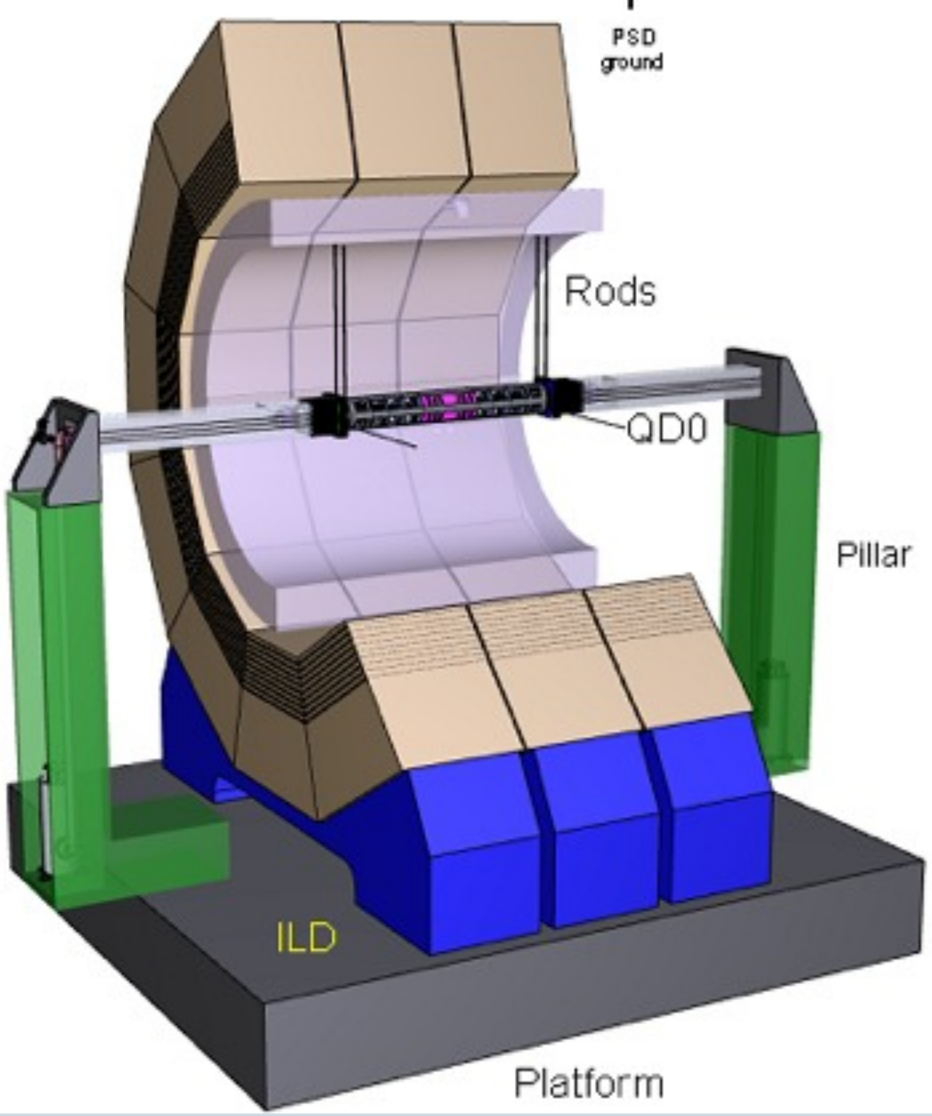


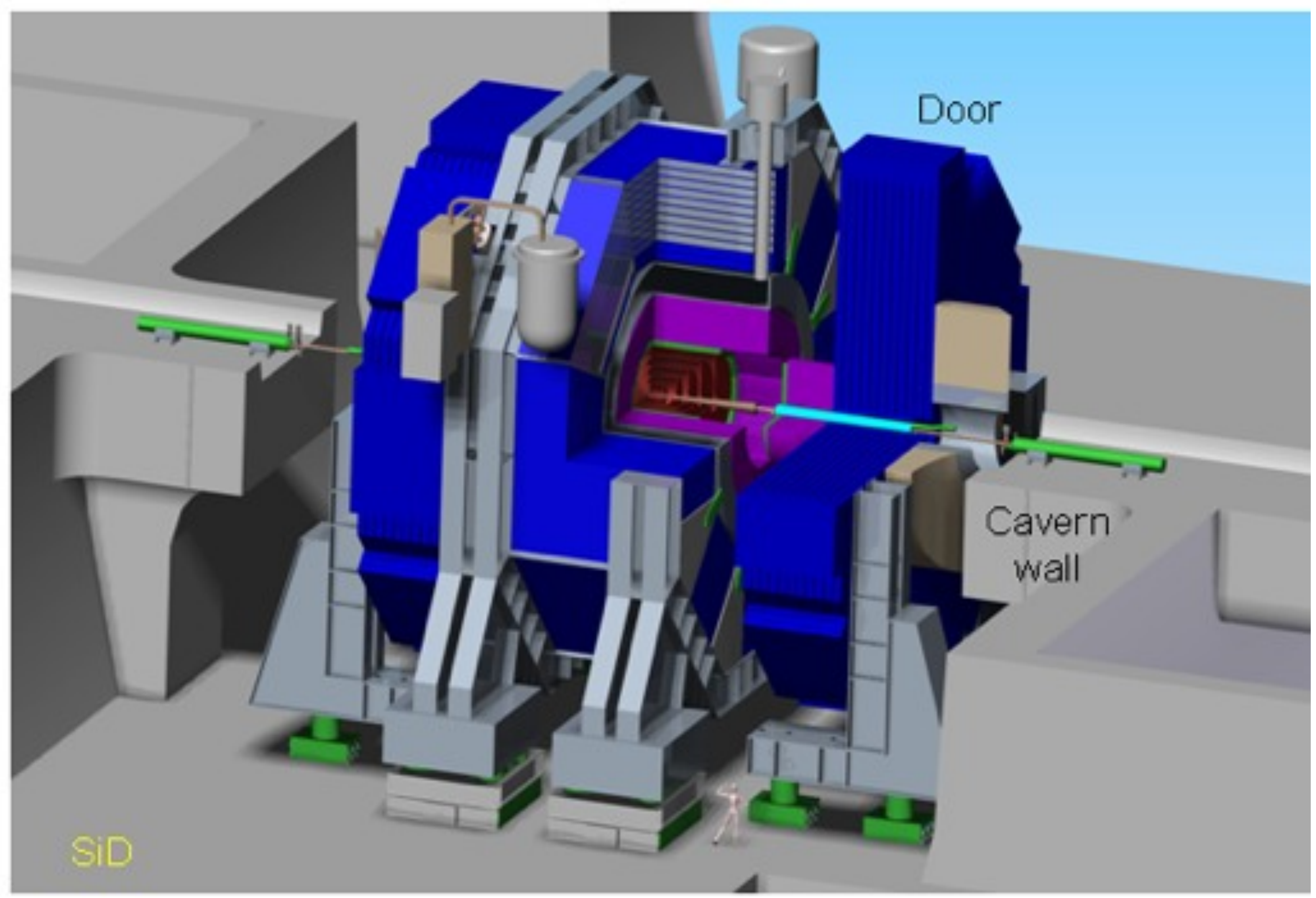
- First look of platform stability look rather promising: resonance frequencies are rather large (e.g. 58Hz) and additional vibration is only several nm

QD0 supports in ILD and SiD

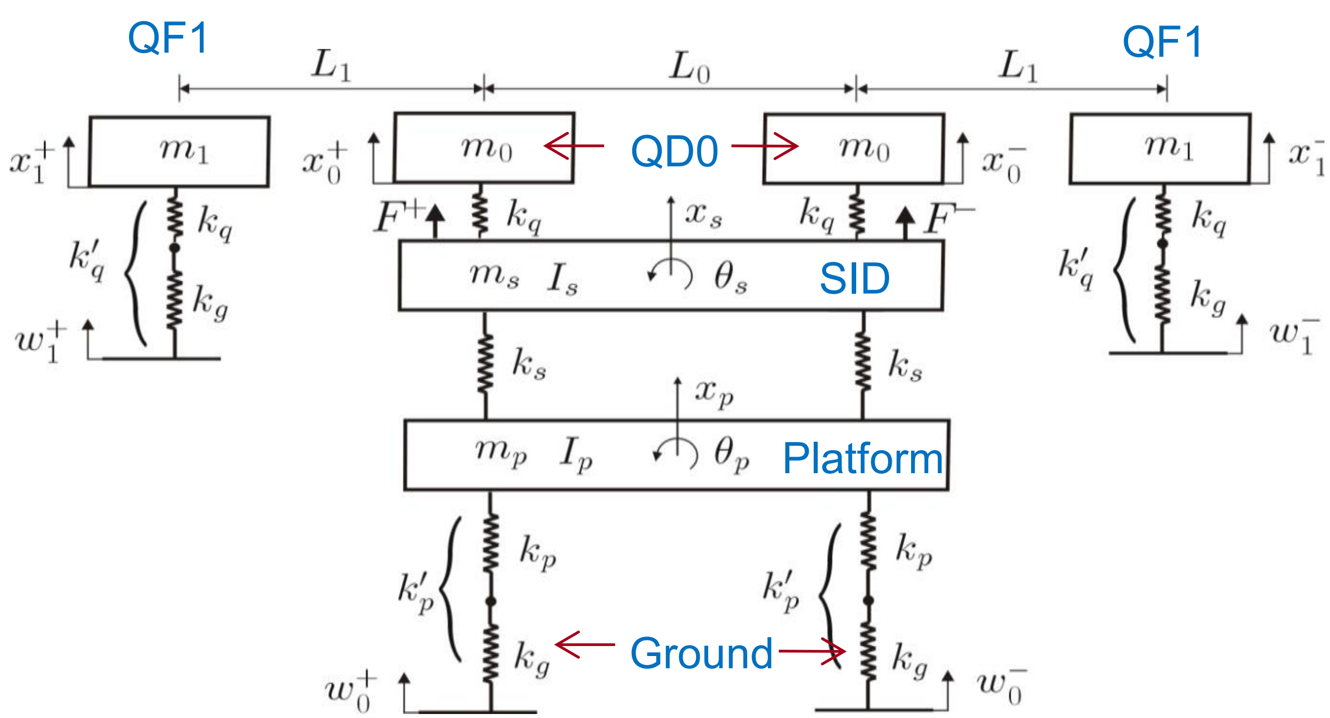


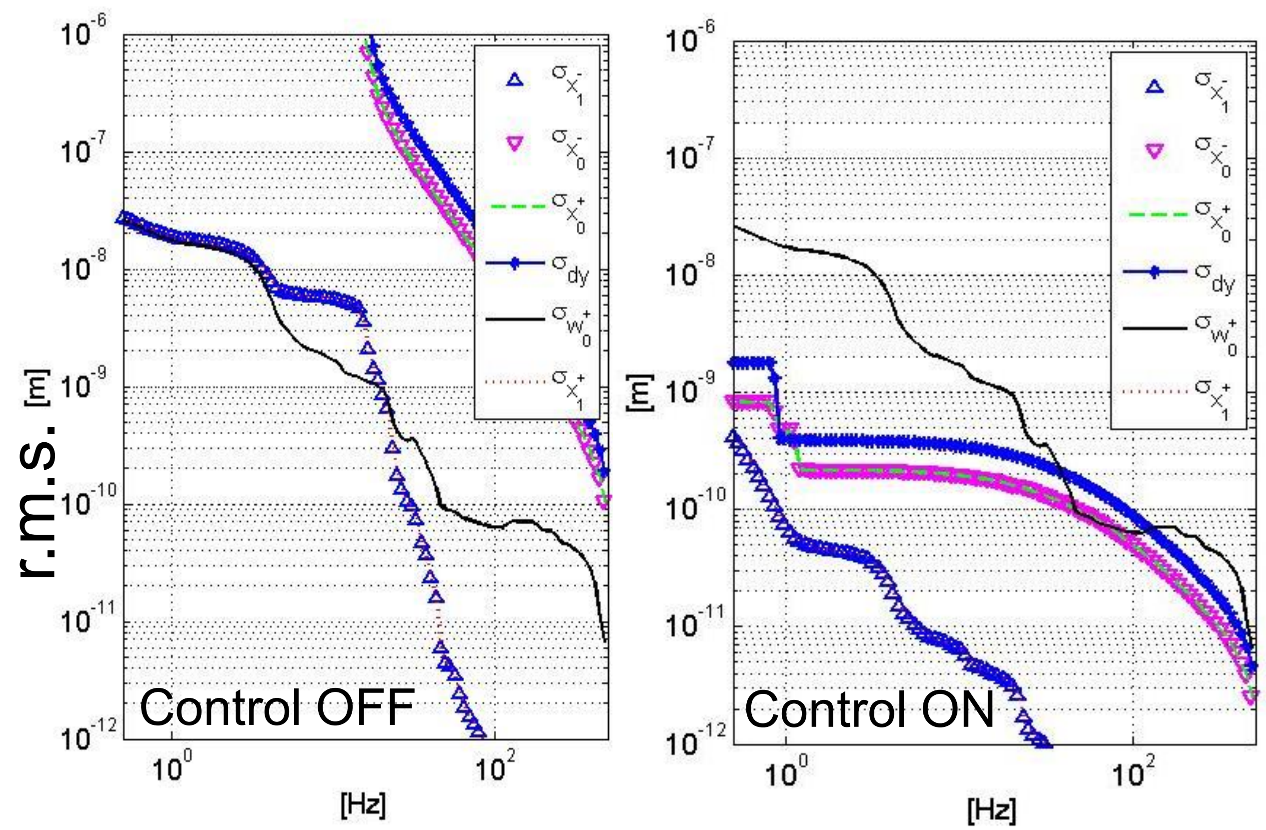






Vibration Study (C.Collette, D.Thsilumba,ULB)

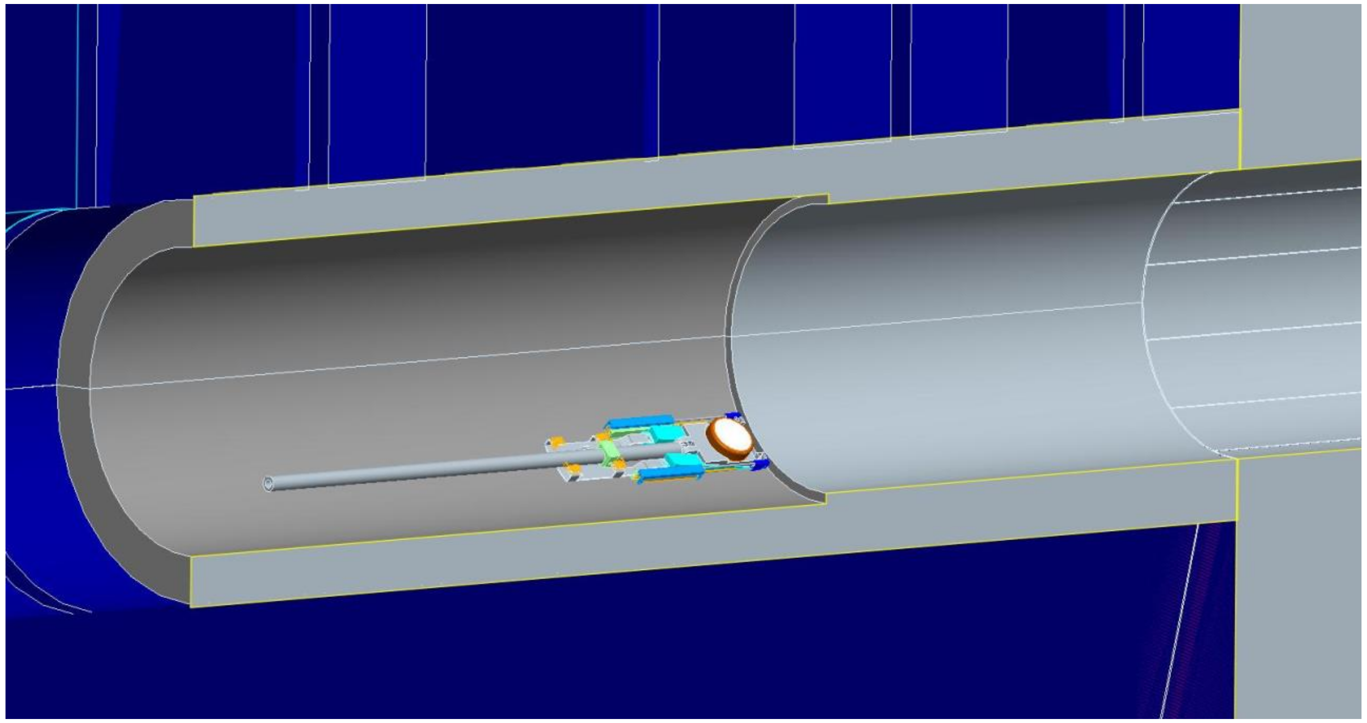


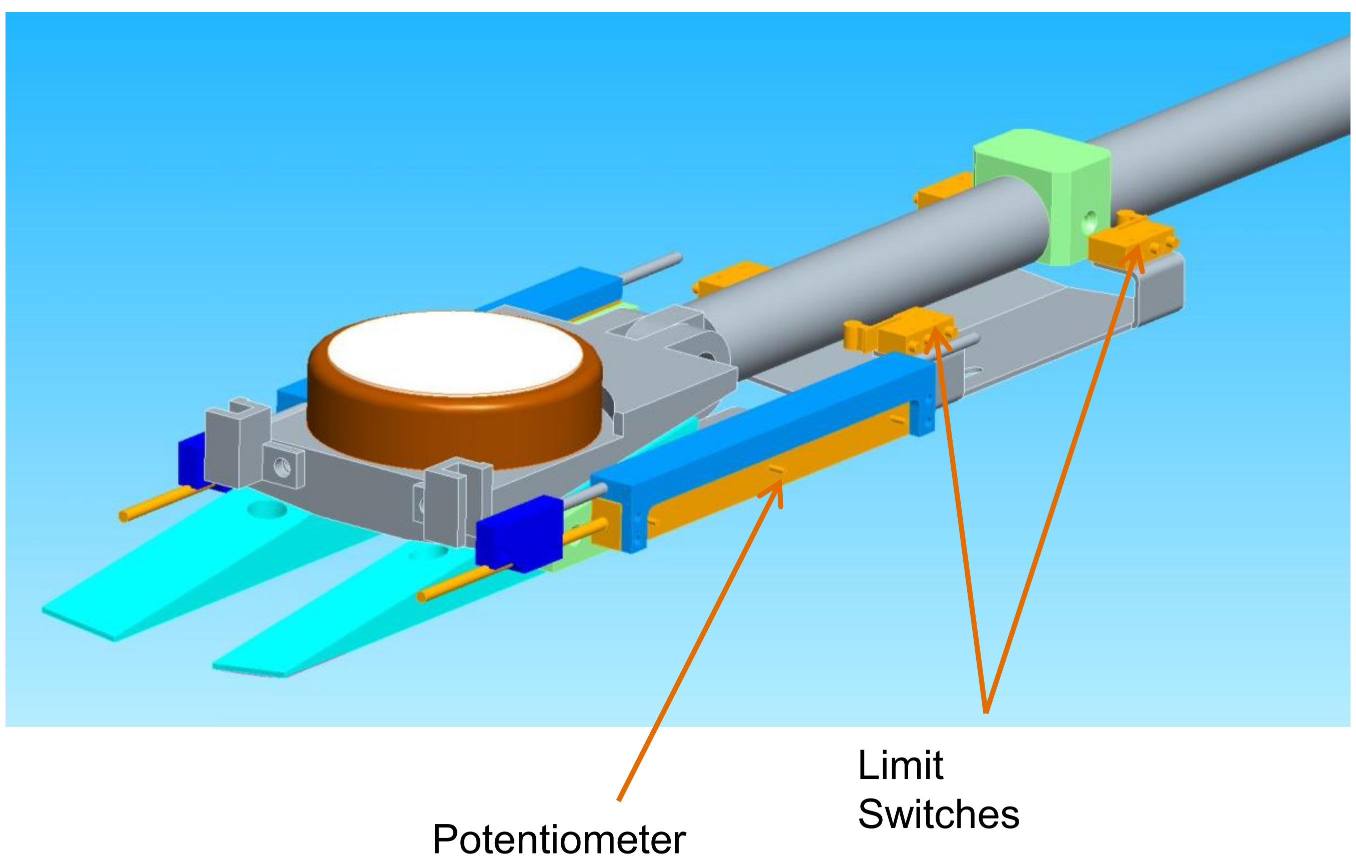


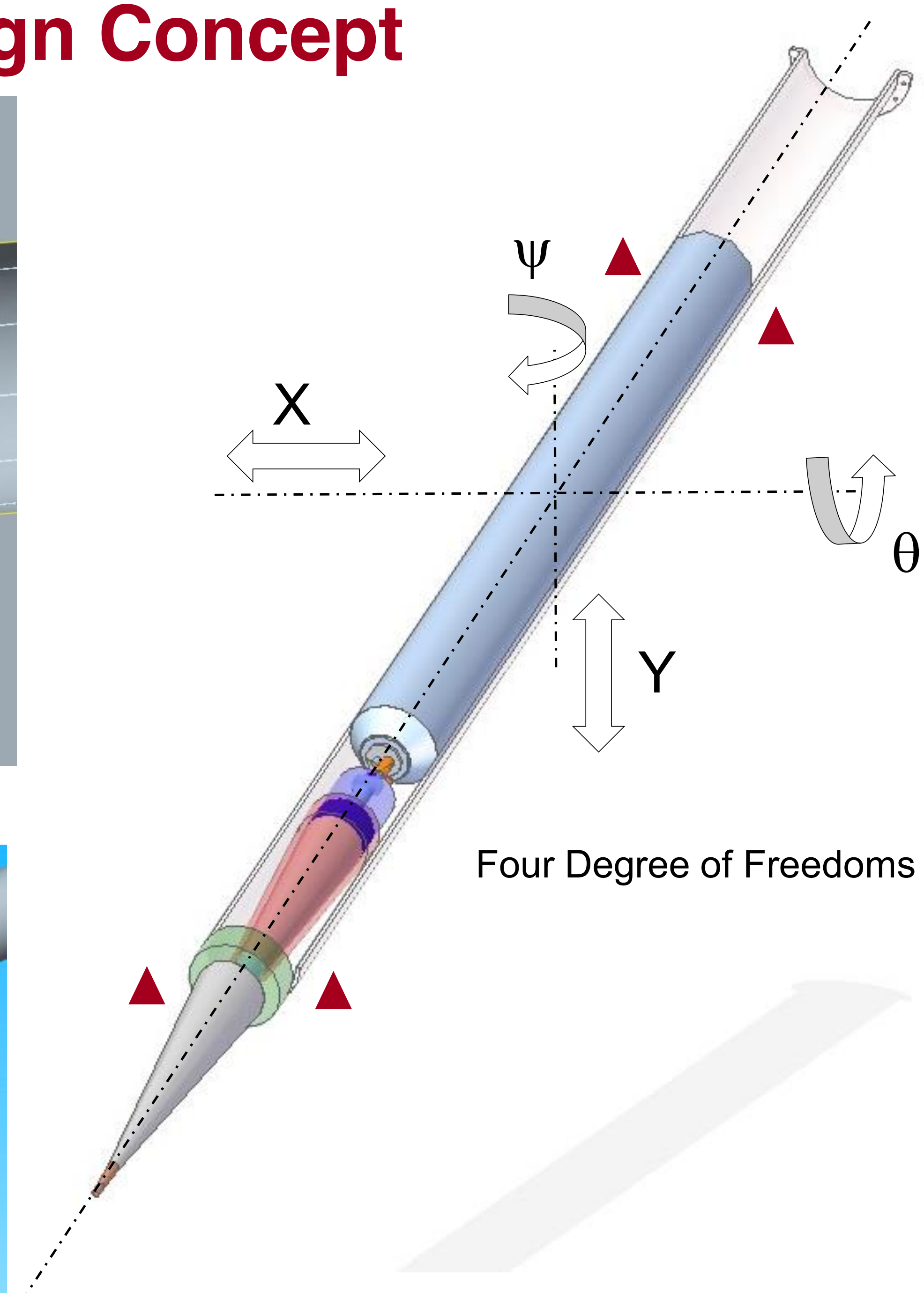
$$y = C_0(x_0^+ - x_0^-) + C_1(x_1^+ - x_1^-)$$

1. Ground Motions measured at the SLD detector hall
2. Conservative spectrum of the technical noise on the detector.
3. The model predicts that the maximum level of *r.m.s.* vibration seen by QDO is well below the capture range of the IP feedback system available in the ILC. With the addiction of an active stabilization system on QD0, it is also possible to achieve the stability requirements of CLIC.
4. Experimental measurements of the technical noise instrumenting CMS during LS1 with permanent vibration sensors

QD0 Wedge Design Concept







Total Pad Travel as is = .475in

Height of pad and distance of displacement will be changed pending analysis on sagging of beam line.

Conceptual design only at this point

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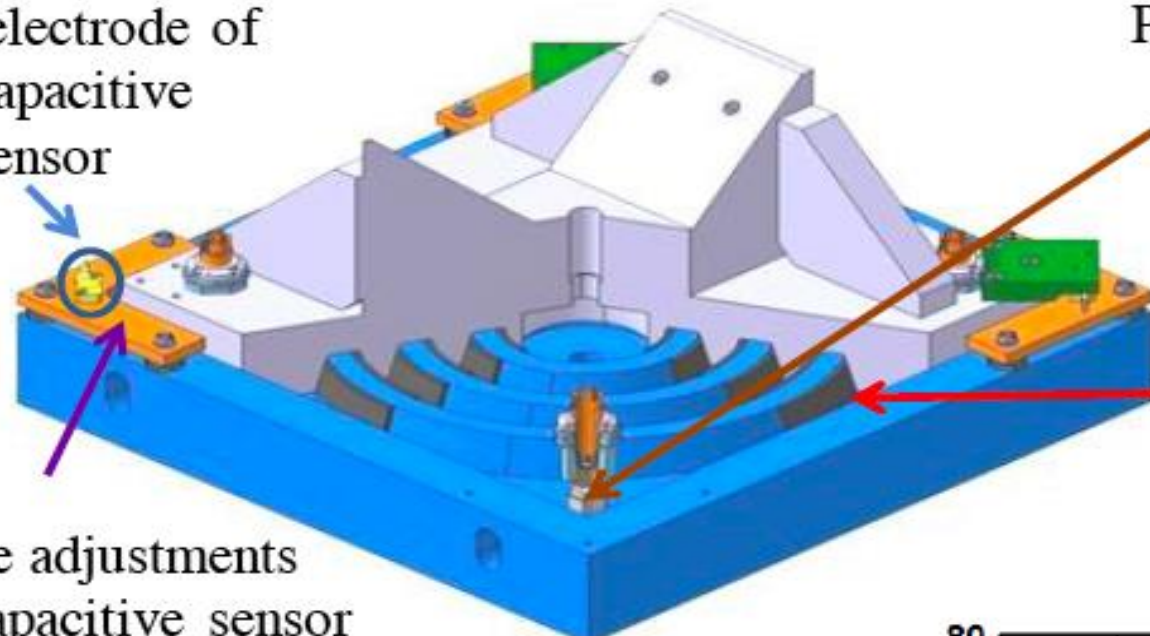
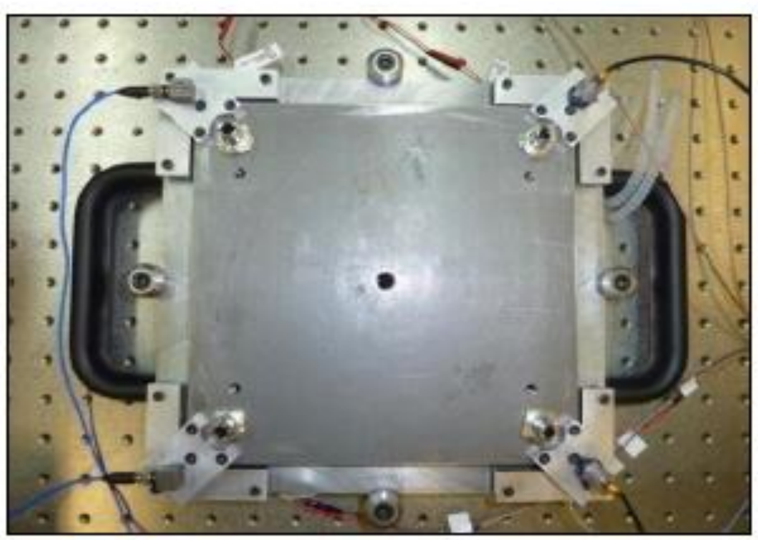
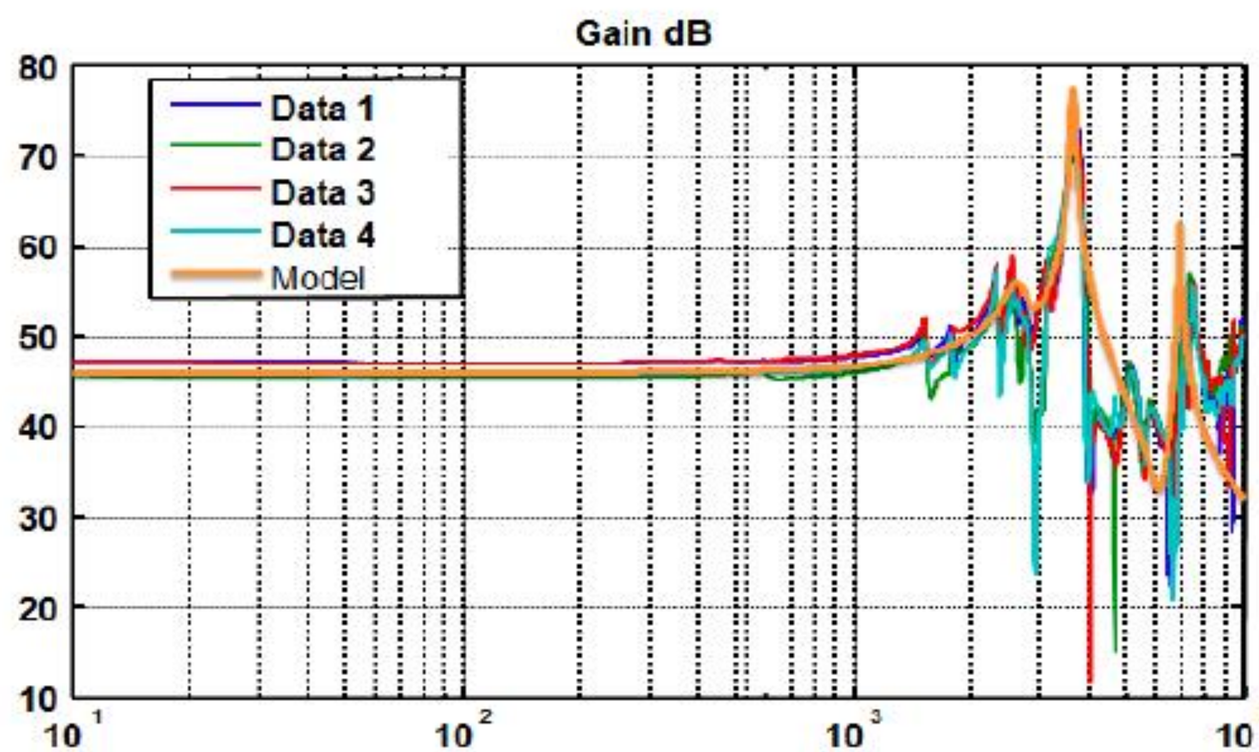
A.Jeremie et al

-Active foot:

rigid support

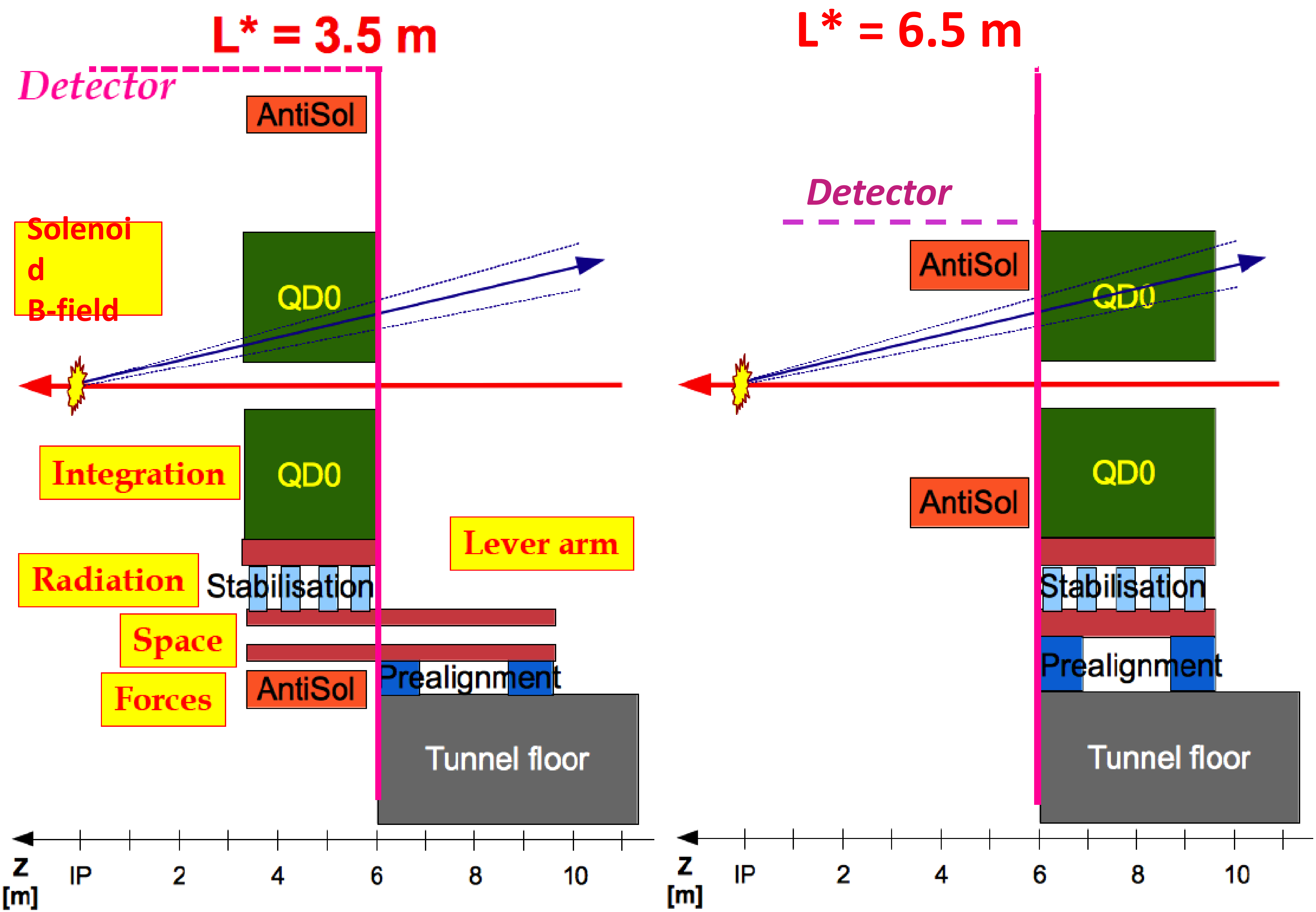






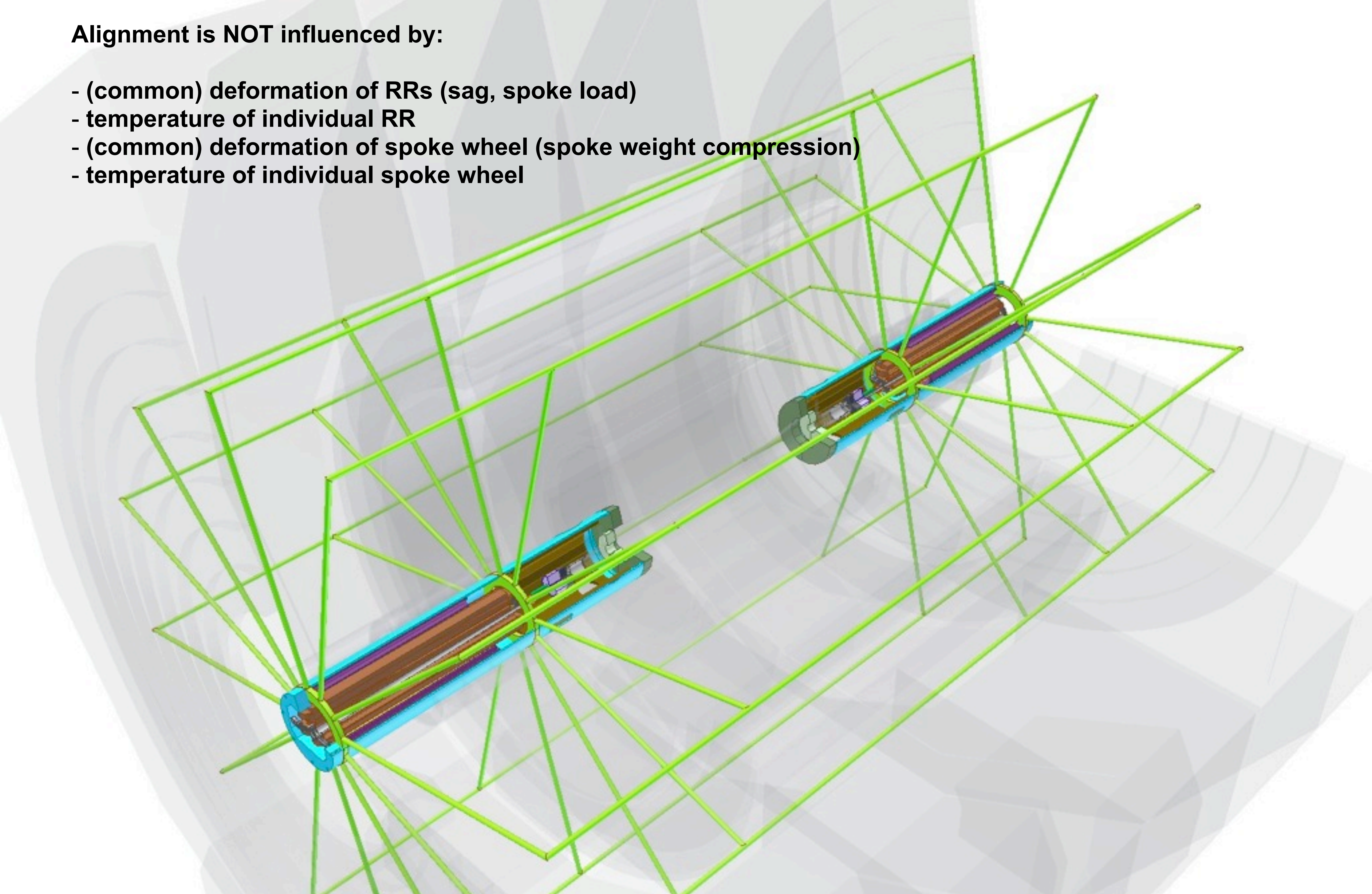
2013年 12月 17日 火曜日

CLIC MDI, presented by L. Gatignon, LCWS2013

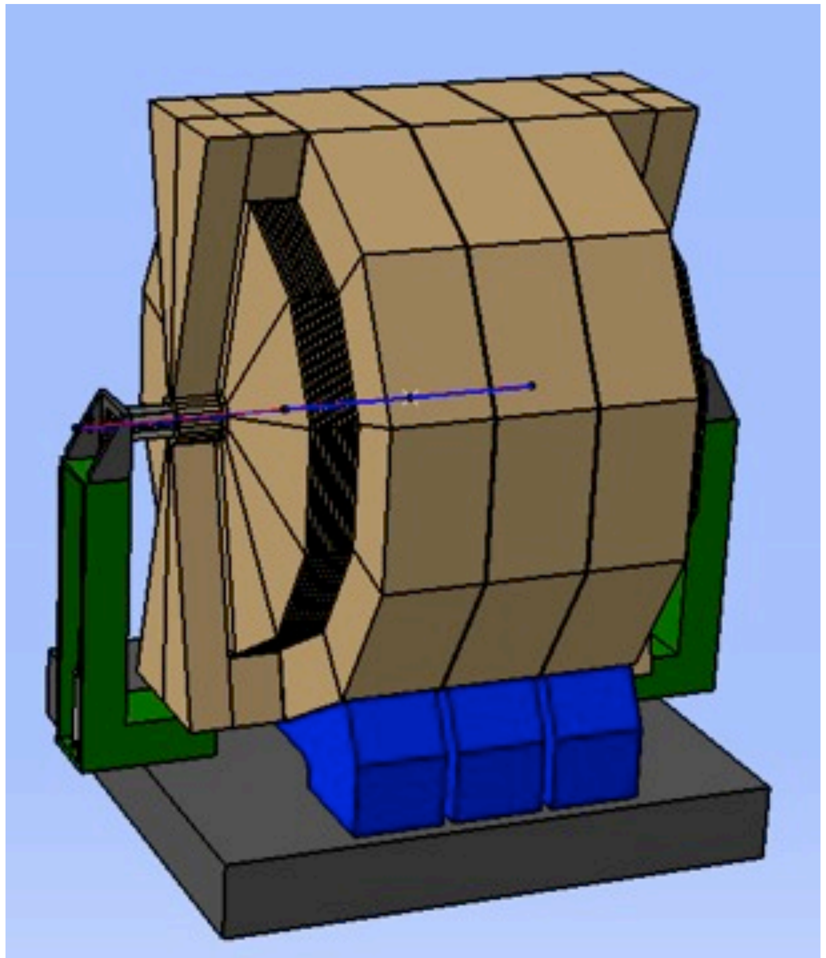


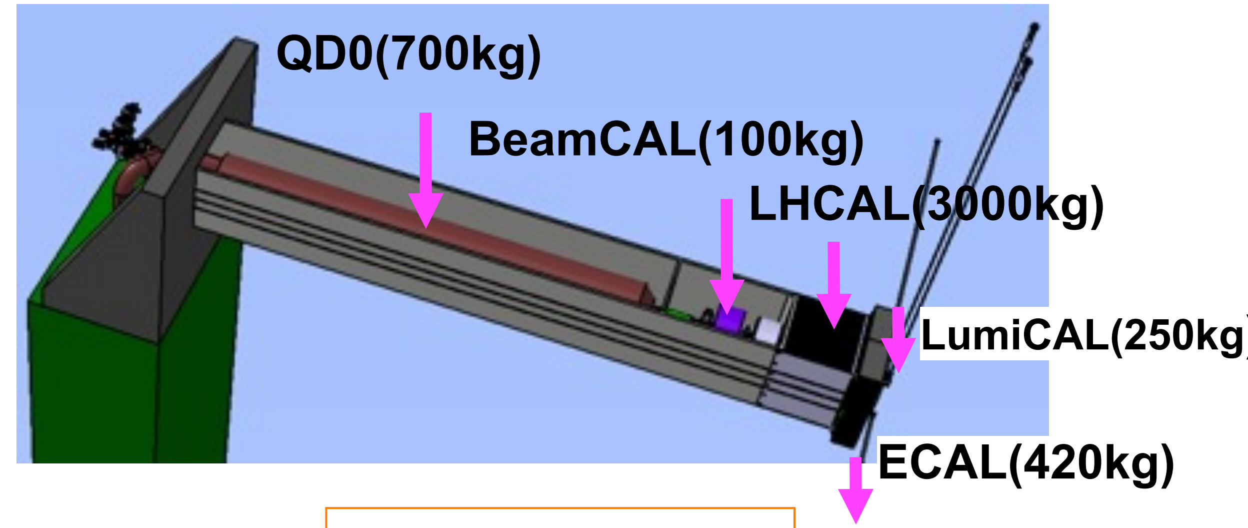
Alignment is NOT influenced by:

- **(common) deformation of RRs (sag, spoke load)**
- **temperature of individual RR**
- **(common) deformation of spoke wheel (spoke weight compression)**
- **temperature of individual spoke wheel**



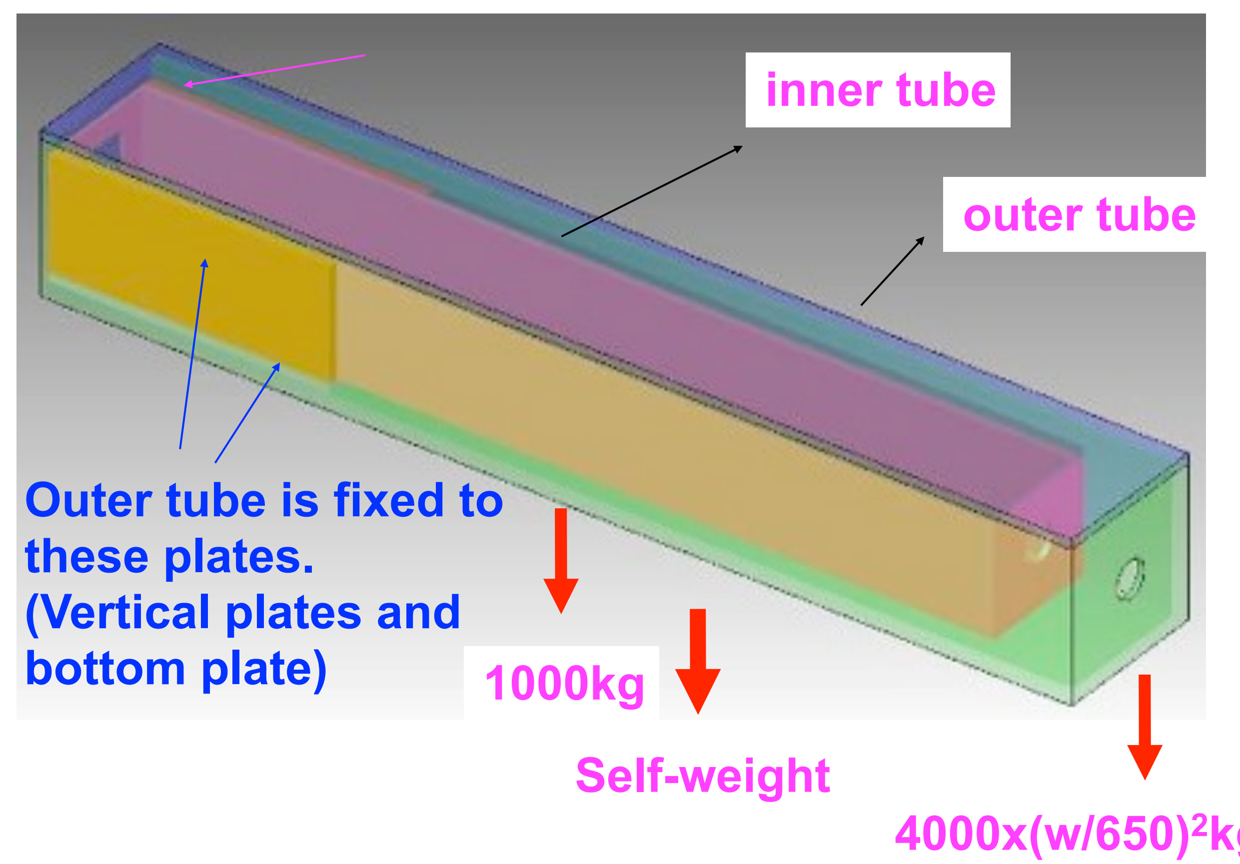
ILD QD0 support, by H. Yamaoka, LCWS2010, Beijing



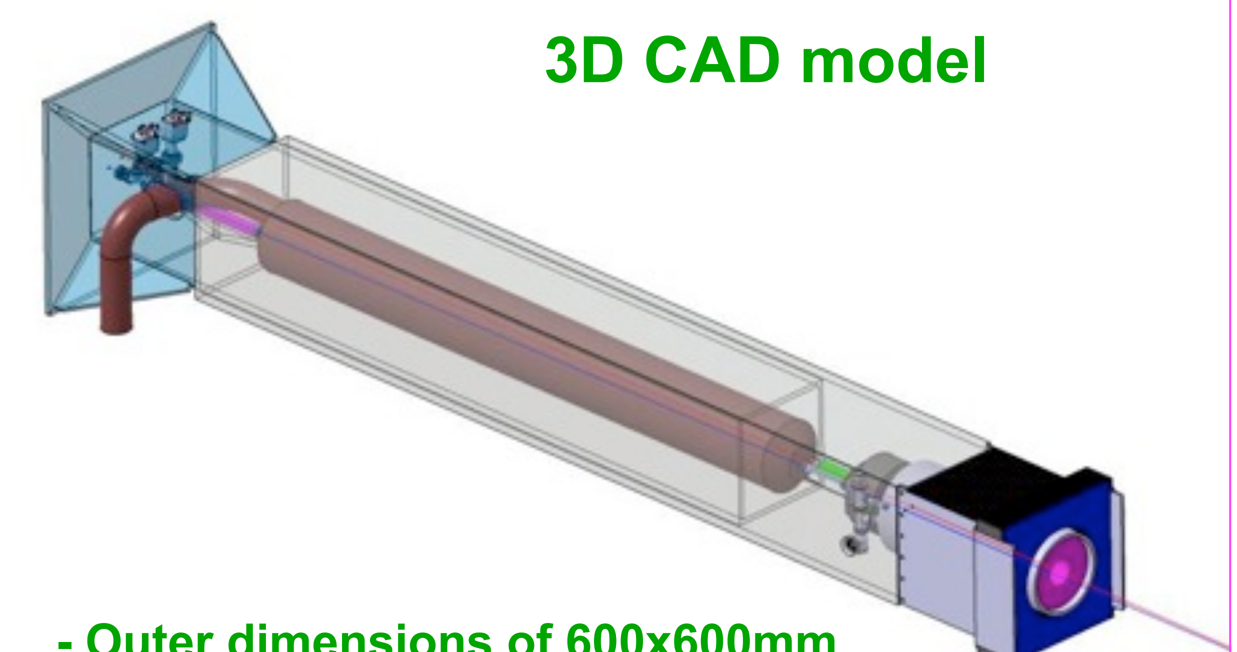


ANSYS model

fixed or support bracket

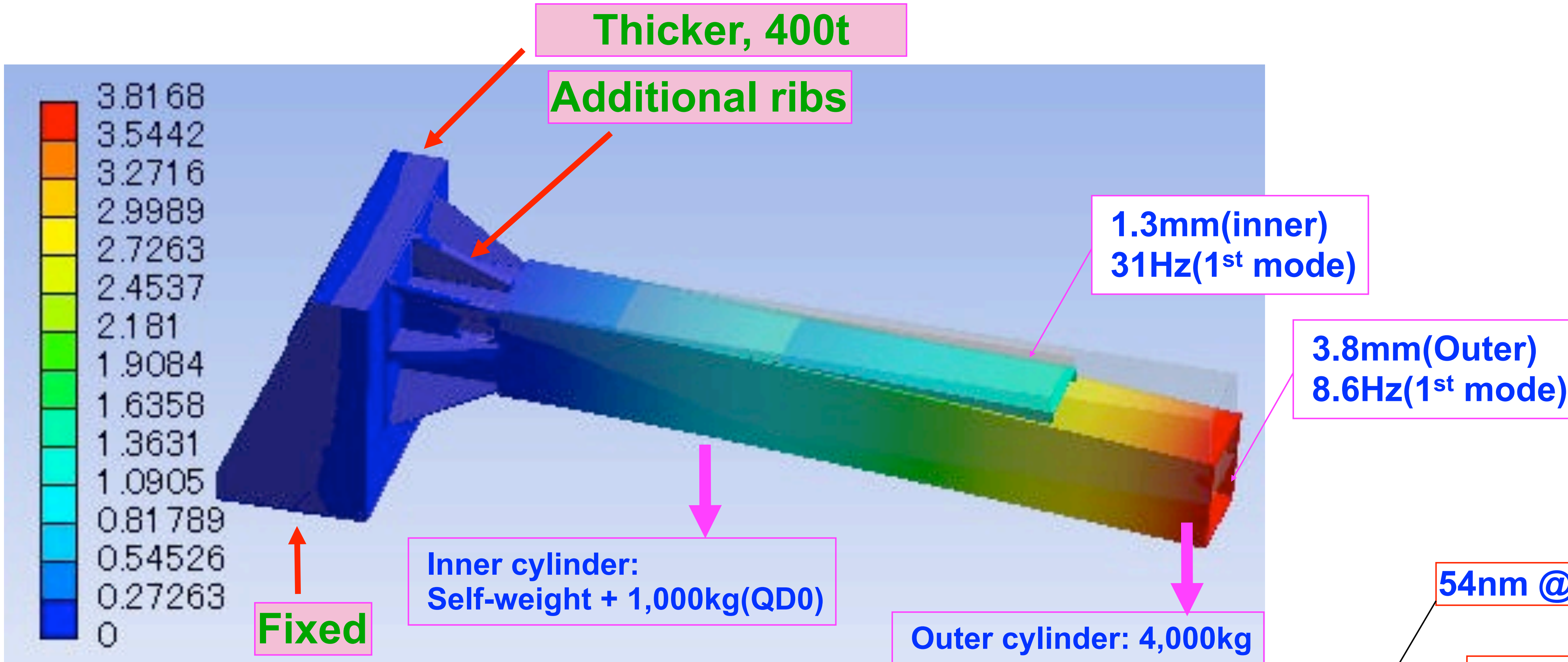


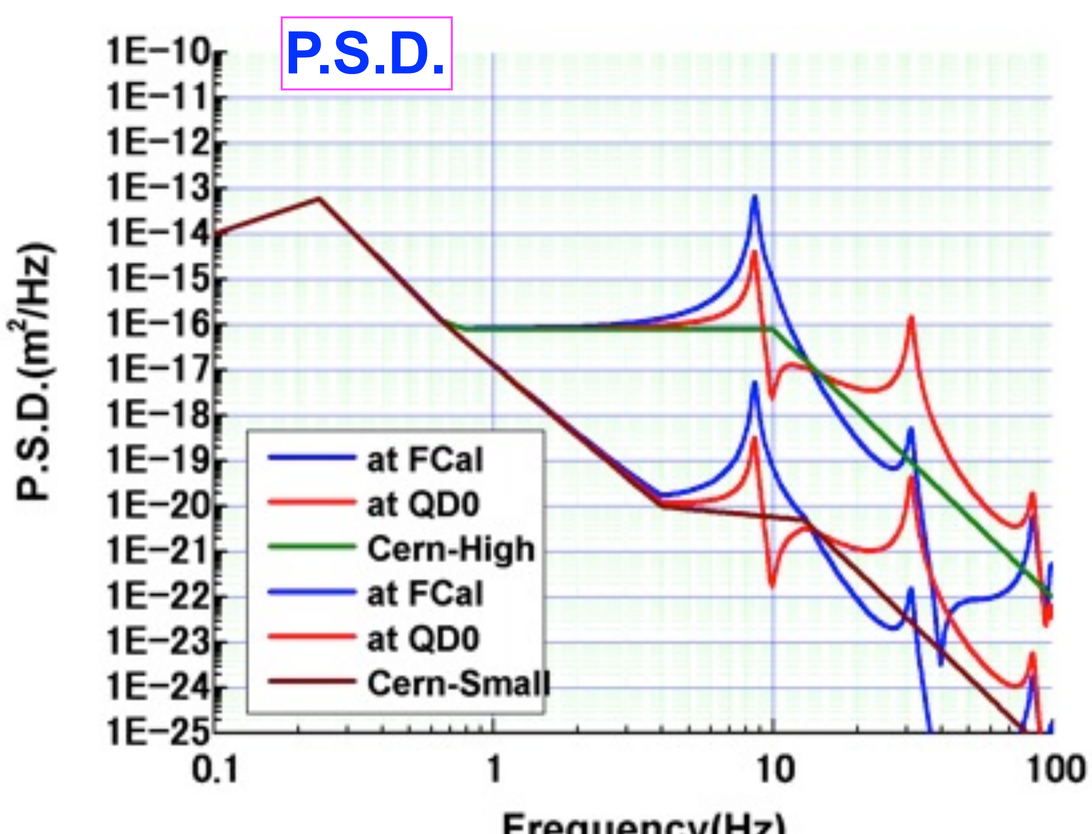
3D CAD model

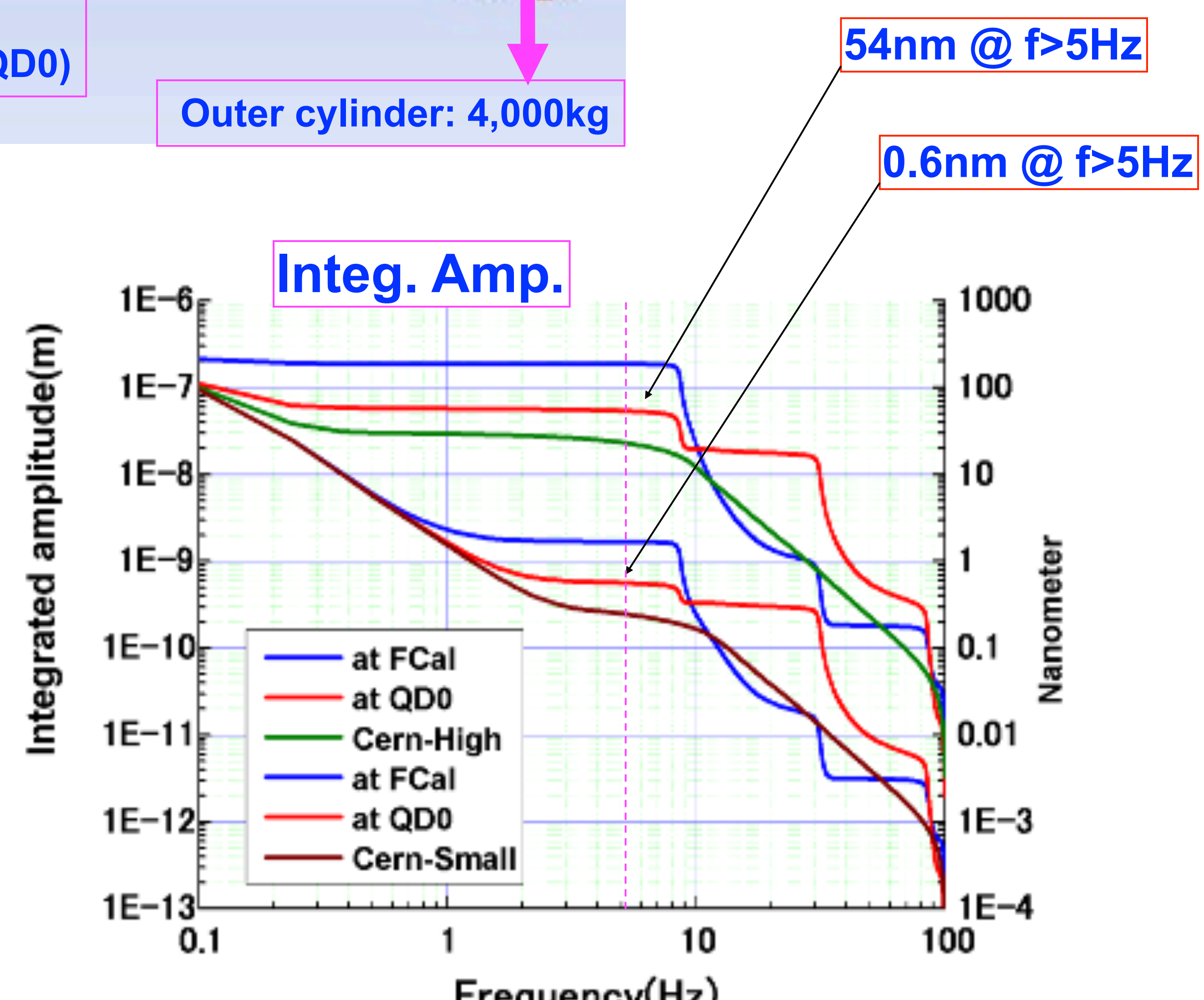


- Outer dimensions of 600x600mm
- 25mm thick

ILD QD0 support, by H. Yamaoka, LCWS2010, Beijing

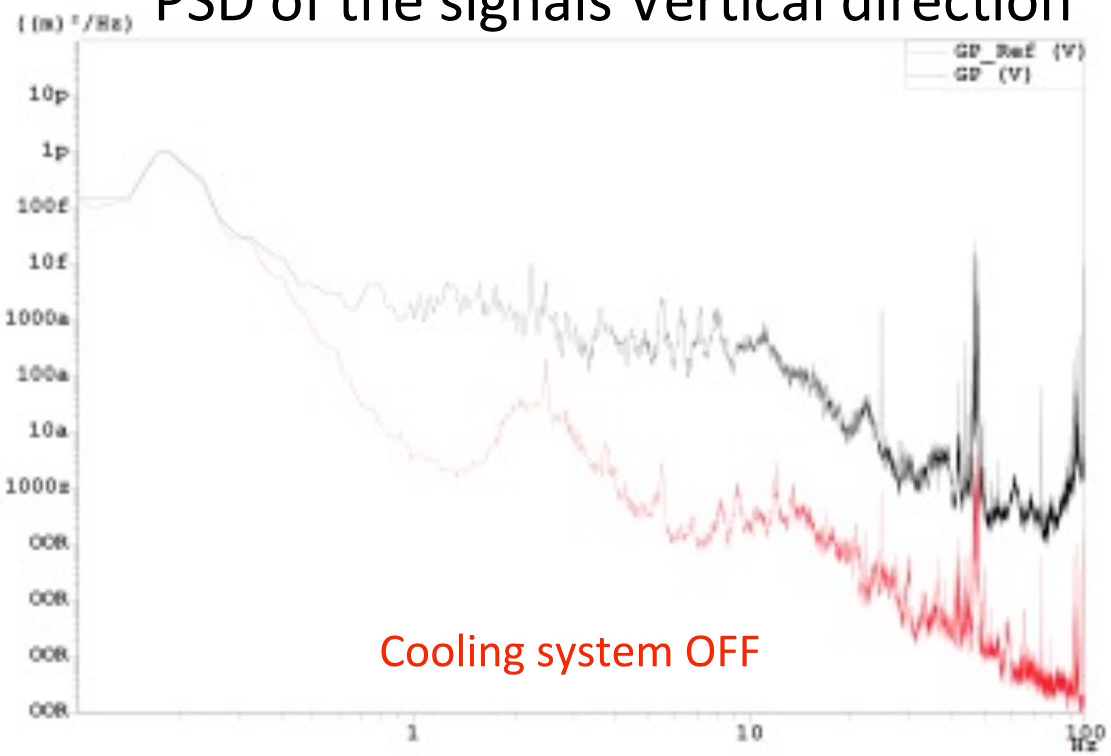


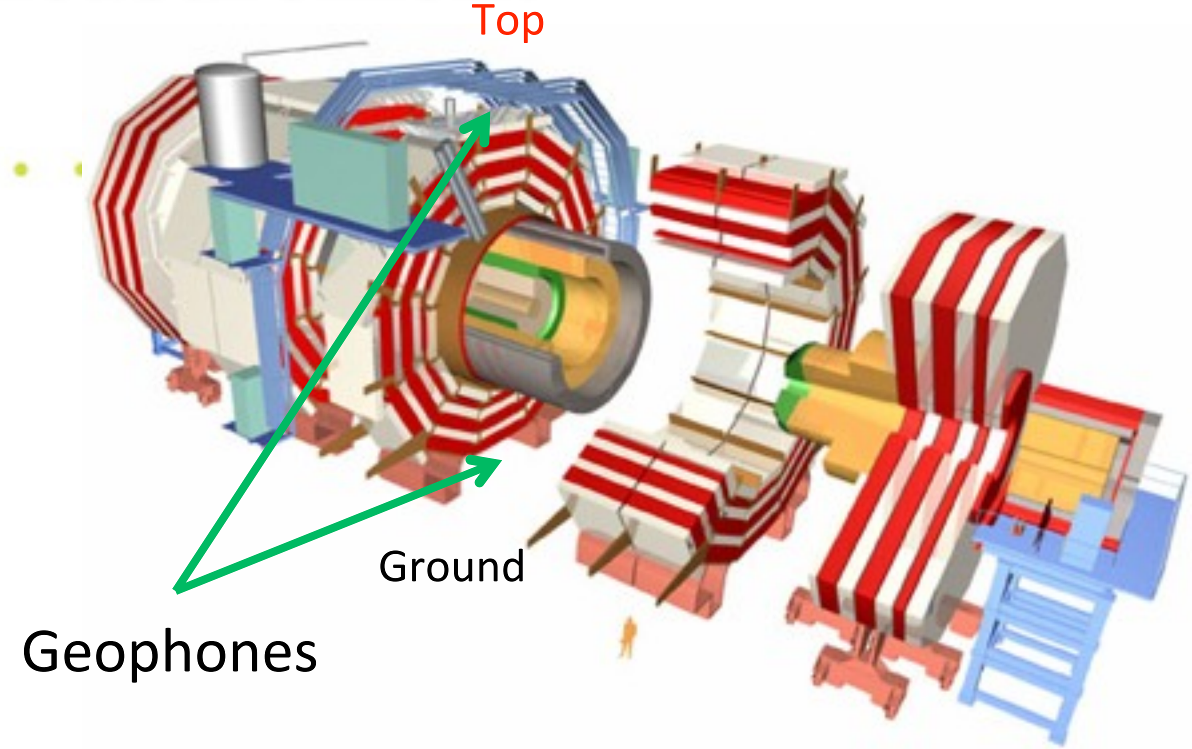




CMS top of Yoke measurement

PSD of the signals Vertical direction

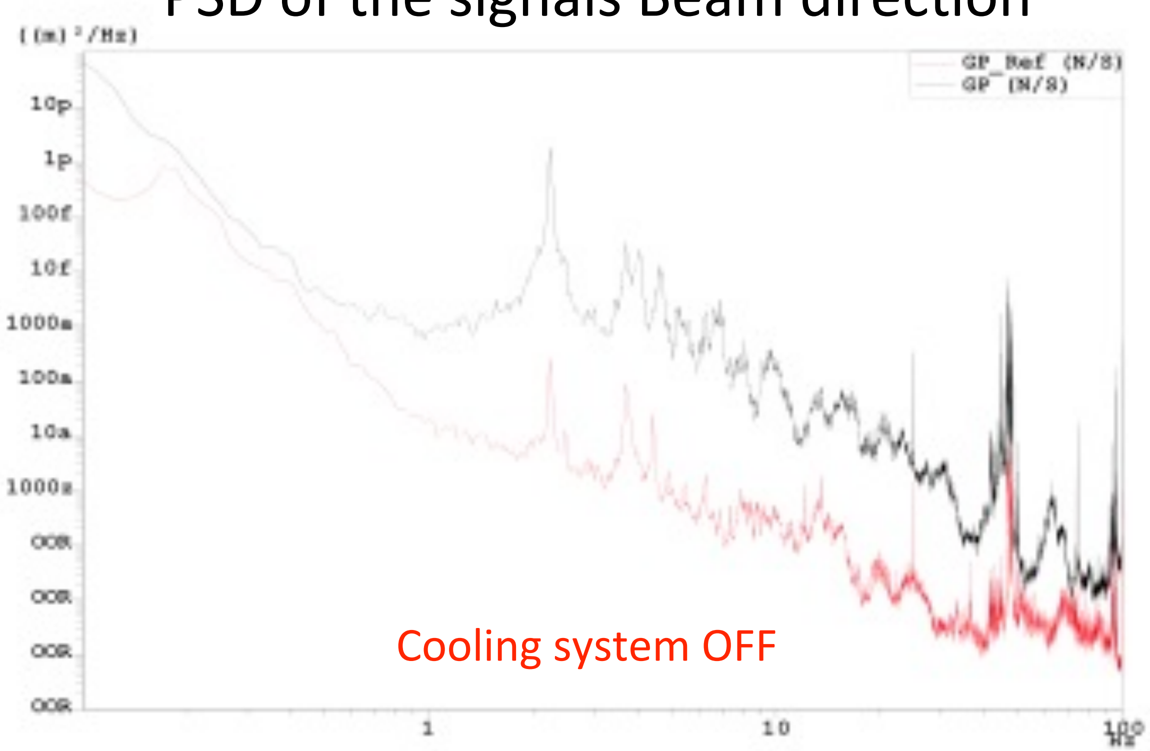


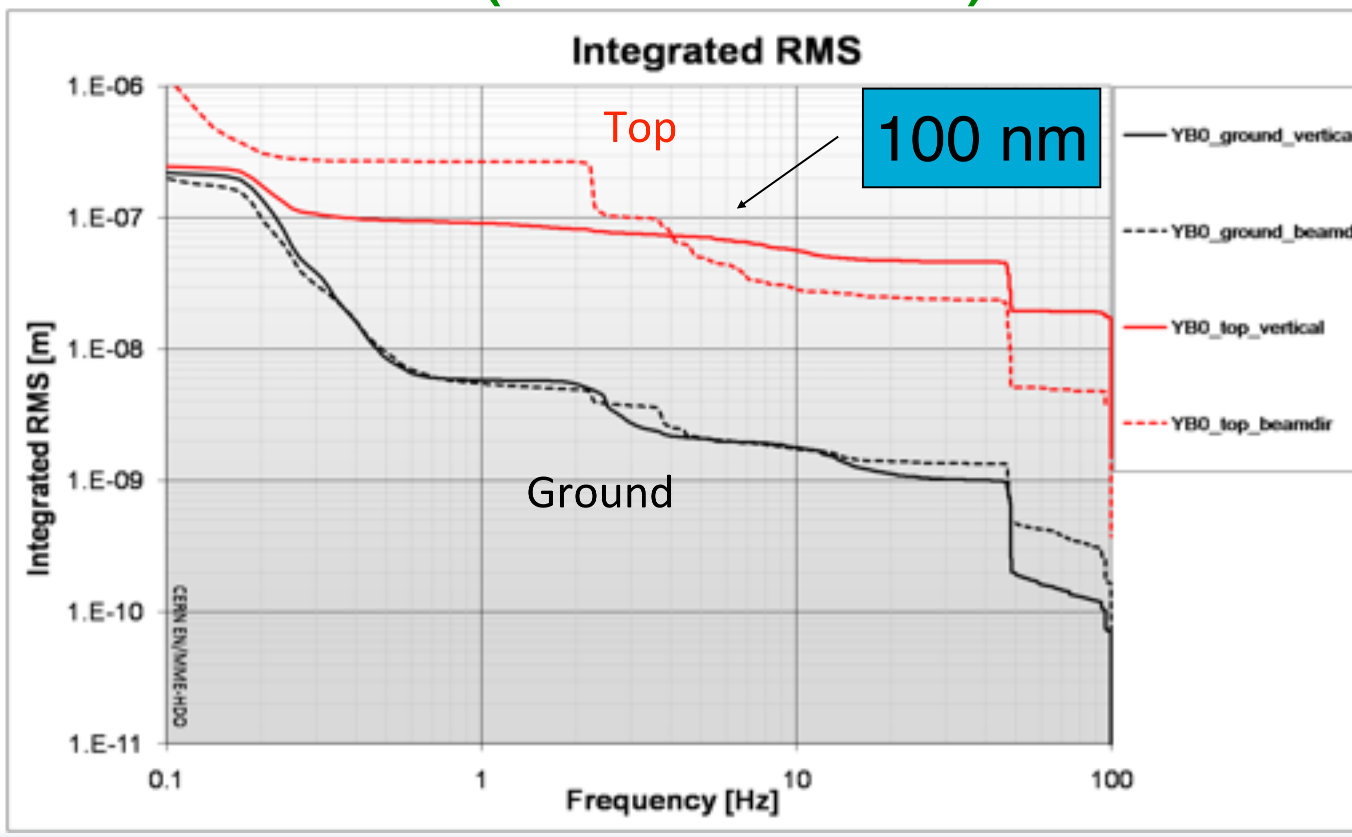


Detector vibrations and QD0 support

Alain Herve (ETH Zurich)

PSD of the signals Beam direction





Summary

1. Kick deflection angles were calculated with the ILC TDR parameters by the CAIN (v2.42), which show more disruptive than the RDR ones.

2. The vertical beam offset between two beams must be kept within 0.5nm by the IP feedback system for the 98% luminosity at Ecm=500GeV.

3. The 50nm tolerance must be re-evaluated with the TDR, which is the RMS jitters at the final doublet.

4. QDO support system must be rigid as the designs by ILD, SID and CLIC to fulfill the above requirement.

5. Beam commissioning strategy is very important. It may affect present IP stabilization scheme.