IR Geometries & Constraints on Forward Detectors

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LCWS Paris

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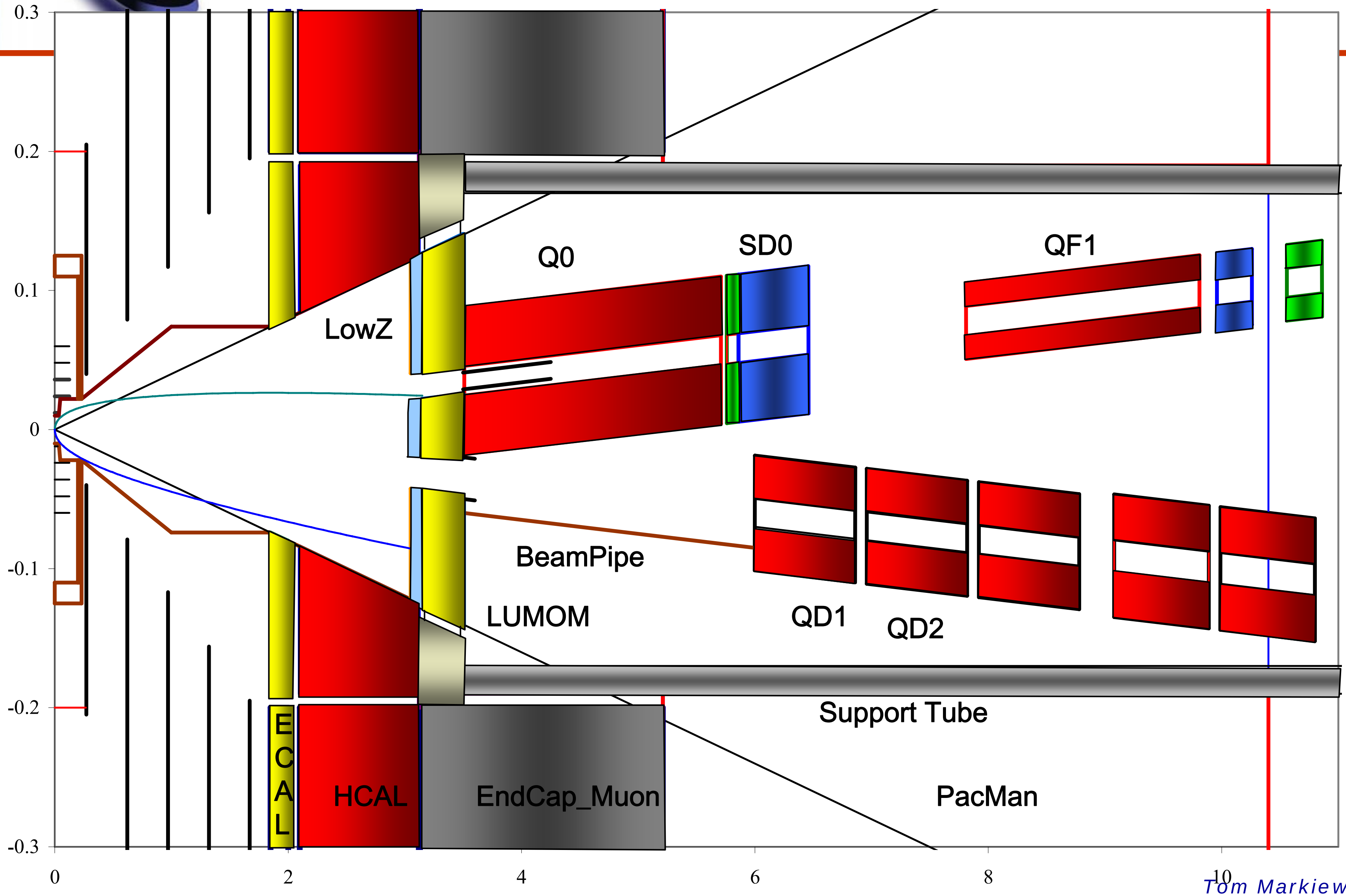
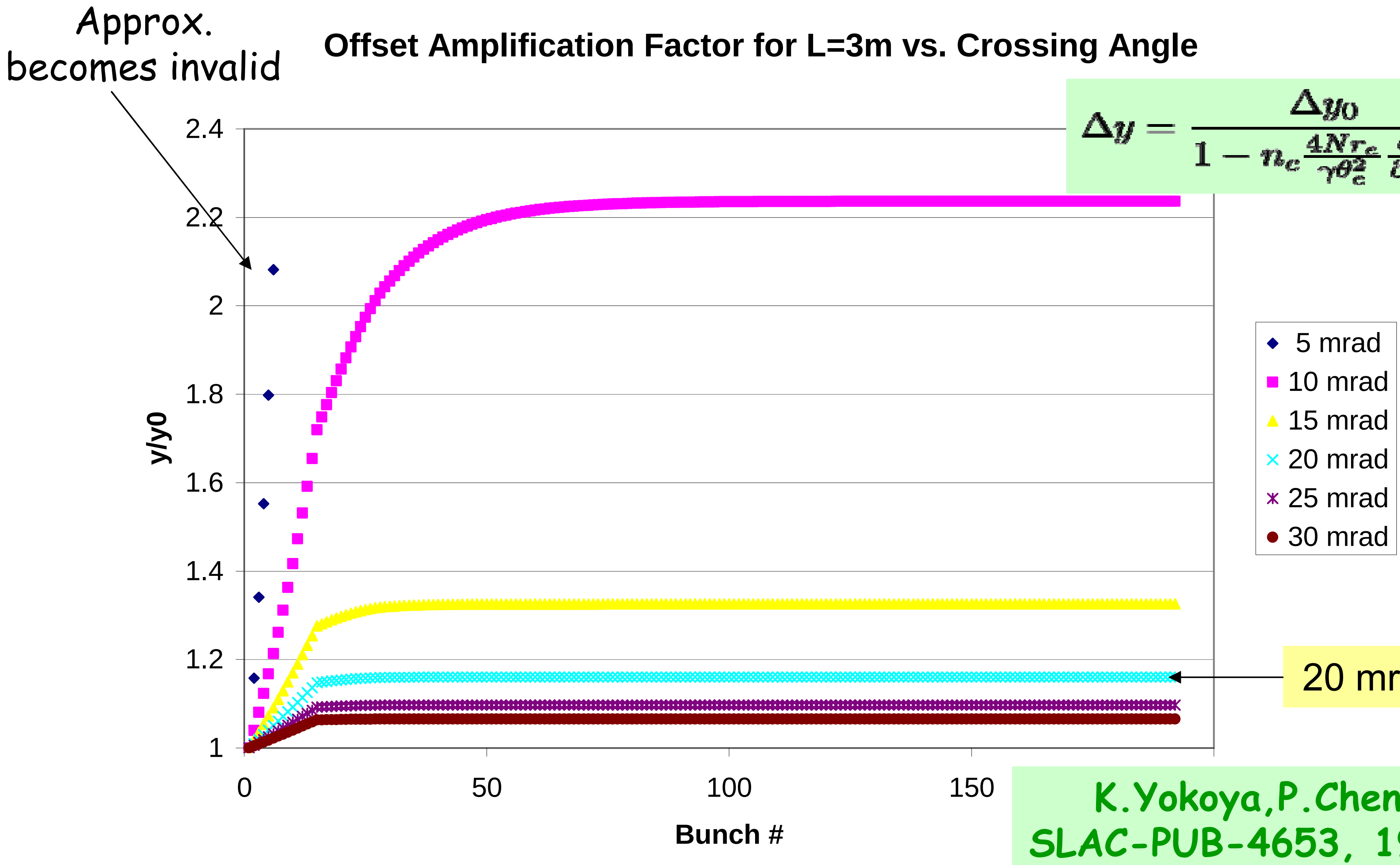
SiD Forward Masking, Calorimetry & Tracking 2004-04-15



Crossing Angle

- Warm LC requires non-zero crossing angle
- Cold LC can choose zero or non-zero angle
- Minimum angle set by:
  - Need to avoid parasitic collisions and beam-beam induced jitter (20 mrad)
  - Need enough transverse space for QD0 magnet, given
    - L* (a semi-free parameter) (3.51m)
    - Exit aperture at LUM (1.2cm→2.0cm→1.5cm)
    - QD0 bore size (1.0 cm)
    - Design choice that exit beam goes outside of QD0
- Maximum angle set by
  - Estimated performance ($\Delta\phi$) of Crab Cavities on either side of IP that rotate bunches (~40 mrad)
  - Beam optics effects:
    - ε growth due to SR in QD0 goes as $(B_s L^* \theta)^{5/2}$

Multi-bunch interaction increases static beam offsets if θ_c too small



$$\Delta y = \frac{\Delta y_0}{1 - n_c \frac{4 N r_e}{\gamma \theta_c^2} \frac{\partial y'}{\partial \Delta y}}$$

K.Yokoya, P.Chen
SLAC-PUB-4653, 1988

NLC Final Doublet Quad Specs

Gradient “easy”; L* & Lum ap define space

TRC (2002) 500 GeV Lattice

Magnet	Aperture	Gradient	Rmax if REC	Radial Space	Z_ip	Length
QD0	1.0 cm	141.6 T/m	5.3cm	7.0cm-R_{LUM}	3.51 m	2.2m
QF1	1.0 cm	80.2 T/m	2.7cm	>7.81cm	7.81 m	2.0 m

Increased LUM aperture decreasing available space

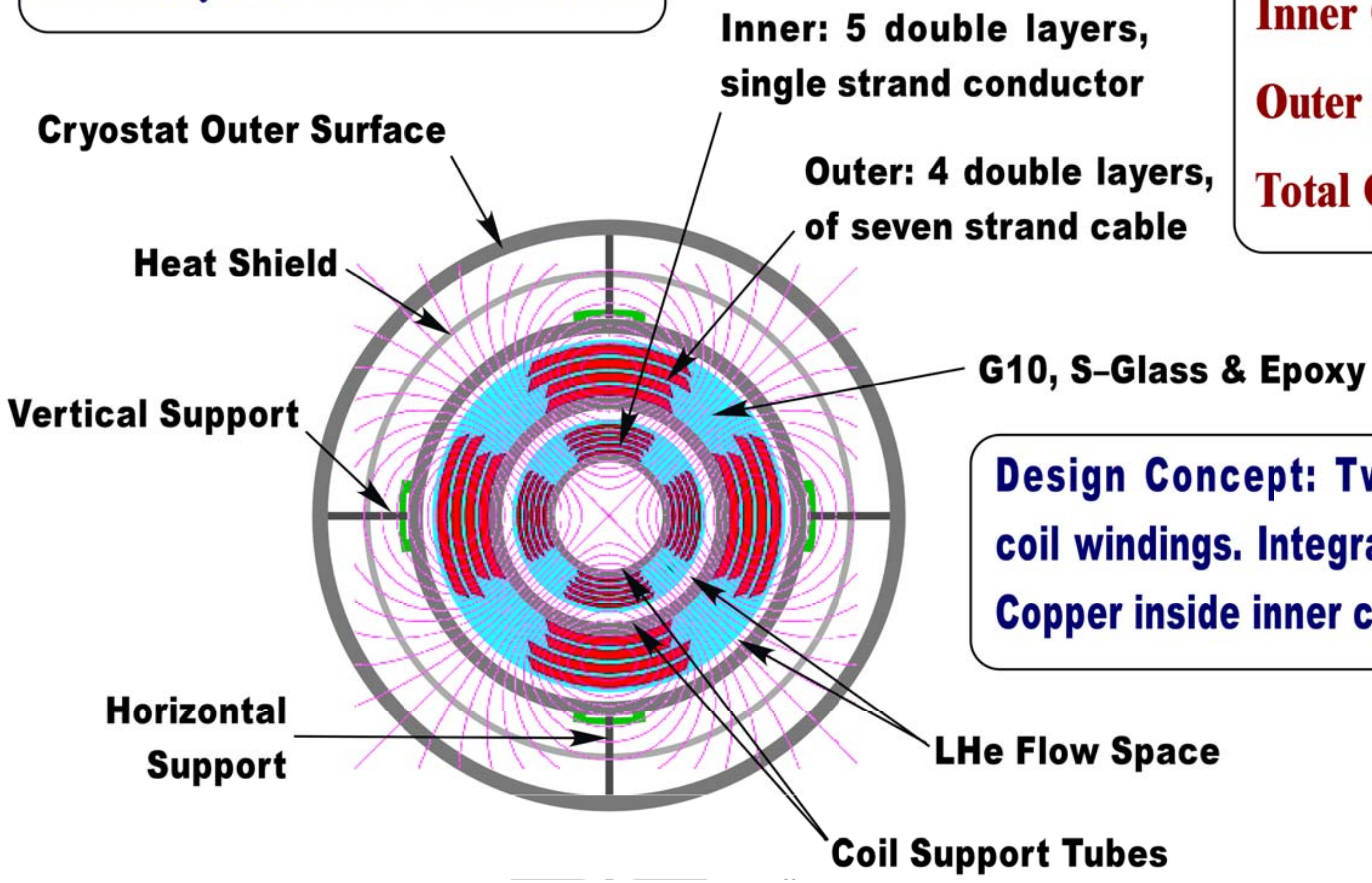
Snowmass 2001 500 GeV Lattice

Magnet	Aperture	Gradient	Rmax if REC	Radial Space	Z_ip	Length
QD0	1.0 cm	144 T/m	5.5cm	5.8cm	3.81 m	2.0m
QF1	1.0 cm	36.4 T/m	2.2cm	>7.81cm	7.76 m	4.0 m

SC Magnet
If r_{in}=10mm, r_{out}=57mm seemed easy

Inner Beam Tube	20 mm ID
Outer Cryostat Tube	114 mm OD

QDO Coil Parameters	
Inner Quad	63 T/m
Outer Quad	81 T/m
Total Quad	144 T/m

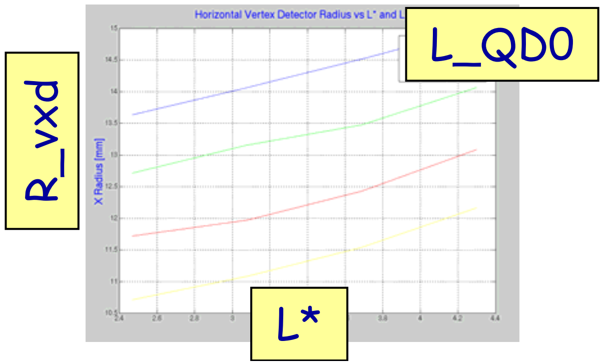


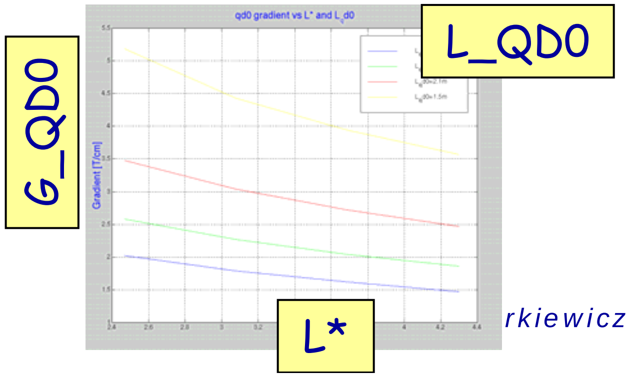
Design Concept: Two independent coil windings. Integrated helium flow. Copper inside inner coil support tube.

L*=Distance from IP to QD0

- A parameter that can be varied within a range for either design
  - r_vxd, z, length, aperture, gradient of QD0, QF1 all enter
- Motivations for larger L*
  - Move QD0 outside the detector to stable ground
  - Move LUMON further back if pair backsplash a problem
- Note: L* of EXTRACTION LINE now 6m
  - Its z position variable as well
  - Especially valuable as it receives biggest hit from 4 GeV pairs

L* Optimization
P.Raimondi
~2001

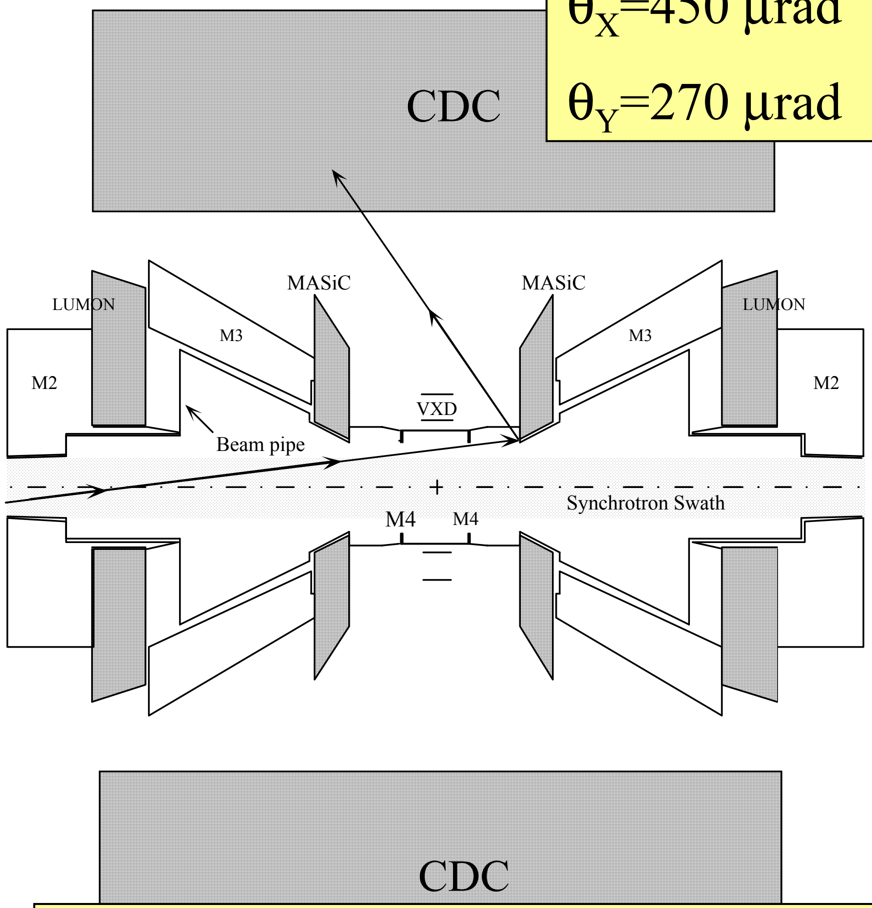




Exit Aperture at LUM
Beam Pipe Radius at IP

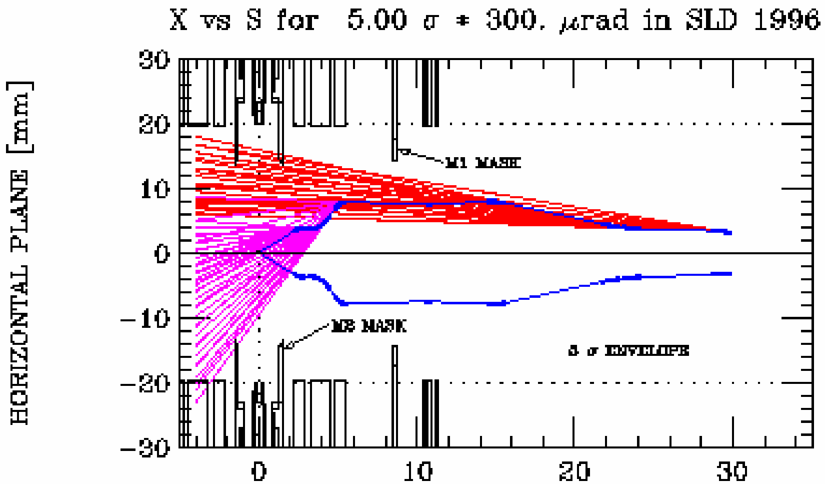
- Same issues for warm vs. cold choice
- Design requirement that ALL Synchrotron Radiation Leaves IP
  - Collimation system design & performance
  - Magnitude and distribution of non-gaussian beam halo
  - Level of aggression in setting collimators and resultant
    - beam jitter amplification due to collimator wakefields
    - muon production
  - Level of conservatism
    - Worst beam conditions that system must safely handle
- The larger the exit, the less the adverse effects of e+e- pairs
  - Less albido from splattered e+e- pairs when high Z LUM is at a larger radius than the low Z albido absorber
  - Largest radiation-dosed area follows high energy exiting pairs

At SLD/SLC SR WAS THE PROBLEM

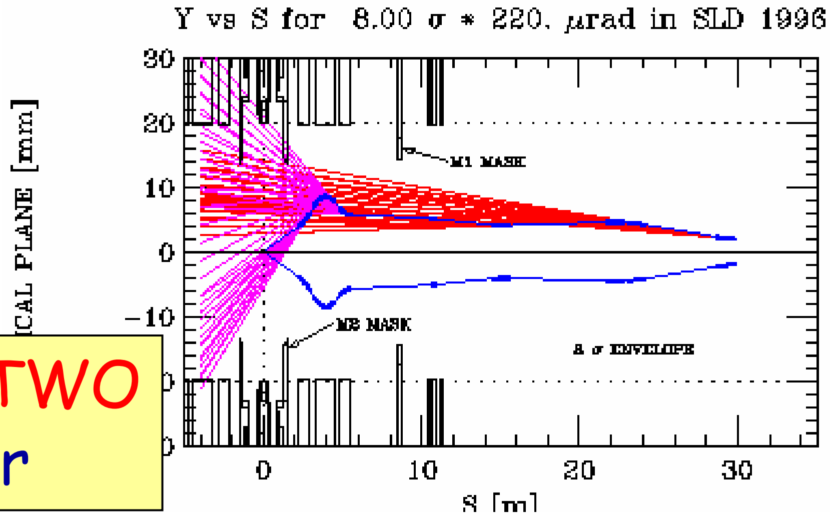


θ_X=450 μrad

θ_Y=270 μrad



SR Fans from Halo in Final Focus



Photons need a minimum of TWO bounces to hit a detector

SR at Warm/Cold LC

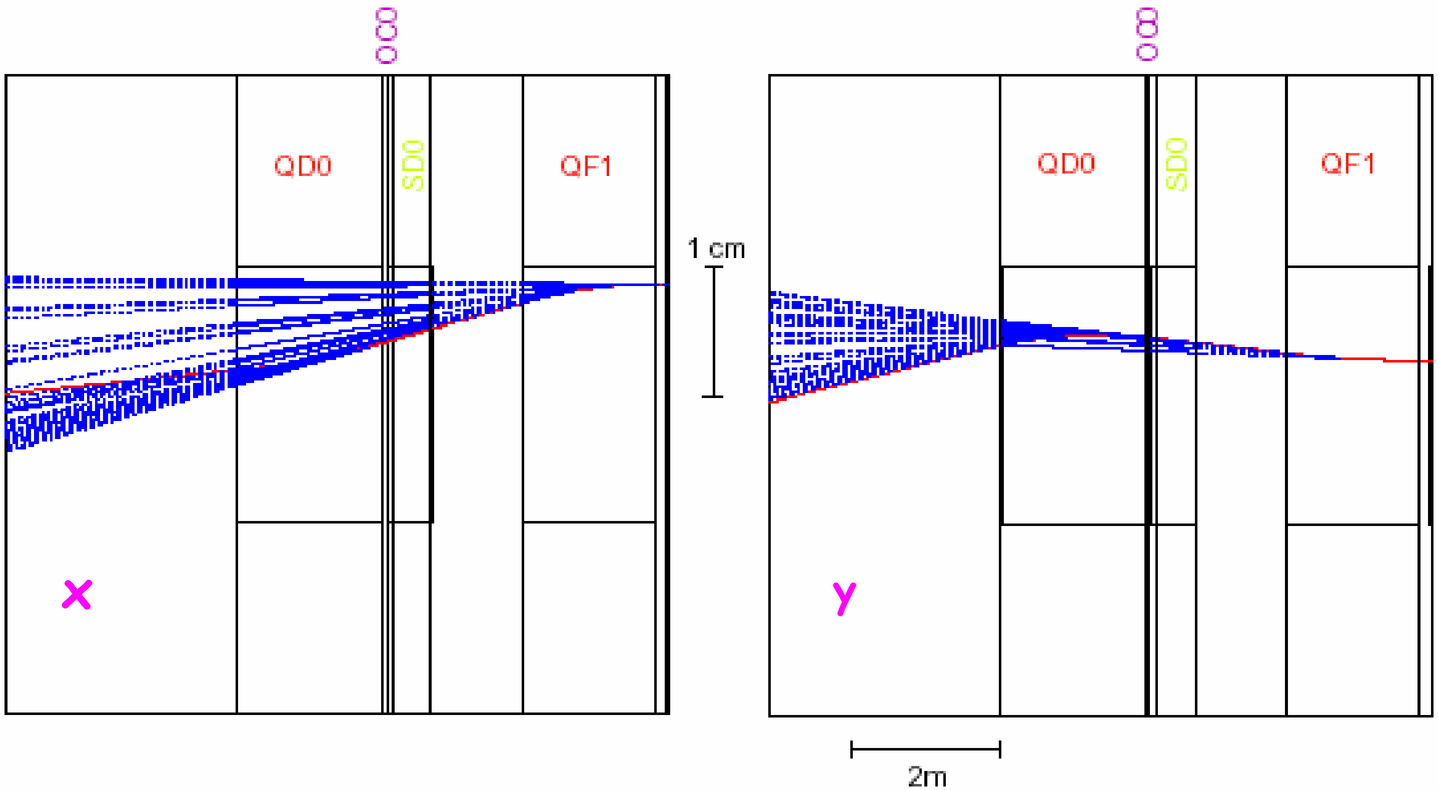
θ_X=30.3 μrad

θ_Y=27.3 μrad

Design Criteria: NO Photons hit beampipe at IP or LUM

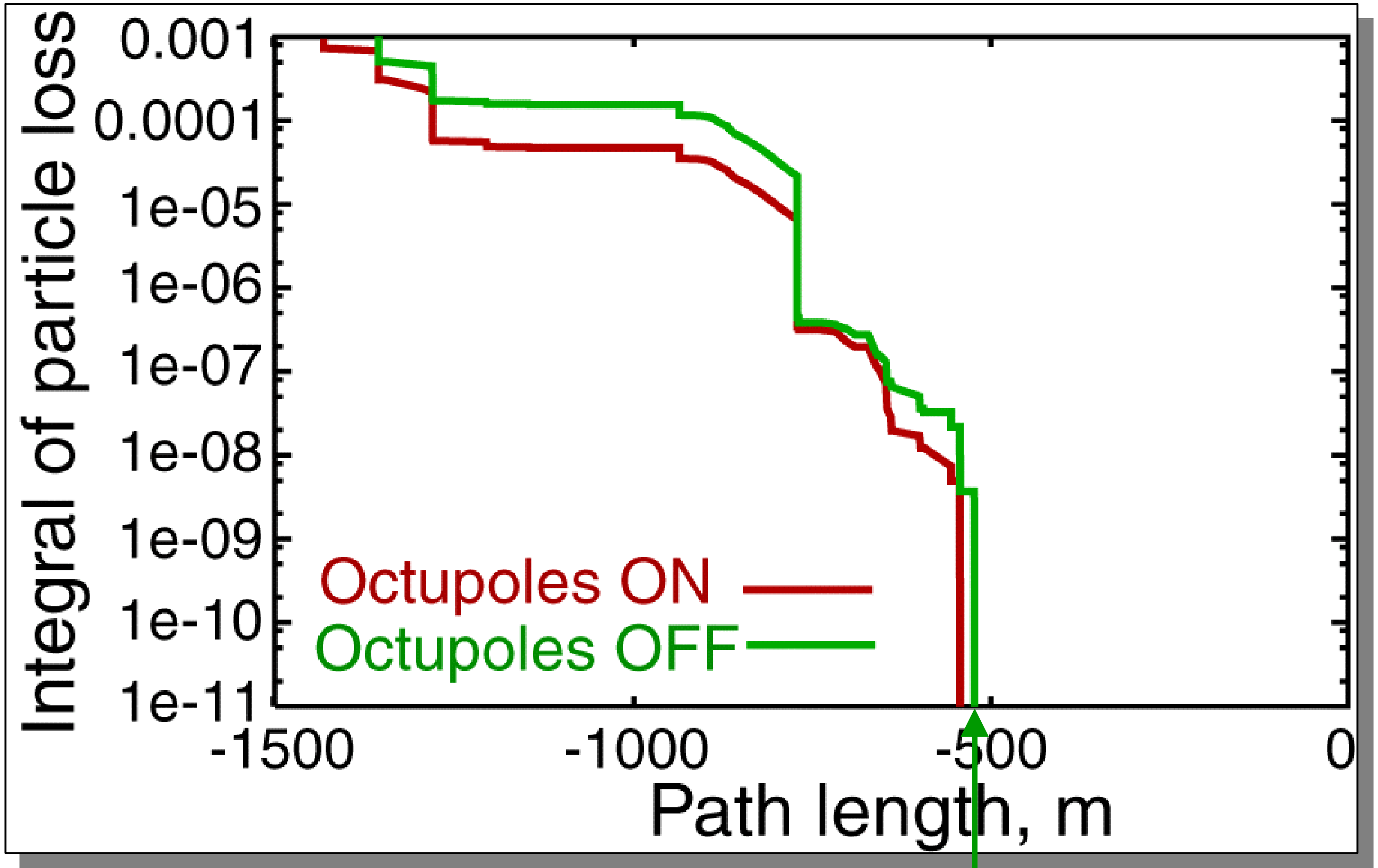
(IP) x' < 570 μrad = 19 x 30.3 μrad   y' < 1420 μrad = 52 x 27.3 μrad

(LUM) x' < 520 μrad = 17 x 30.3 μrad   Y' < 1120 μrad = 41 x 27.3 μrad



NLC Collimation System Designed to Make Detector Free of Machine Backgrounds

TRC Collimator Study



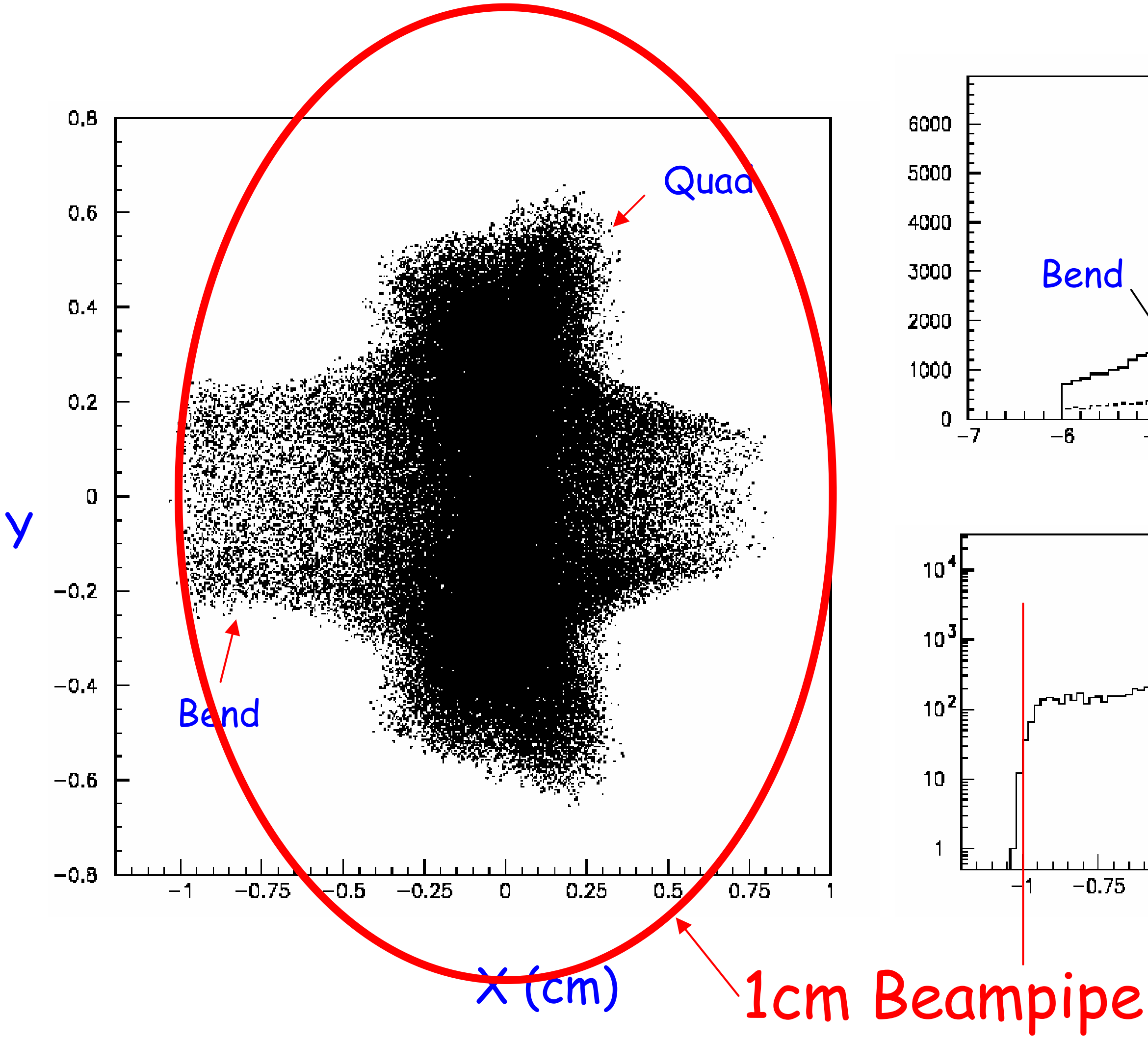
Last Lost e- 500m from IP

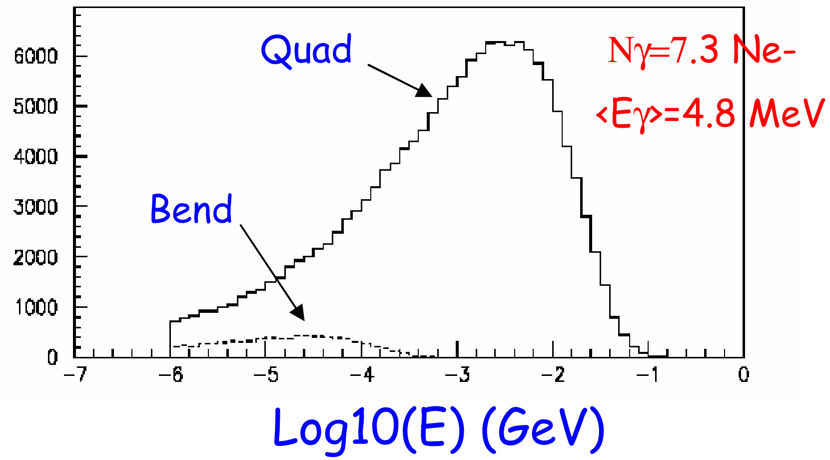
E=250 GeV

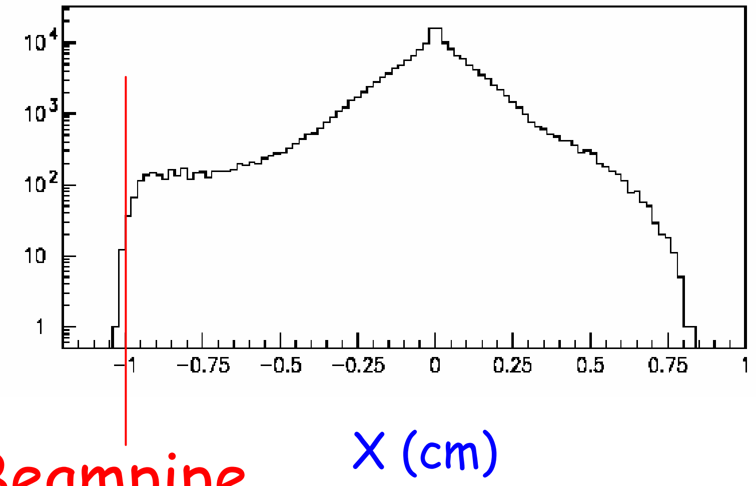
N=1.4E12

0.1% Halo distributed as 1/X and 1/Y for $6<A_x<16\sigma_x$ and $24<A_y<73\sigma_y$ with **$\Delta p/p=0.01$** gaussian distributed

SR at IP due to Halo at DESIGN collimator settings

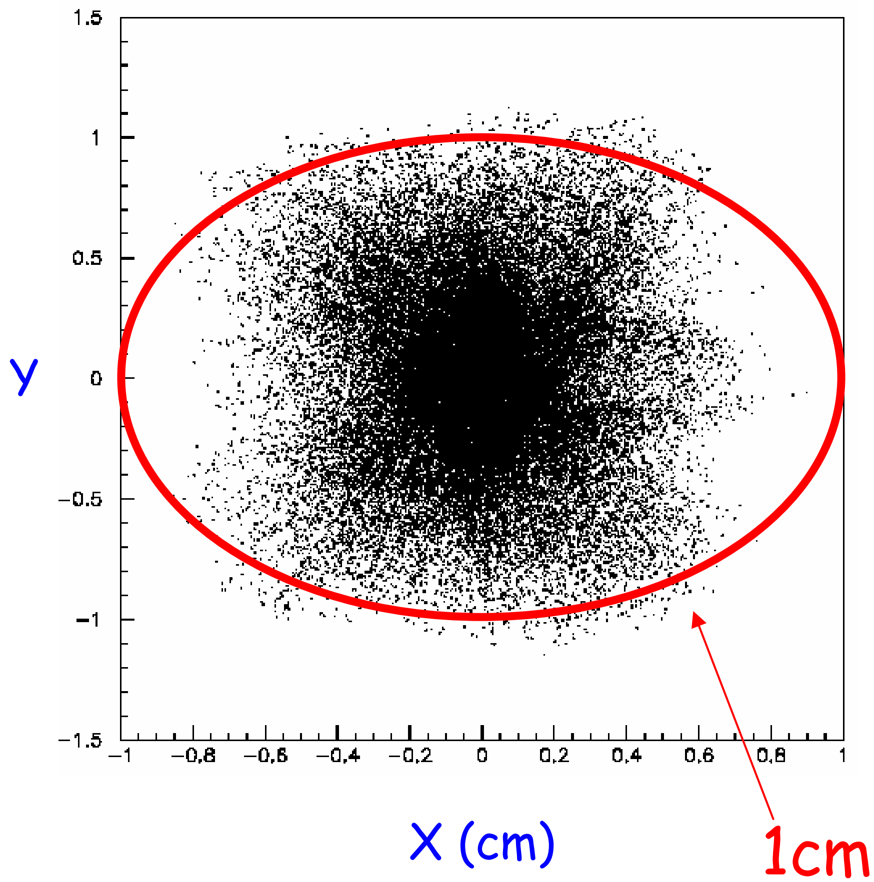


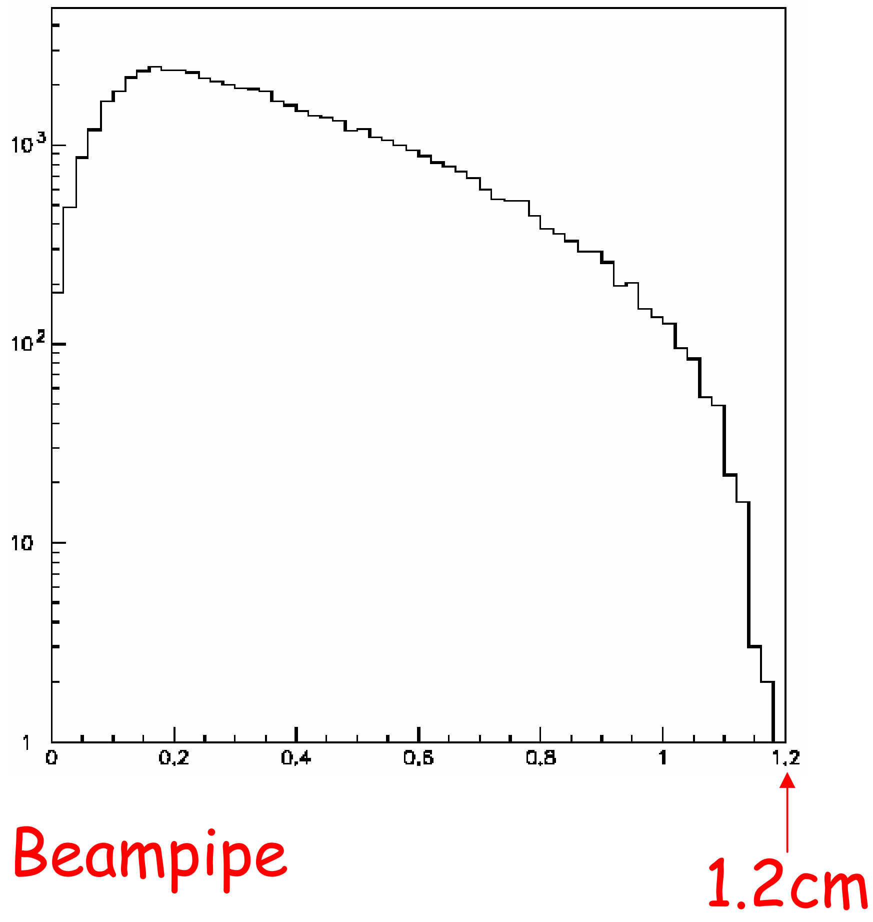




SR at z=3.15m due to Halo at DESIGN collimator settings

Set Low Z Mask aperture at 1.2cm

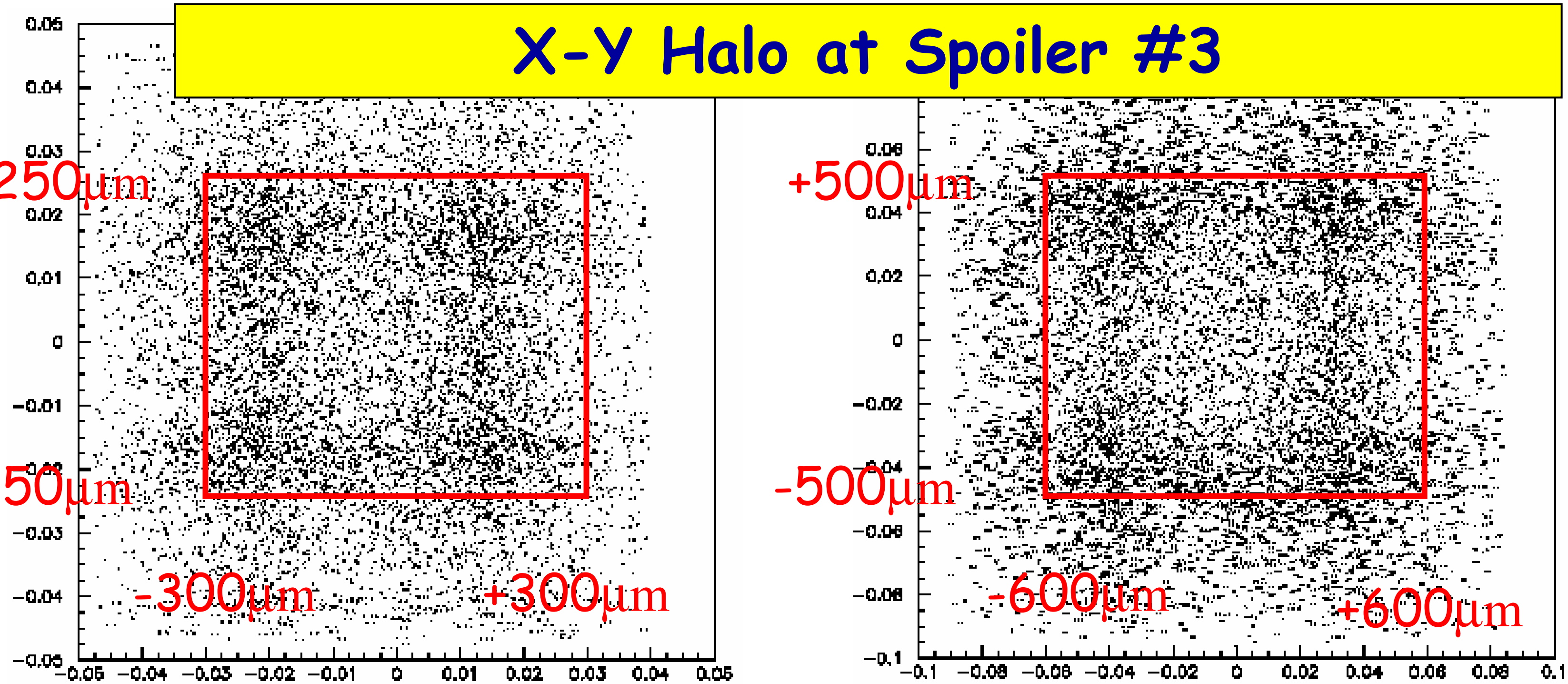




Study Non-Optimal Running Conditions

Open Collimators x2 & Broaden Halo x2 so that 10^{-5} of beam is lost on SR Dump at IP

X-Y Halo at Spoiler #3

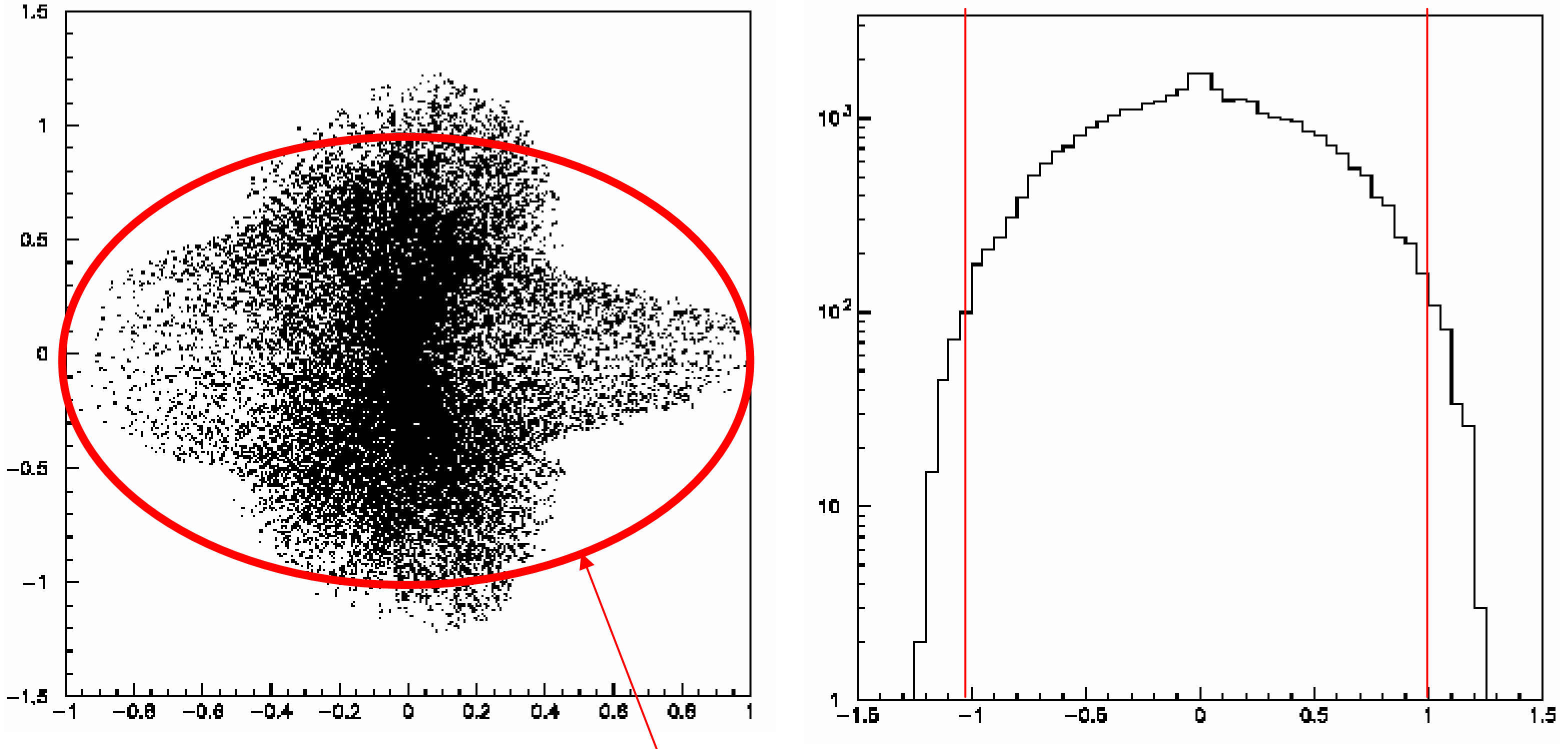


Design

$\pm 300\mu m \times \pm 250\mu m$	$\pm 600\mu m \times \pm 500\mu m$
$6\sigma_x < A_x < 16\sigma_x$	$12\sigma_x < A_x < 32\sigma_x$
$24\sigma_y < A_y < 73\sigma_y$	$48\sigma_y < A_y < 146\sigma_y$

SR at IP in "1000x worst case" Study

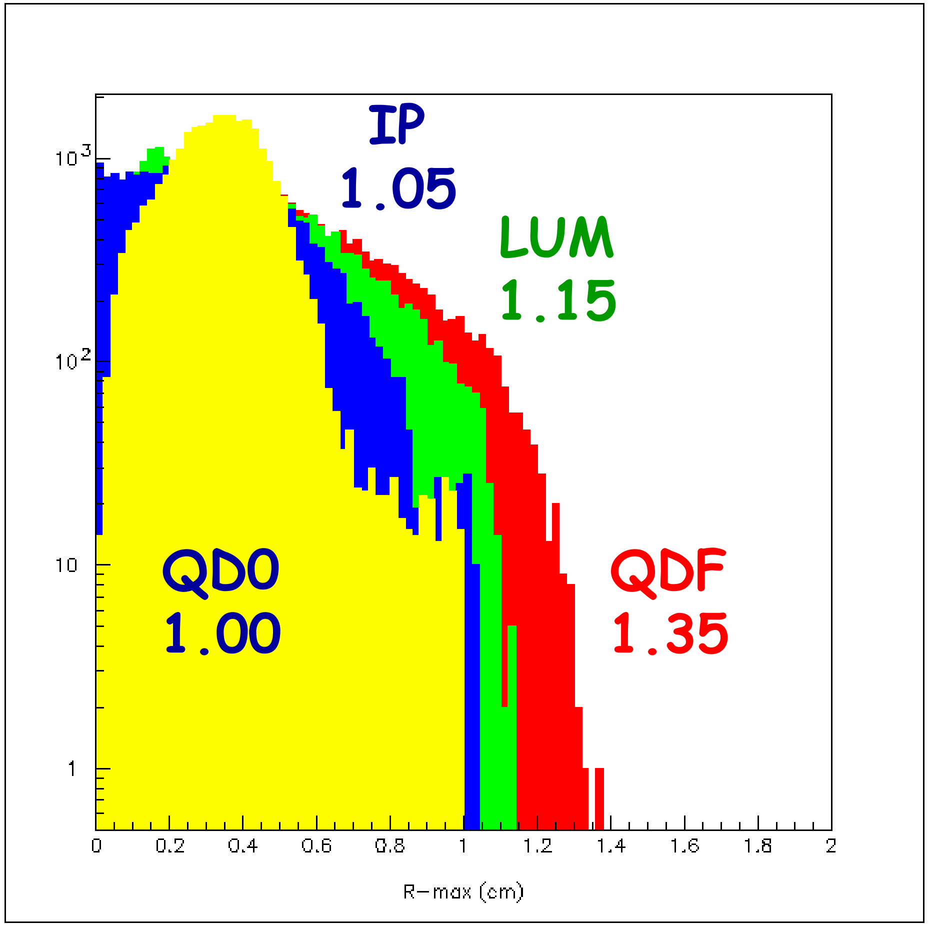
SR distribution ~2x wider in y at IP with direct hits unless BP >1.25cm



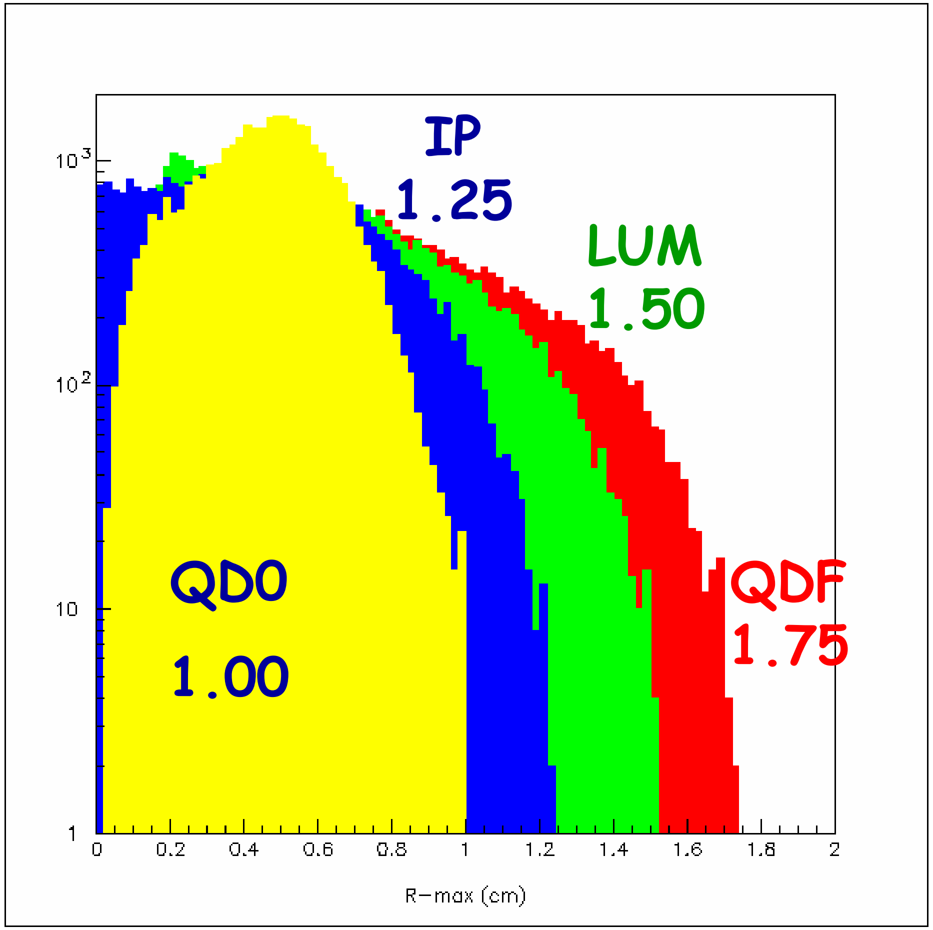
1cm Beampipe

Max Radius of SR @ z=-3.5, 0, 3.0 & 5.0 m

Nominal Collimator Gaps & ε



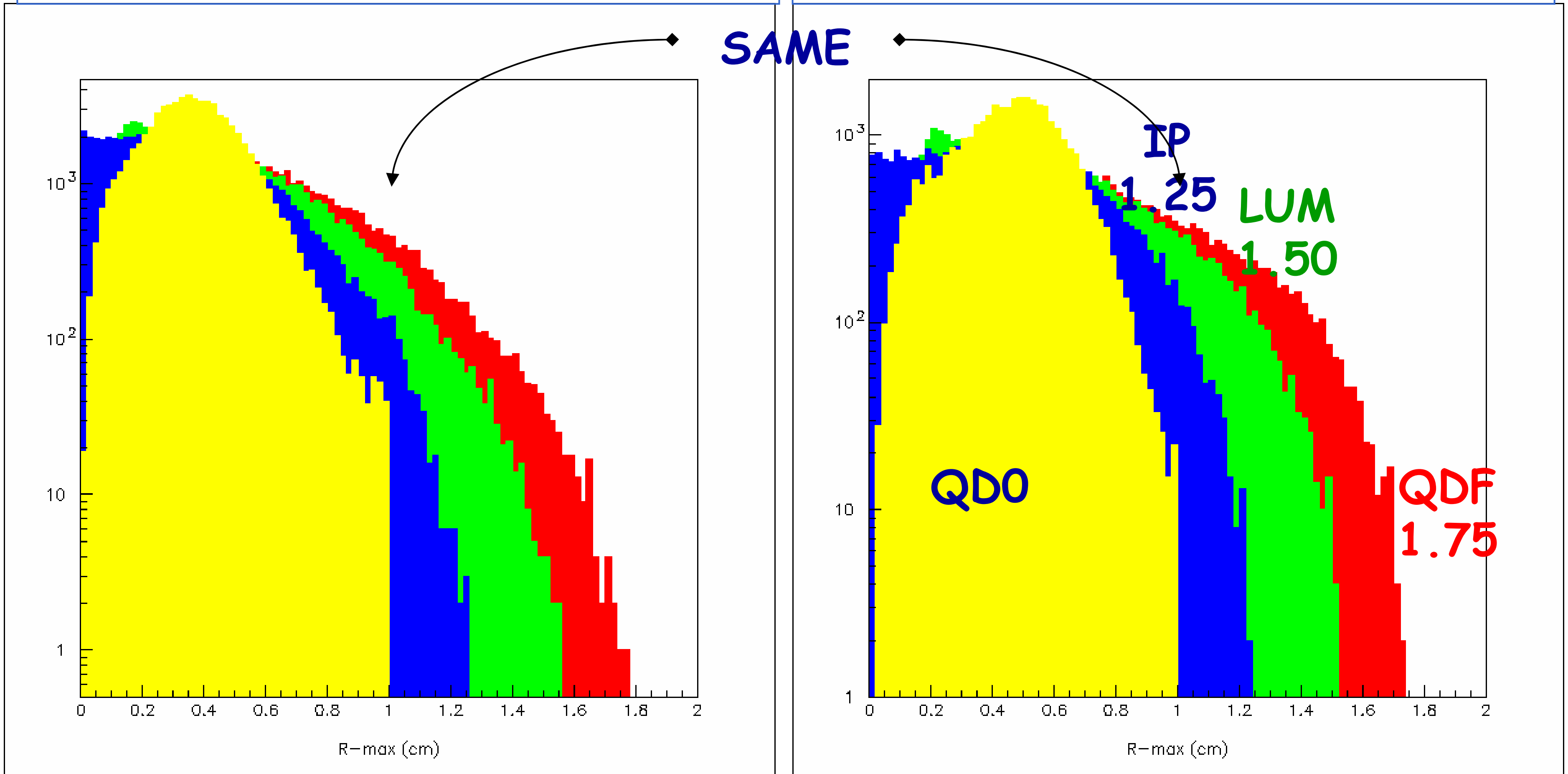
2x Nominal Collimator Gaps, 2x ε



Max R of SR @ z=-3.5, 0, 3.0 & 5.0 m

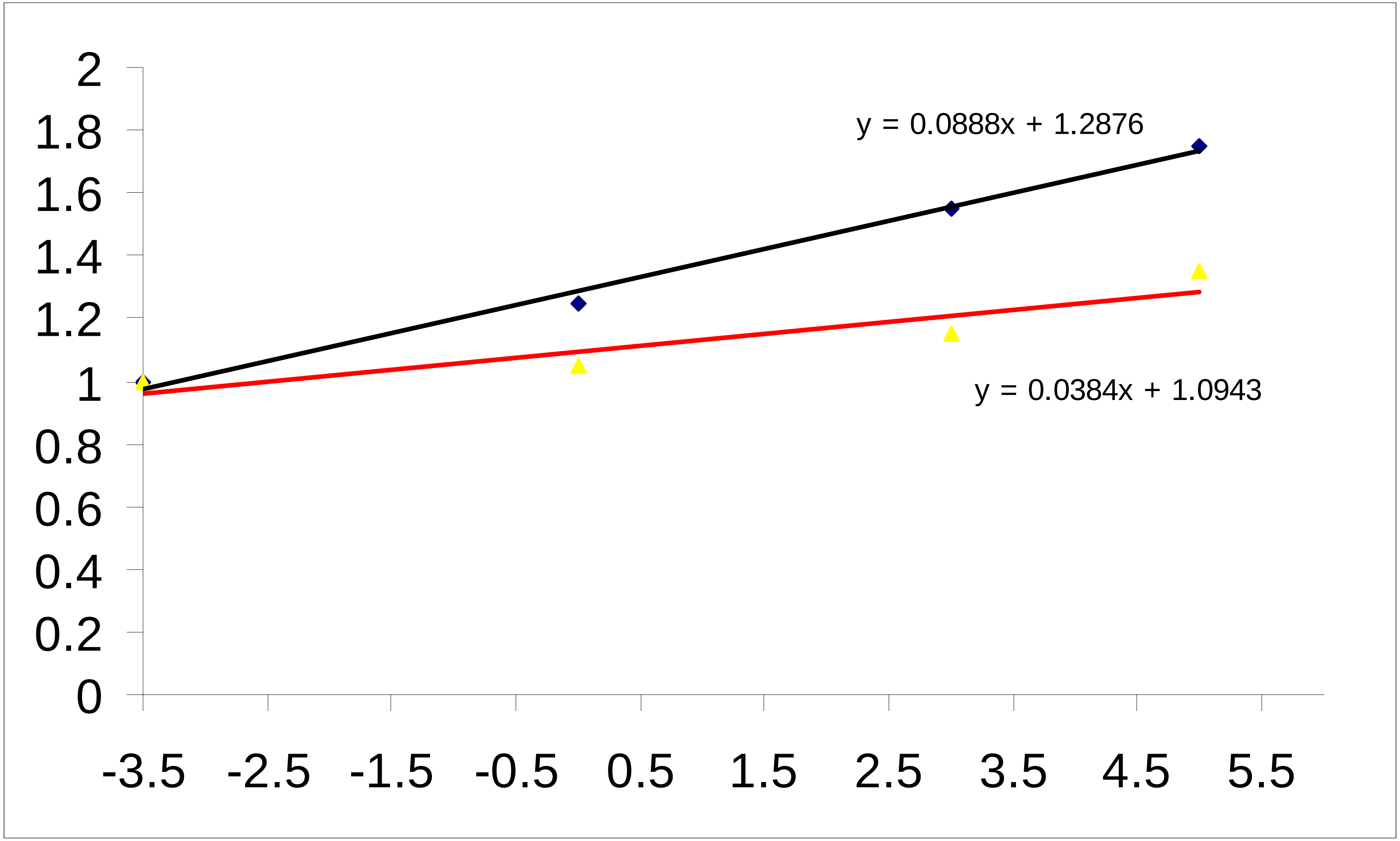
2x Nominal Collimator Gaps, 1x ε

2x Nominal Collimator Gaps, 2x ε

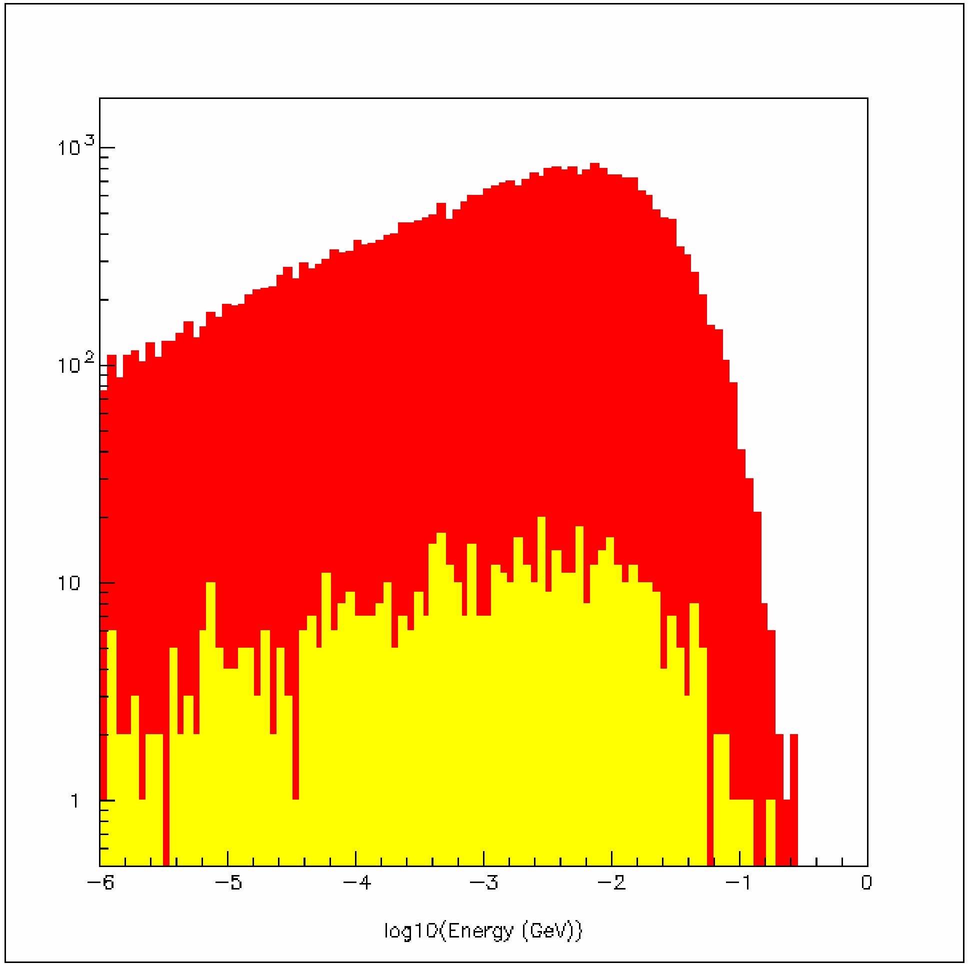


Point: If collimators ever open, regardless of halo level you will need larger apertures for safety

Increase in Minimum Aperture vs. z as Collimator Gap Doubled



SR Photon Energy at IP with x2 Gaps assuming x2 ε



825 TeV per beam at 1E-3 Halo rate

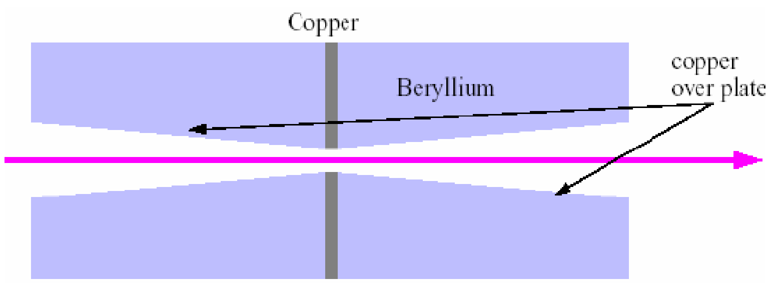
12.5 TeV per beam at r > 1.0 cm at 1E-3 Halo rate

Comparison: e+e- pairs
200 TeV per bunch
~ TeV at r > 1.0 cm

Collimator Wakefields

Jitter Amplification from Collimator Wakefields may put Luminosity at Risk if Collimator Gaps too small

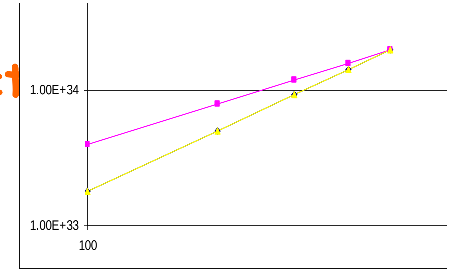
Jitter amplification in y-plane (due to y') is $(1+A_\beta^2)^{0.5}$ times



NLC spoiler is tapered to reduce wake-fields

Ab~0.7 (NLC w/Octupoles) Amp~1.22
A_b~1.3 (NLC w/o Octupoles) Amp~1.64
Ab~3 (TESLA TDR)

1) Effect scales as 1/Energy
2) NLC allows 25% of emittance dilution due to this effect
3) $A_\beta \sim \beta N / (\sigma_z^{1/2} \gamma\, gap^{3/2})$ or $A_\beta \propto \dfrac{N L_*^2}{\gamma \beta^* \sigma_z^{1/2} R_{VX}^{3/2}}$

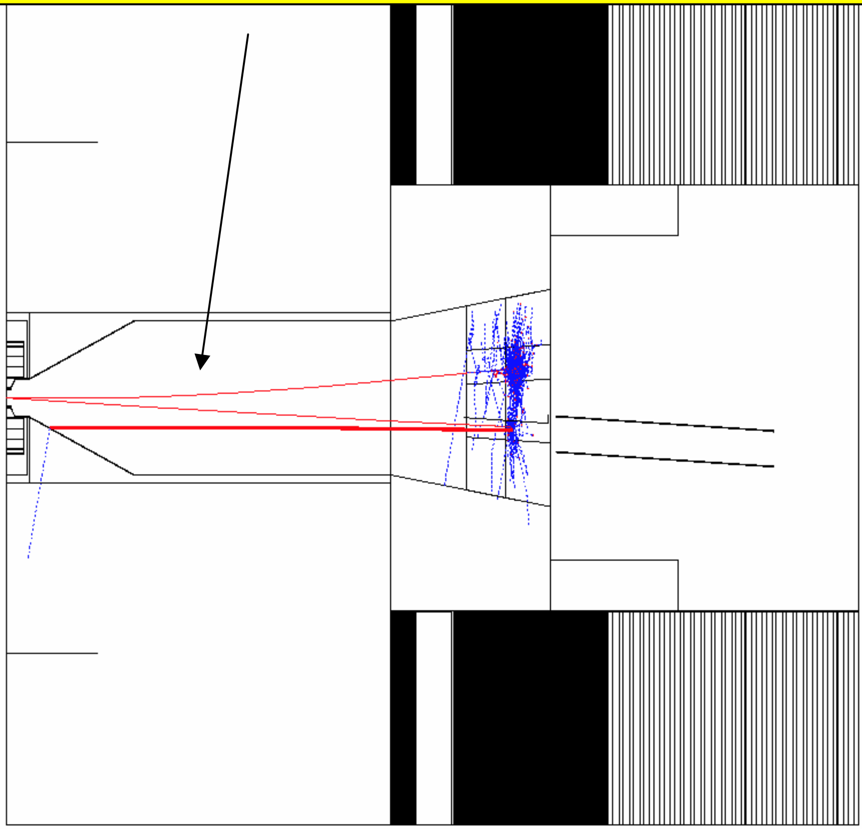


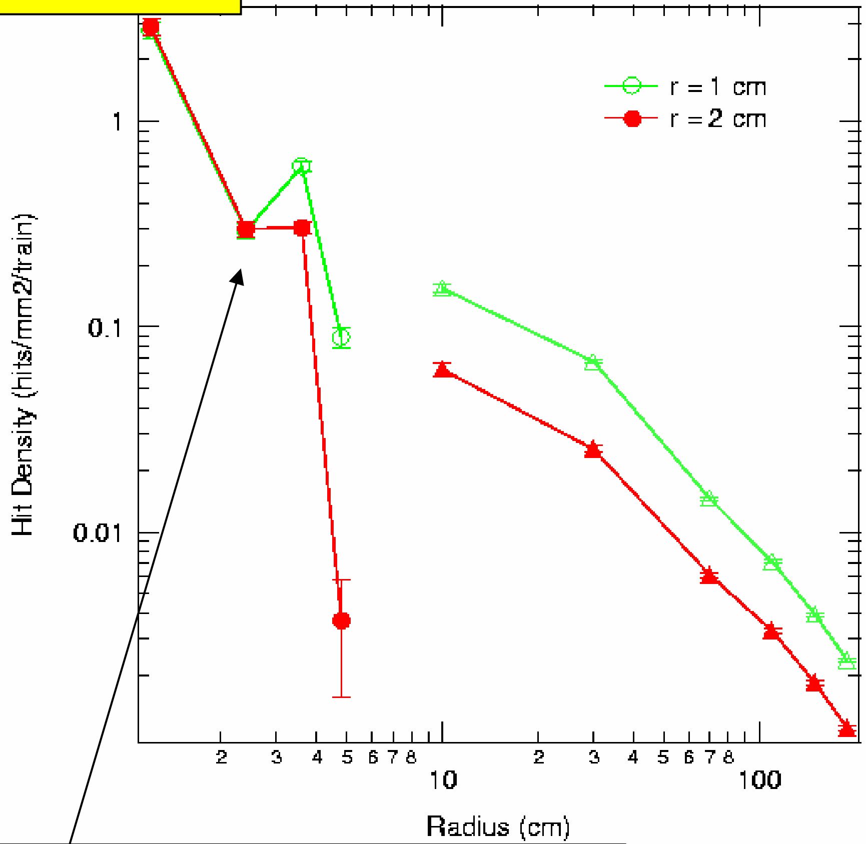
to keep A_β constant increase β as energy decreases

4) Nominal Lum at nominal E at risk if amplification too big

If LUM Aperture 1cm→2cm Hit Density r>3cm improves

Albido from pairs making hits in VXD

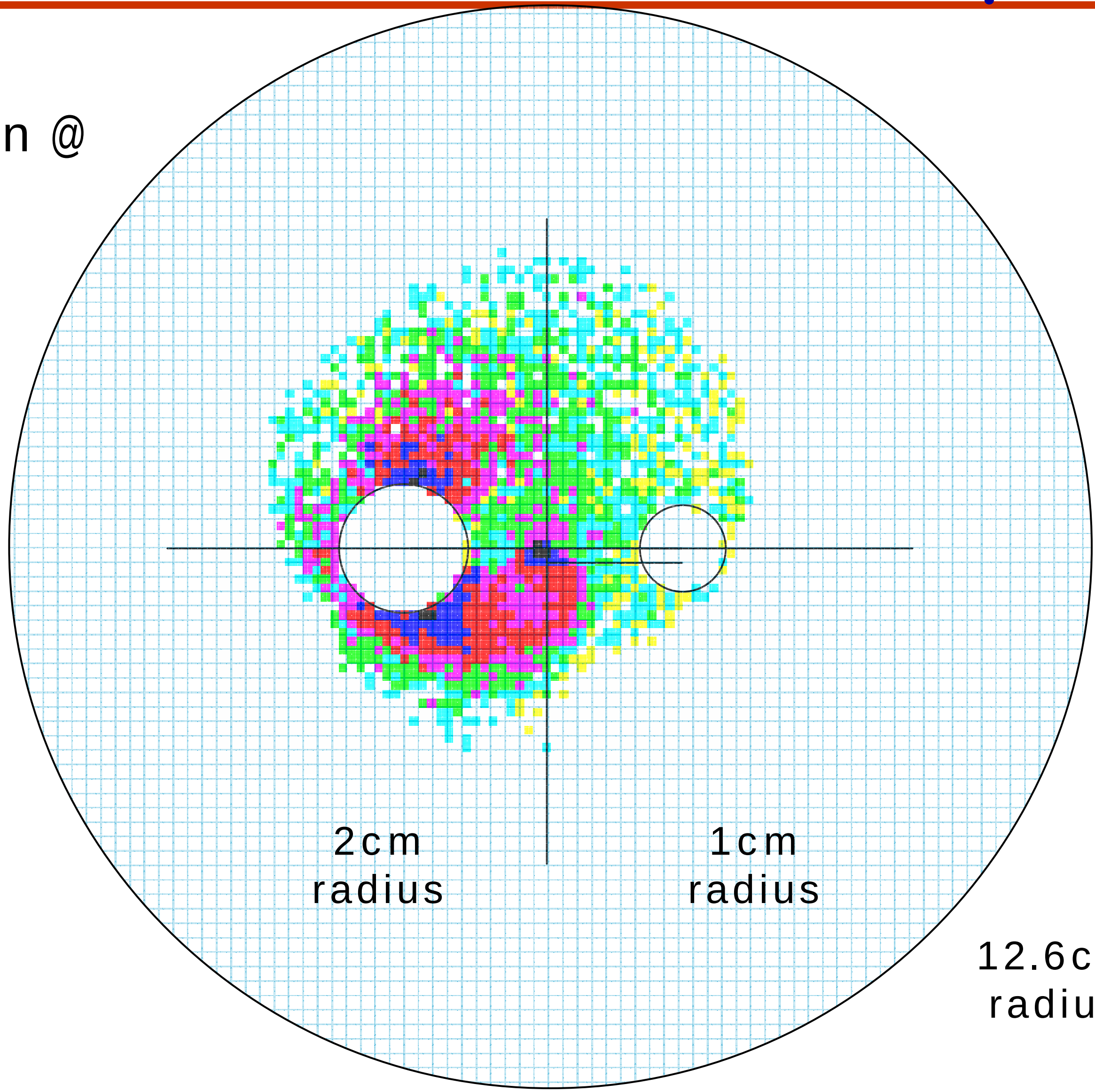




L1 & L2 of VXD Unchanged
Improvements for outer detectors

40 mrad Pair-Lum-Mon at 3.15m with 1.0/1.5cm entrance/exit apertures

SiD
Lum-PairMon @
z=3.15m



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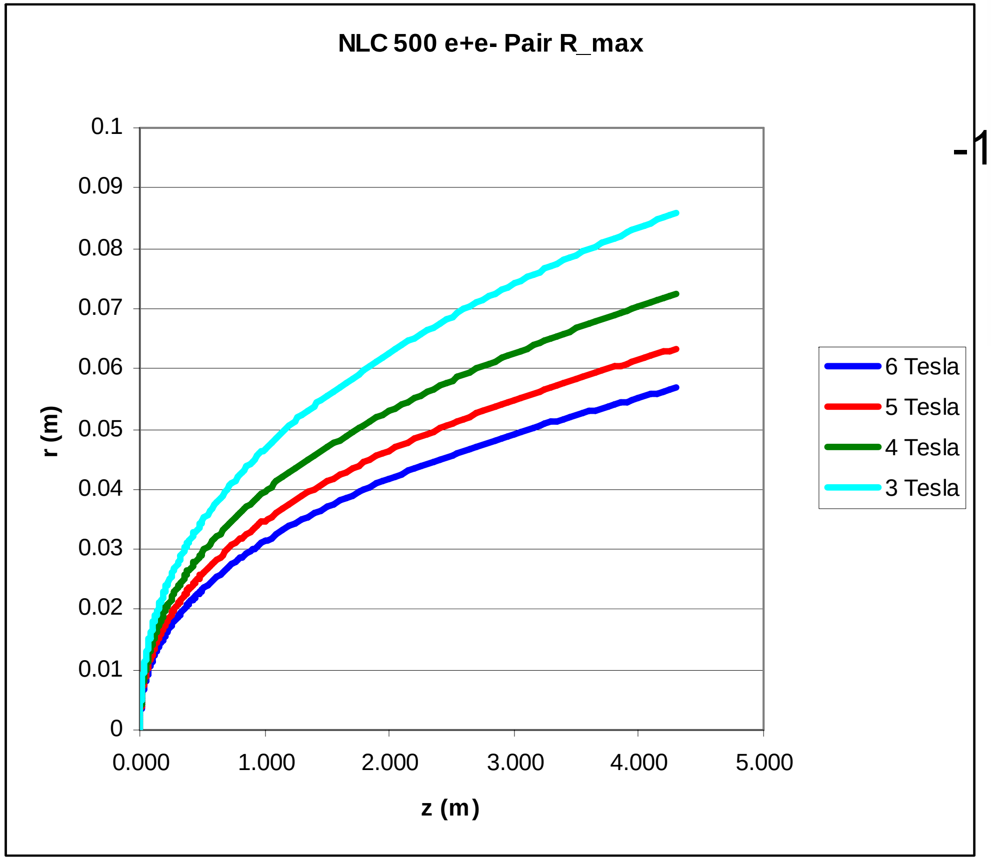
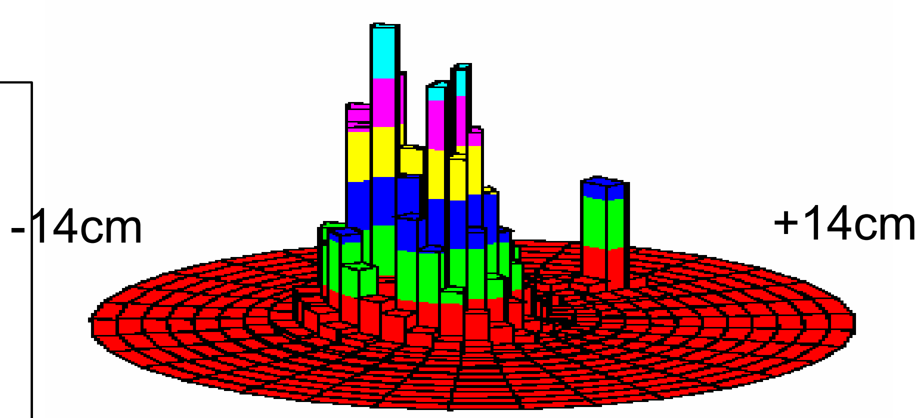
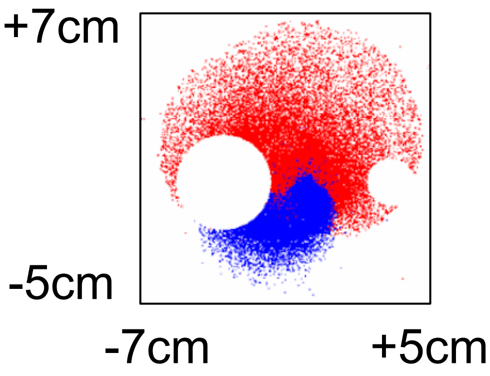
Pairs Hammer LUMON to r~6cm
Half the radius of the 40mrad detector
NOT an efficient design







Pair Energy Flow per Bunch (e+e-, 20mrad X, SC Magnets)

Detector	GeV	mW	%
QDF1-A	74909.1	276.4902	37.58%
Escape	57783.6	213.2797	28.99%
LUMON	26265.8	96.94732	13.18%
QDF1-B	11457.8	42.29085	5.75%
QDF1-C	11113.7	41.02083	5.58%
PACMAN	10342.7	38.17509	5.19%
M2	2983.87	11.01347	1.50%
QD0	2059.58	7.601915	1.03%
LOWZ	1286.89	4.749903	0.65%
SD0	555.73	2.051204	0.28%
QF1	364.764	1.346347	0.18%
M1	166.624	0.615011	0.08%
Endcap MUON	40.964	0.151198	0.02%
Instr. Mask	0.466	0.00172	0.00%
S.S. Beampipe	0.271	0.001	0.00%
Be Beampipe	0.196	0.000723	0.00%
Endcap EM	0.164	0.000605	0.00%
Endcap HAD	0.146	0.000539	0.00%
Barrel EM	0.117	0.000432	0.00%
VXD	0.08	0.000295	0.00%
TOTAL	199333	735.7383	100.00%

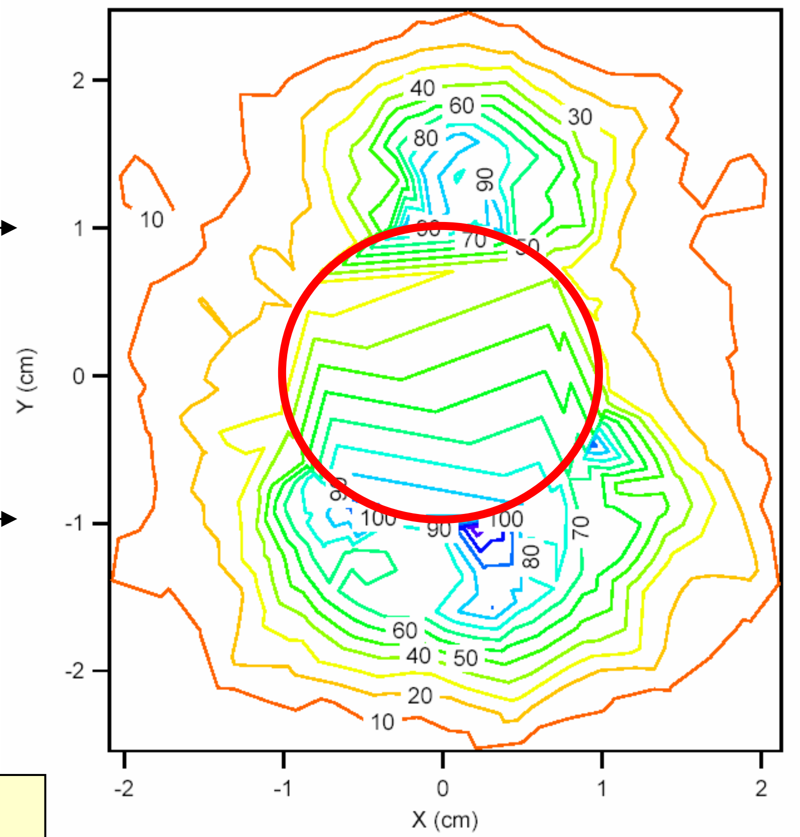
QDF1-A Detail

Detector	GeV	mW	%
QDF1-A	74909.1	276.4902	37.58%
S.S. Beampipe	14136.6	52.17827	18.87%
S.S. BP cooling	10457.6	38.5991	13.96%
S.S. Coil support	15281.3	56.40346	20.40%
Inner Coil	14939.7	55.14262	19.94%
G10 support	1249.34	4.611309	1.67%
Inner Liq. He	80.796	0.298219	0.11%
G10 Liq. He	271.492	1.002079	0.36%
S.S. Coil support	6307.23	23.28003	8.42%
Outer Coil	7275.19	26.85278	9.71%
G10 support	819.179	3.023596	1.09%
Outer Liq. He	36.84	0.135977	0.05%
G10 Liq. He	125.983	0.465004	0.17%
S.S. support	1563.19	5.76975	2.09%
Heat shield	376.997	1.391499	0.50%
Cryostat shell	1987.66	7.336473	2.65%

Maximum Dose Rate at QDF1 in MRad/10^7 sec

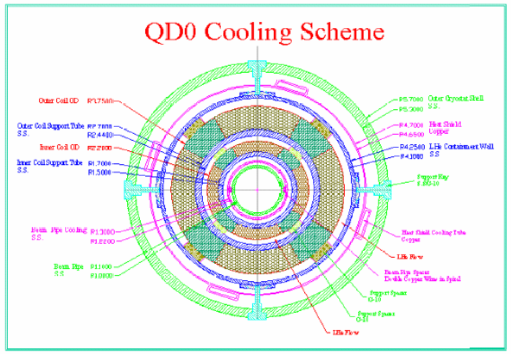
Max. DOSE rate ~100 MRad/year

QDF1 2cm aperture

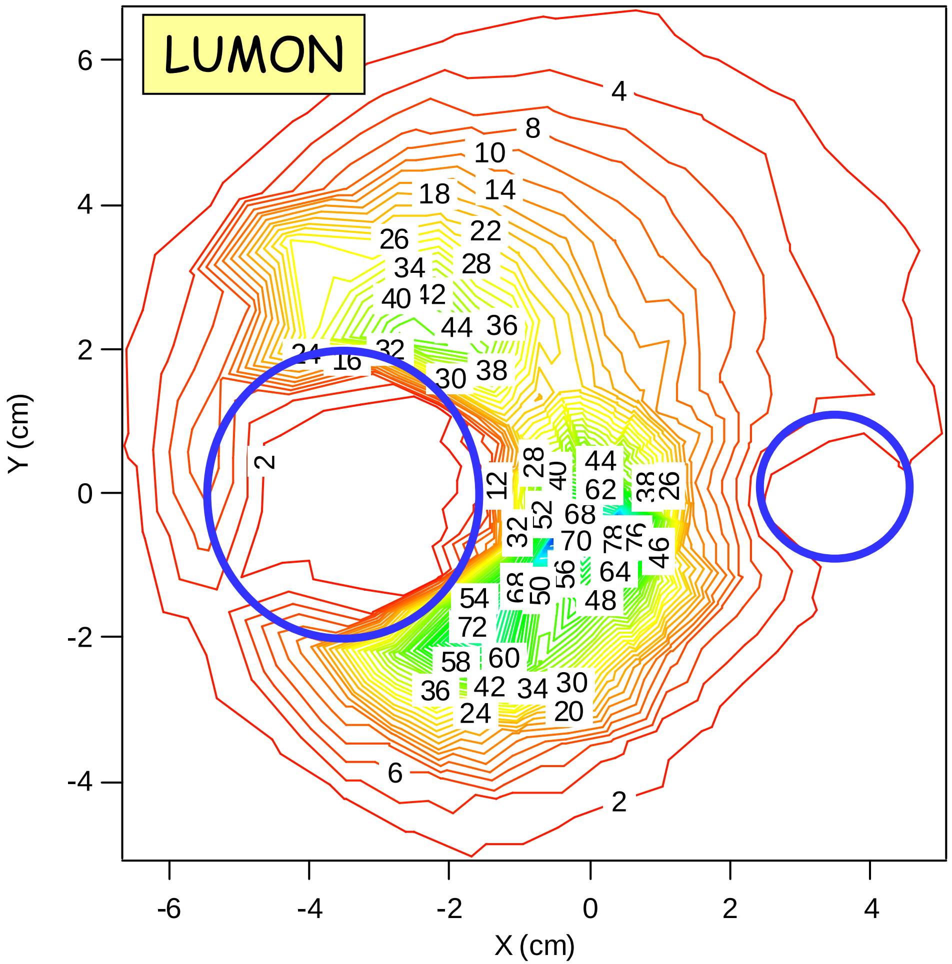


Field sweeps e+e- pairs UP and DOWN

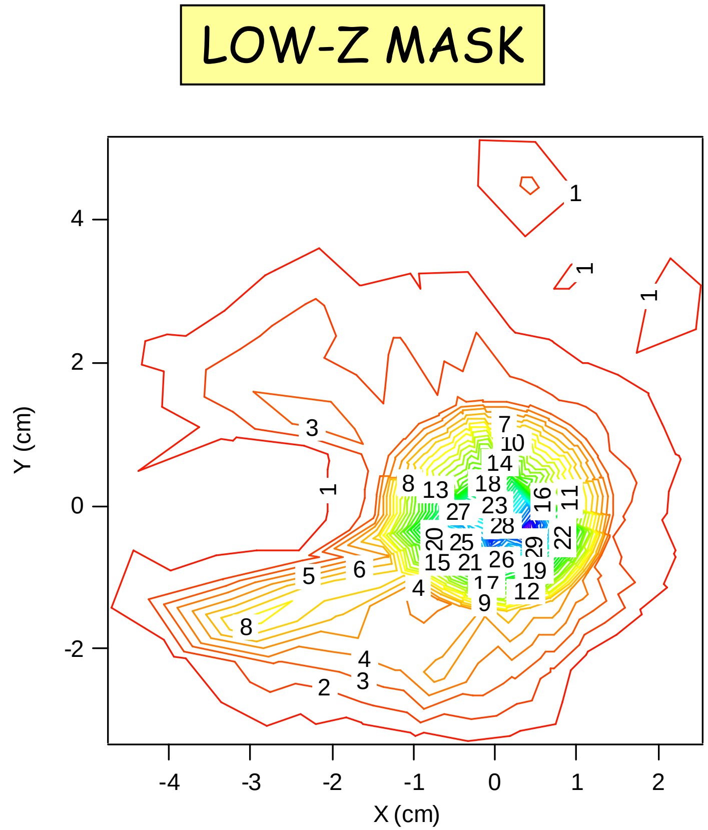
QDF1 examined in 7.5° ϕ, 2 cm z cells; maximum dose plotted



Max. DOSE Rate in LUMON and LOW-Z



Max. DOSE rate ~70 Mrad/year



Max. DOSE rate ~30 Mrad/year

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Conclusions

- Have not really spoken to
  - fact that crossing angle opens up the extraction line & its instrumentation
  - constraints due to detector access and final quadrupole support
- I have urged that a small loss of acceptance in the <25 mrad region
  - Allows for more freedom in extracting damaging SR and e+e- pairs
  - is a reasonable price to pay for clean extraction
    - "Hold the line" on VXD radius as long as possible
    - Acceptance "hole" is physically small & in a very ugly area of detector
    - Pair/lumon detector region should be minimized from 40 to ~25 mrad
- There is still freedom to optimize L*, theta, L* extraction
- From the "Detector survival point of view" crossing angle is only as important as aperture: 70Mrad/year damage
- Extraction quad magnet heating and radiation dose issues more a function of aperture than crossing angle
- Need to understand if 7 mrad JLC crossing angle is OK from jitter
- Need to understand is there really is an issue to "crab" ±10 deg.
  - If so, IR2, promised by Spec. document, is in trouble