IR SR Update with a PEP-II Perspective

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Outline

- **Introduction**
- **Upstream SR**
  - **Nominal settings**
  - **Upstream SR backscattering from dump line apertures**
  - **Mask setting where SR starts to hit the inner chambers**
- **Downstream SR from the dump line**
  - **Model 3 different beam energies**
    - **250 GeV (optics set to this value from the lattice)**
    - **225 GeV (Above optics scaled to this energy 90% of nom.)**
    - **200 GeV (Above optics scaled to this energy 80% of nom.)**
  - **Get rates for photons striking downstream surfaces**
  - **Compute backscatter rate to the detector beam pipe and cryostats**
- **Summary and Conclusions**

Introduction

- **Started this study in order to become more familiar with the IR design**
  - **A lot of people have looked at this already**
  - **Another cross-check never hurts**
- **An important consideration is that the machine WILL NOT perform at design values either when the accelerator starts up nor when the first detector rolls online**
- **Yet the detectors will want to start taking data as soon as possible after startup AND they need to know when the machine settings (masks, coll., etc.) can damage subsystems**

Intro (2)

- **Both B-factories had a preliminary minimal detector in place before the main detector rolled onto the beam line in order to see what the radiation levels were from the machine**
  - **I'm sure this has been considered here**

- **In addition, simulation of the non-optimal machine can guide thinking about how to handle early machine conditions**

IP parameters

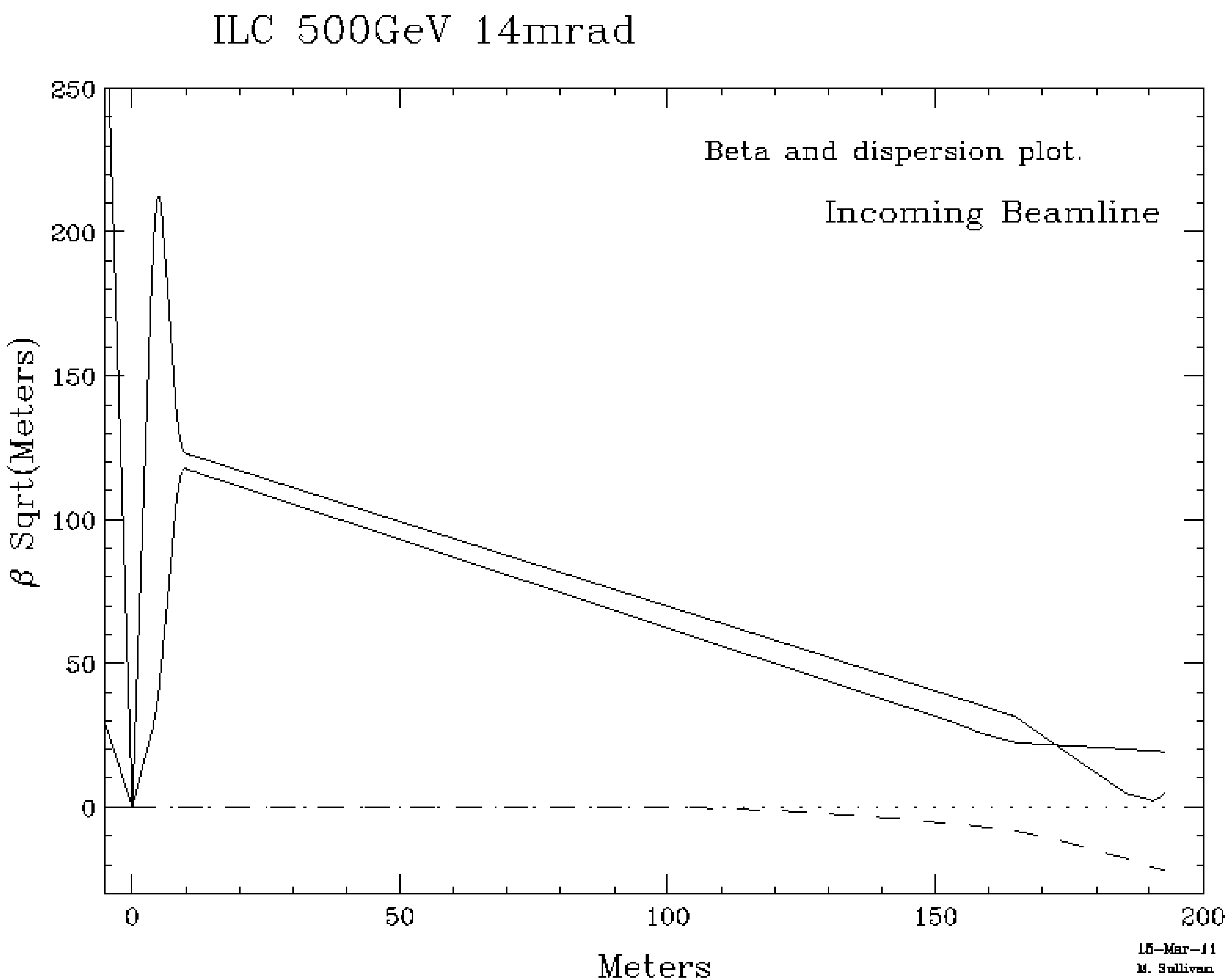
IP and General Parameters							
							upgrade
Centre-of-mass energy	E_{cm}	**GeV**	**200**	**250**	**350**	**500**	**1000**
Beam energy	E_{beam}	GeV	100	125	175	250	500
Lorentz factor	γ		1.96E+05	2.45E+05	3.42E+05	4.89E+05	9.78E+05
Collision rate	f_{rep}	Hz	5	5	5	5	4
Electron linac rate	f_{linac}	Hz	10	10	5	5	4
Number of bunches	n_b		1312	1312	1312	1312	2625
Electron bunch population	N_-	$\times 10^{10}$	2	2	2	2	2
Positron bunch population	N_+	$\times 10^{10}$	2	2	2	2	2
Bunch seperation	Δt_b	ns	740	740	740	740	356
Bunch seperation $\times f_{RF}$	$\Delta t_b f_{RF}$		962	962	962	962	463
Pulse current	I_{beam}	mA	4.33	4.33	4.33	4.33	9.00
RMS bunch length	σ_z	mm	0.3	0.3	0.3	0.3	0.3
Electron RMS energy spread	$\Delta p/p$	%	0.22	0.22	0.22	0.21	0.11
Positron RMS energy spread	$\Delta p/p$	%	0.17	0.14	0.10	0.07	0.04
Electron polarisation	P_-	%	80	80	80	80	80
Positron polarisation	P_+	%	31	31	29	22	22
Horizontal emittance (linac exit)	$\gamma\varepsilon_x$	µm	10	10	10	10	10
Vertical emittance (linac exit)	$\gamma\varepsilon_y$	nm	35	35	35	35	35
IP horizontal beta function	β_x^*	mm	16	12	15	11	30
IP vertical beta function (no TF)	β_y^*	mm	0.48	0.48	0.48	0.48	0.30
IP vertical beta function (TF)	β_y^*	mm	0.2	0.2	0.2	0.2	0.2

IP parameters

		IP RMS horizontal beam size	σ_x *	nm	904	700	662	474		554	
		IP RMS veritcal beam size (no TF)	σ_y *	nm	9.3	8.3	7.0	5.9		3.3	
		IP RMS veritcal beam size (TF)	σ_y *	nm	6.0	5.3	4.5	3.8		2.7	
No TF		Horizontal distruption parameter	D_x		0.2	0.3	0.2	0.3		0.1	
		Vertical disruption parameter	D_y		20.7	23.8	21.3	24.9		19.2	
		Horizontal enhancement factor	H_{Dx}		1.1	1.1	1.1	1.2		1.0	
		Vertical enhancement factor	H_{Dy}		5.7	6.0	5.8	6.1		3.6	
		Total enhancement factor	H_D		1.8	1.9	1.8	2.0		1.5	
		Geometric luminosity	L_{geom}	$\times 10^{34}$ $cm^{-2}s^{-1}$	0.2	0.4	0.5	0.8		1.8	
		Luminosity	L	$\times 10^{34}$ $cm^{-2}s^{-2}$	**0.5**	**0.7**	**0.8**	**1.5**		**2.8**	
		Fraction of luminosity in top 1%	$L_{0.01}/L$			0.96	0.88	0.73			
		Average beamstrahlung parameter	Υ_{av}		0.013	0.021	0.032	0.063		0.109	
		Maximum beamstrahlung parameter	Υ_{max}		0.032	0.051	0.075	0.150		0.260	
		Average number of photons / particl	n_γ		0.96	1.22	1.28	1.74		1.46	
		Average energy loss	δE_{BS}	%	0.53	1.04	1.55	3.76		4.83	
		Number of pairs per bunch crossing	N_{pair}	$\times 10^3$		97.4	214	494			
With TF		**Luminosity**	L	$\times 10^{34}$ $cm^{-2}s^{-2}$	**0.5**	**0.8**	**1.0**	**2.0**			
		Average energy loss	δE_{BS}	%		0.6	1.6	3.6			
		Number of pairs per bunch crossing	N_{pair}	$\times 10^3$		115	255	596			
		Fraction of luminosity in top 1%	$L_{0.01}/L$			0.89	0.77	0.72			

Upstream

- **Description**
  - Beta functions
  - IR Beam pipe
  - 11 m mask
- **Three cases with different mask settings and beam profiles**
- **Upstream radiation hitting downstream pipes/septums/coll., etc.**
  - Backscatter rates
  - Hit rates on detector beam pipe for various cases


ILC 500GeV 14mrad
Beta and dispersion plot.
Incoming Beamline
β Sqrt(Meters)
$D_{x,y}$ × 1000 (Meters)
Meters
0
50
100
150
200
250
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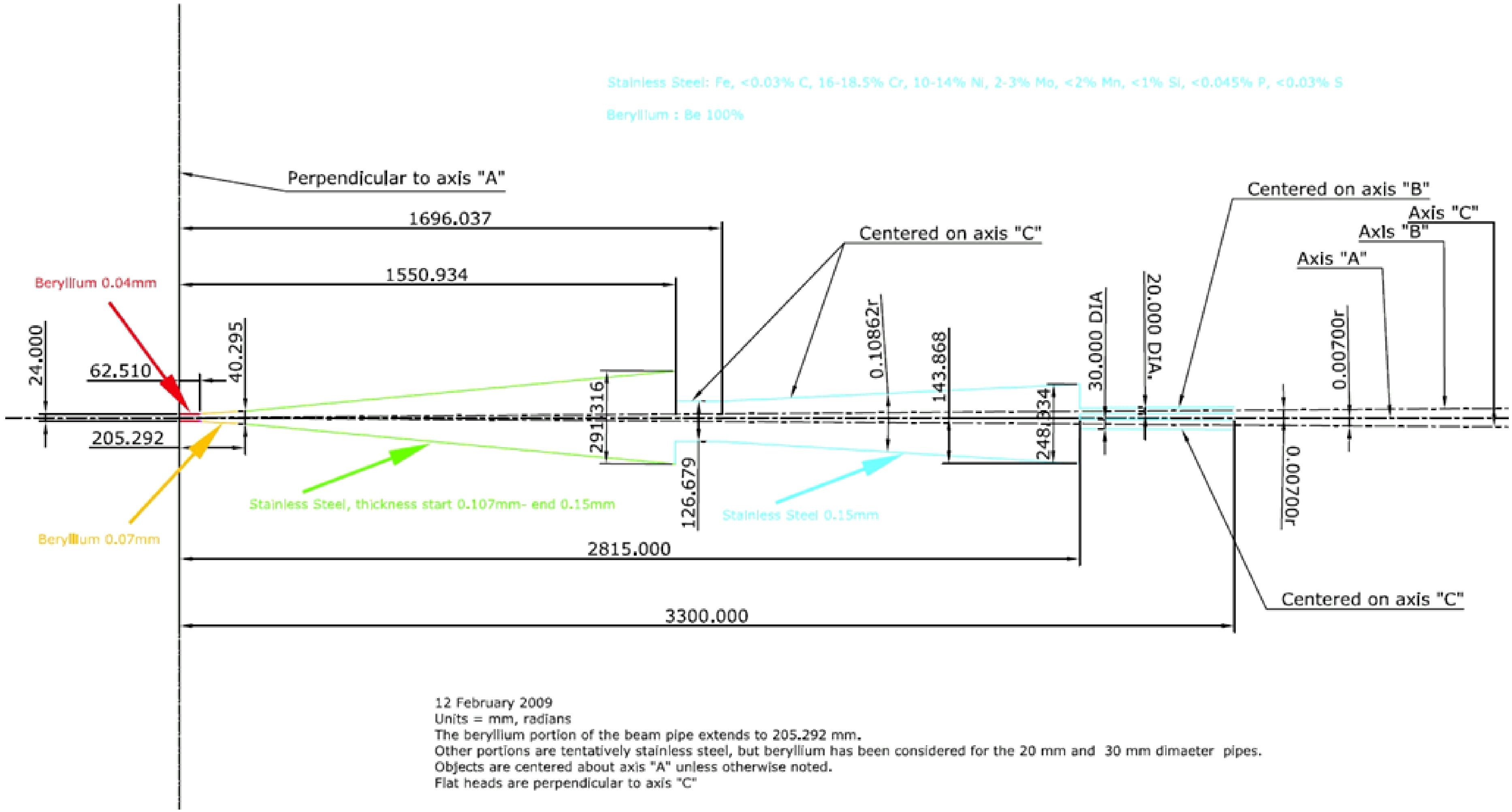
IP Beam pipe



Stainless Steel: Fe, <0.03% C, 16-18.5% Cr, 10-14% Ni, 2-3% Mo, <2% Mn, <1% Si, <0.045% P, <0.03% S
Beryllium : Be 100%
Perpendicular to axis "A"
1696.037
1550.934
Centered on axis "C"
Centered on axis "B"
Axis "C"
Axis "B"
Axis "A"
Beryllium 0.04mm
24.000
62.510
40.295
205.292
291.316
126.679
0.10862r
143.868
248.334
30.000 DIA
20.000 DIA.
0.00700r
0.00700r
Stainless Steel, thickness start 0.107mm- end 0.15mm
Stainless Steel 0.15mm
Beryllium 0.07mm
2815.000
3300.000
Centered on axis "C"
12 February 2009
Units = mm, radians
The beryllium portion of the beam pipe extends to 205.292 mm.
Other portions are tentatively stainless steel, but beryllium has been considered for the 20 mm and 30 mm dimaeter pipes.
Objects are centered about axis "A" unless otherwise noted.
Flat heads are perpendicular to axis "C"

SR upstream rates

- Have run three cases with the mask at 11.15 m from the IP at various settings
  - Case 1 (nominal design)
    - Mask nominal (2.5 mm radius) (~5σ_x)
    - Beam profile -- design gaussian (no tails)
    - Beam scan out to 5σ_x 50σ_y
  - Results
    - No direct hits on the detector beam pipe
    - No direct hits on downstream septum

SR rates

- Case 2
  - Mask opened to a 5 mm radius (~10σ_x)
  - Beam profile -- design gaussian (no tails)
  - Beam scan out to 10σ_x 50σ_y
- Results
  - Direct hits on the upstream cryostats (>6σ_x)
    - Power level very small and photon rate (10^{-3}/bunch)
  - No direct hits on the detector beam pipe
  - Direct hits on downstream septum (2.8m, >8σ_x)
    - Rate too small to worry about with design gaussian beam profile

SR rates

- Case 3
  - Mask opened (r = 5 mm, ala case 2) (~10σ_x)
  - Beam profile design gaussian but with tails (~0.5% 4-12σ)
  - Beam scan out to 10σ_x 50σ_y
- Results (same as case 2 but higher numbers)
  - Direct hits on the upstream cryostats (>6σ_x)
    - Power level low (3×10^{-4}W) and photon rate 10^4/bunch (possible outgassing)
  - No direct hits on the detector beam pipe
  - Direct hits on downstream septum (2.8m, >8σ_x)
    - Rate 2.5×10^5/bunch → 5×10^3 backscatter → Inc. on central BP= 0.08/bunch

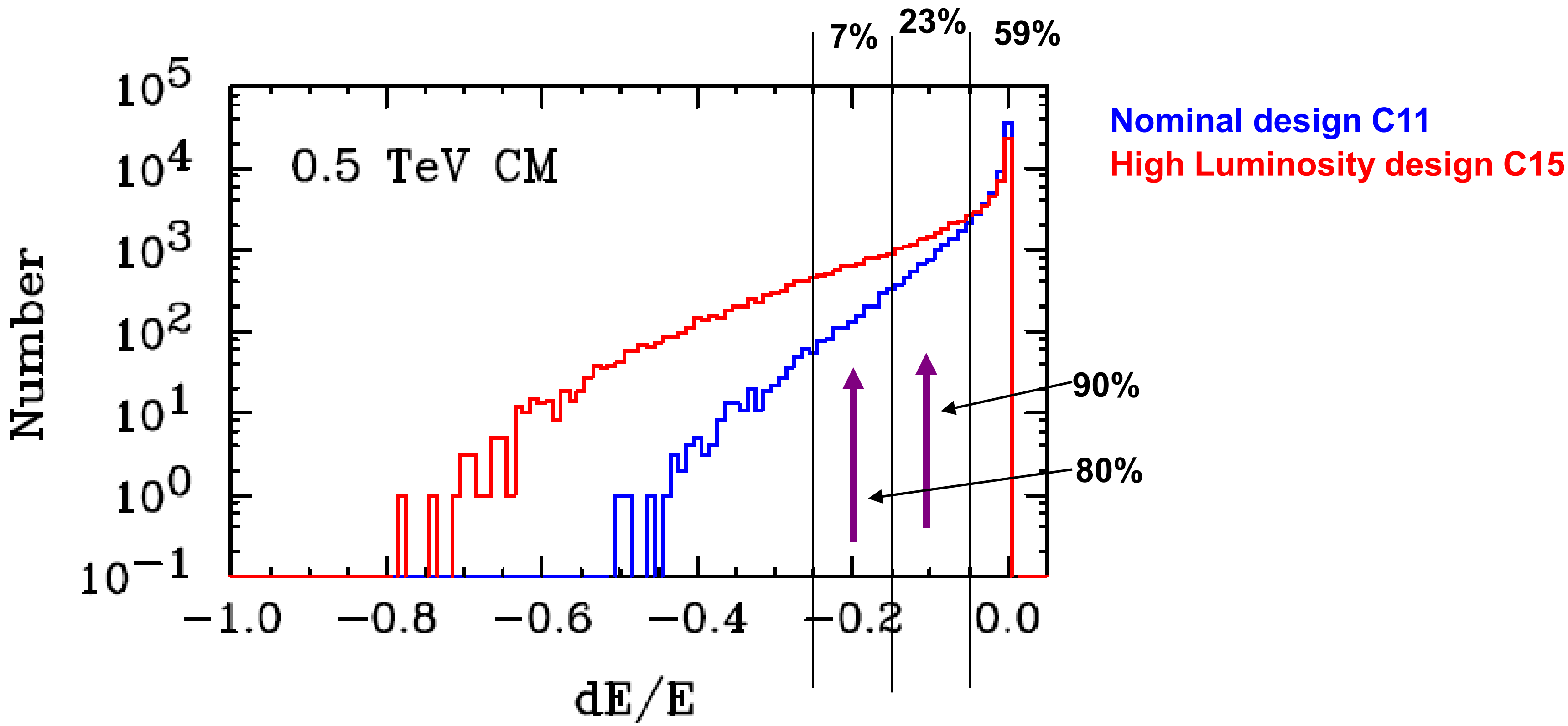
Upstream SR Summary

- Nominal case (mask radius 2.5 mm)
  - OK
- Opening up the mask to 5 mm radius
  - Some direct hits on upstream cryostats and on downstream septum. Levels very low with design gaussian beam profile. 6-8σ_x.
- Mask at 5 mm radius + non-gaussian tails
  - Power levels and photon rates increase as the beam tail particle density increases. With 0.5% in the tails photon rate may cause outgassing on cryo beam pipe
- No direct hits on IP beam pipe with mask out to 10 mm radius

Downstream

- Downstream SR generation
  - There has been a study of the SR photon rates for various surfaces on the dump line apertures “ILC BDS Collimation System Performance and extraction beam lines simulations”, Drozhdin, Yang, 2006. I have not had a chance to fully study this work.
- Energy distribution for disrupted beam
- Beta functions at 90% and 80% of 250 GeV
- Magnet apertures
- SR hits and power results
- SR backscatter and hit rate on detector beam pipe and cryostats

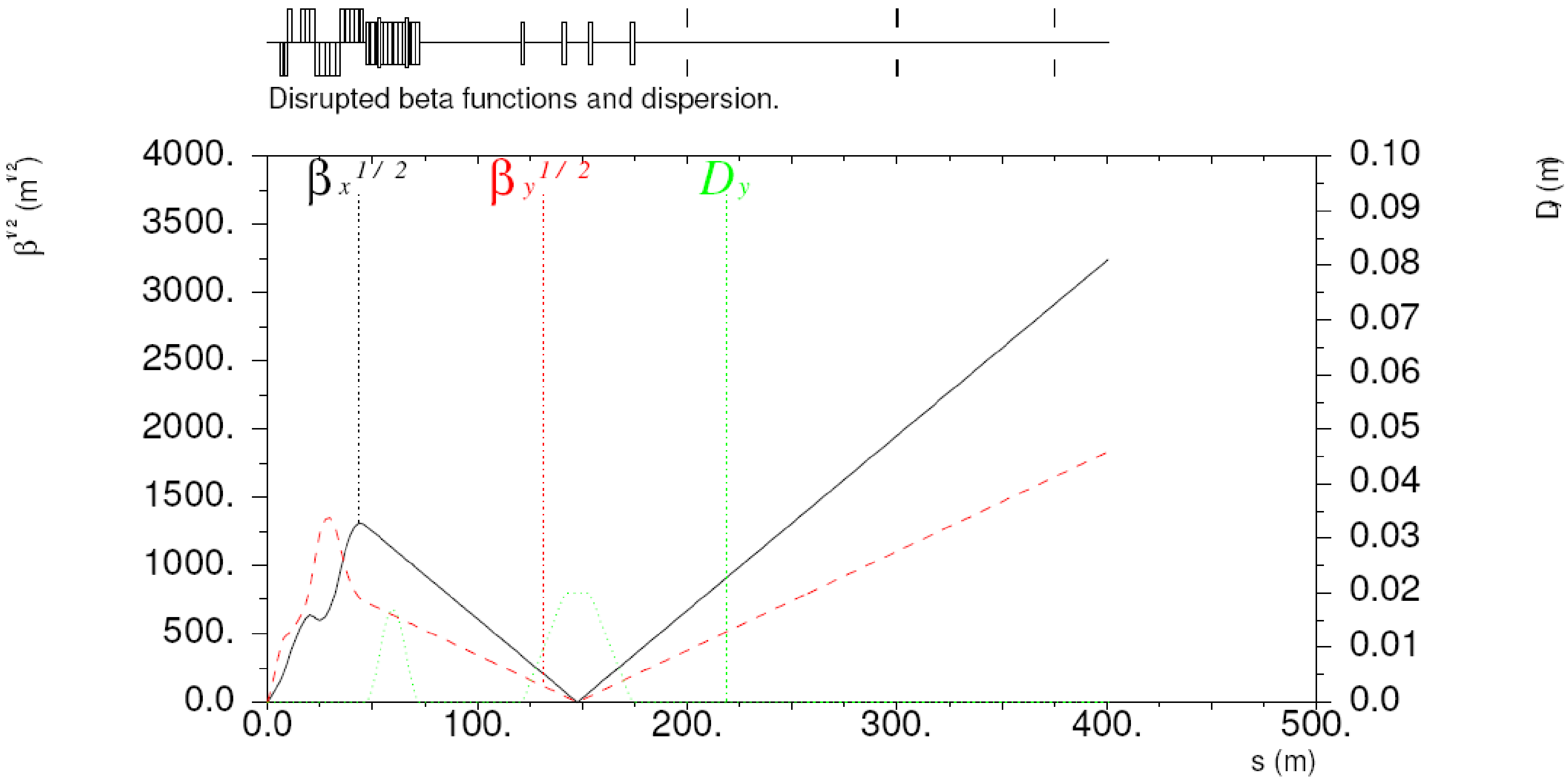
Beam Energy Distribution



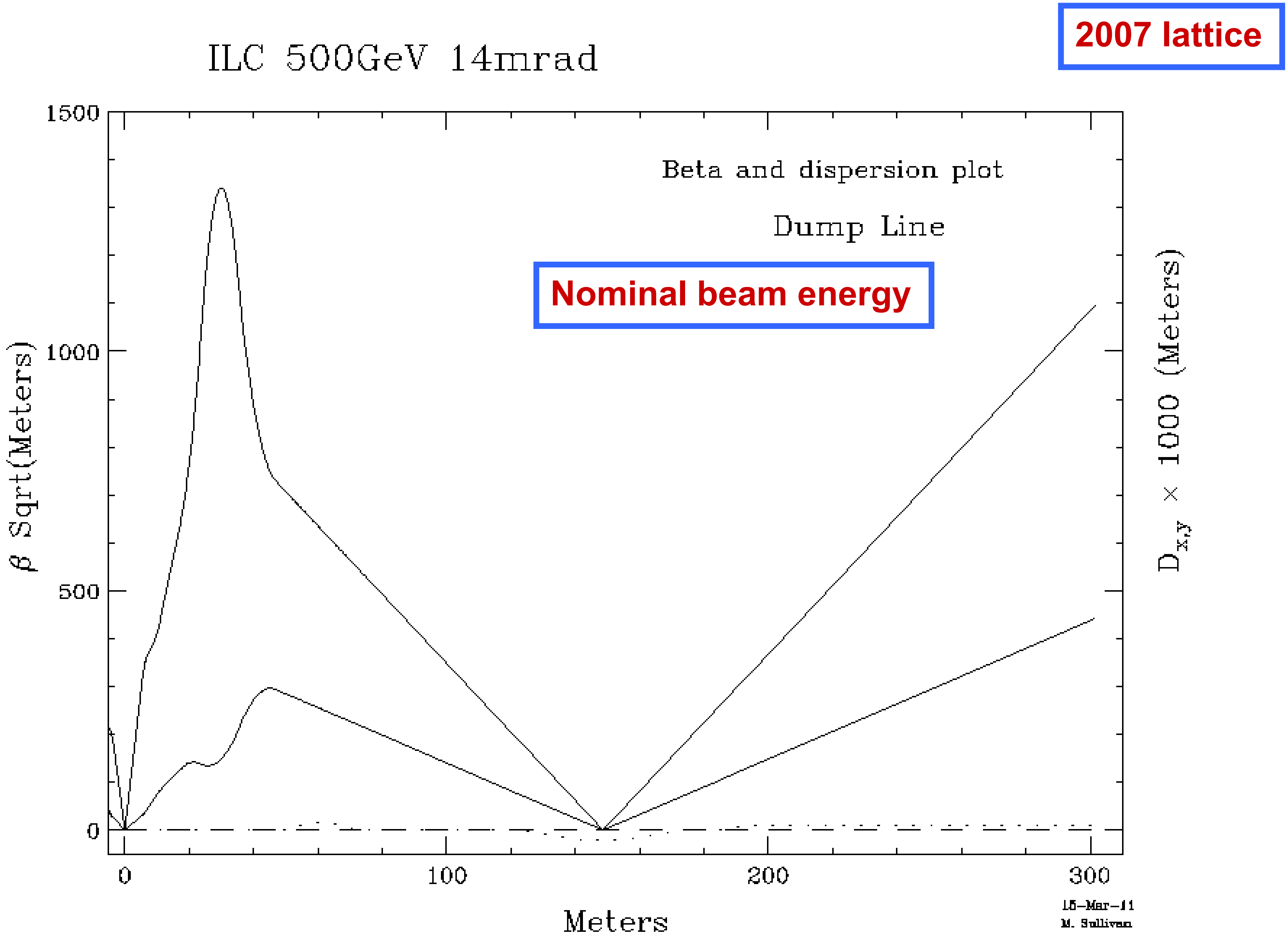
Beam energy distribution going into the dump line

From SLAC-PUB-1159, Nosochkov, *et. al*., "ILC Extraction Line for 14 mrad Crossing Angle", 2005

Beta functions



Dump Line beta functions from 2005 paper


2007 lattice
ILC 500GeV 14mrad
Beta and dispersion plot
Dump Line
Nominal beam energy
1500
1000
500
0
0
100
200
300
Meters
β Sqrt(Meters)
$D_{x,y}$ × 1000 (Meters)
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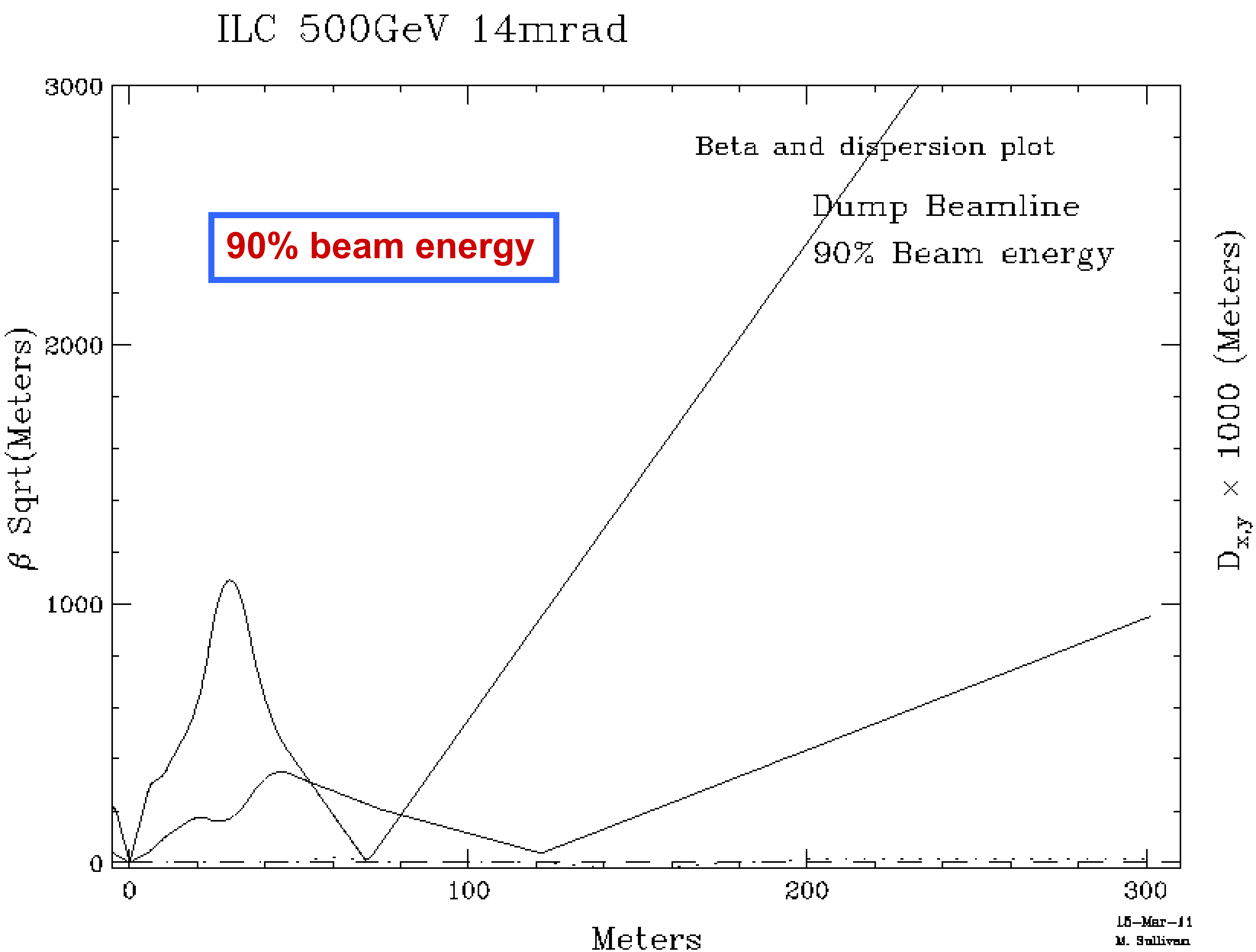
ILC 500GeV 14mrad
3000
2000
1000
0
Beta and dispersion plot
Dump Beamline
90% Beam energy
90% beam energy
β Sqrt(Meters)
$D_{x,y}$ × 1000 (Meters)
0
100
200
300
Meters
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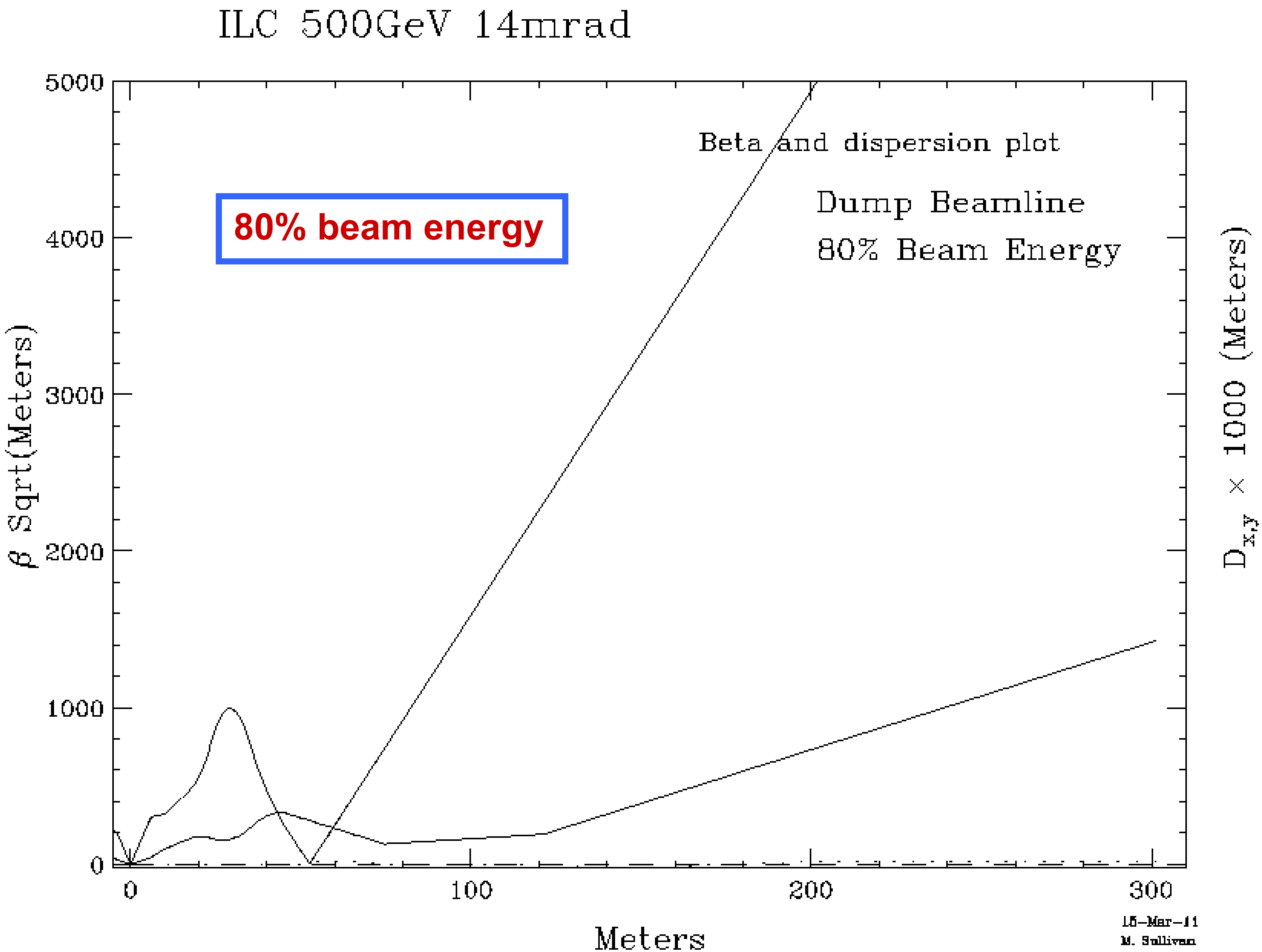
ILC 500GeV 14mrad
80% beam energy
Beta and dispersion plot
Dump Beamline
80% Beam Energy
β Sqrt(Meters)
$D_{x,y}$ × 1000 (Meters)
5000
4000
3000
2000
1000
0
100
200
300
Meters
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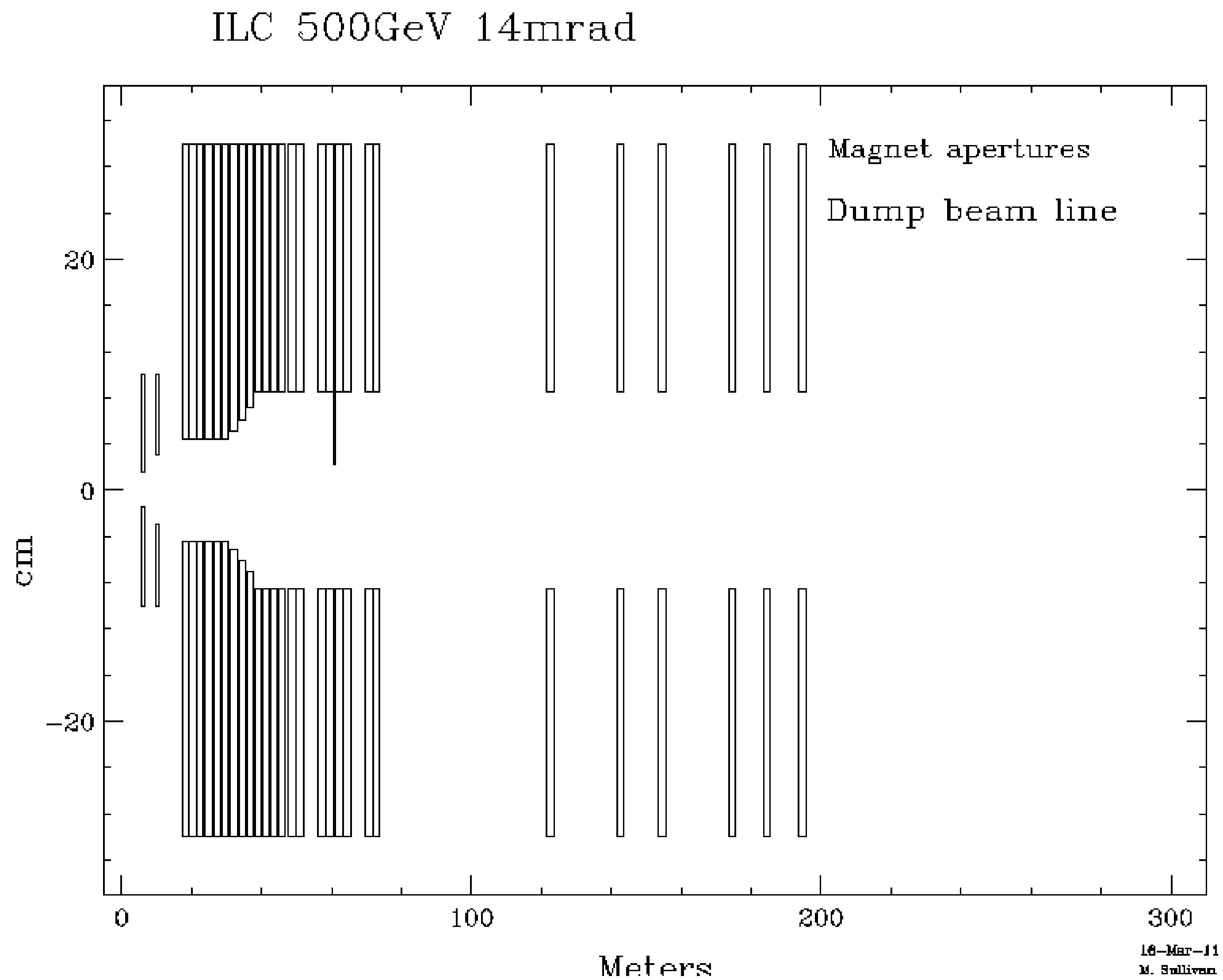
Magnet Apertures



Magnet values

Name	Z (face) (m)	L (m)	r or ½ gap (mm)
QDEX1	5.5	1.06	15
QFEX2A	9.6	1.1	30
QFEX2B	17.2	1.9	44
QFEX2C	19.4	1.9	44
QFEX2D	21.6	1.9	44
QFEX3A	23.8	2.1	44
QFEX3B	26.2	2.1	44
QFEX3C	28.6	2.1	44
QFEX3D	31.0	2.1	51
QFEX3E	33.3	2.1	61

Magnet values

Name	Z (face) (m)	L (m)	r or ½ gap (mm)
QDEX4A	35.7	1.96	71
QFEX4B	38.0	1.96	85
QFEX4C	40.2	1.96	85
QFEX4D	42.5	1.96	85
QFEX4E	44.7	1.96	85
BVEX1	47.7	2.0	85
BVEX2	50.0	2.0	85
BVEX3	56.2	2.0	85
BVEX4	58.5	2.0	85

Magnet values

Name	Z (face) (m)	L (m)	r or ½ gap (mm)
BVEX5	47.7	2.0	85
BVEX6	50.0	2.0	85
BVEX7	56.2	2.0	85
BVEX8	58.5	2.0	85
BVEX1P	58.5	2.0	85
BVEX2P	58.5	2.0	85
BVEX3P	58.5	2.0	85
BVEX4P	58.5	2.0	85
BVEX1G	58.5	2.0	85
BVEX2G	58.5	2.0	85

Downstream SR Results

Beam enr.	Pwr (W)	60 m ECOLL γ/bunch	2% bkscat. Frac. γ/bunch to IP	2% bkscat. Frac. γ/bunch to Cryost.
Solid ang. frac.			4×10^{-10}	8×10^{-9}
Nom. (Undis.)	173	1.4×10^{10}	0.11	2.2
Nom. (Dis.)	102	6×10^{8}	0.005	0.10
90% (Dis.)	146	1.1×10^{9}	0.009	0.18
80% (Dis.)	62	5.6×10^{8}	0.004	0.09

Downstream SR Results

	75-100 m beam pipe		2% bkscat. Frac.	
Beam enr.	Pwr (W)	γ/bunch	γ/bunch	
			to IP	to Cryost.
Solid ang. frac.			1.7×10^{-10}	1.4×10^{-9}
Nom. (Undis.)	616	4.9×10^{10}	0.11	1.3
Nom. (Dis.)	363	2.2×10^{9}	0.007	0.084
90% (Dis.)	60	4.4×10^{8}	0.001	0.012
80% (Dis.)	9.7	8.8×10^{7}	0.0003	0.004

Downstream SR Results

Beam enr.	100-125 m beam pipe Pwr (W)	γ/bunch	2% bkscat. Frac. γ/bunch to IP	to Cryost.
Solid ang. frac.			9.0×10^{-11}	1.2×10^{-10}
Nom. (Undis.)	1823	1.4×10^{11}	0.25	0.34
Nom. (Dis.)	1076	6.5×10^{9}	0.012	0.16
90% (Dis.)	368	2.7×10^{9}	0.005	0.006
80% (Dis.)	83	7.5×10^{8}	0.0014	0.0018

Downstream SR Summary

- Rates look pretty good (too low to worry about)
- Need to do a more careful estimate of the backscatter rate (2% assumed right now)
- No backscatter rates worth noting on either the cryostats or the IP chamber

Further work

- More cross-checks
- Use actual disrupted energy distribution
- More carefully model backscatter rates
- Some concern about forward scattering from far upstream SR sources (reflection from the inside beam pipe surface)

Conclusions

- **Nominal running conditions are OK**
- **Larger beam emittances and/or a larger upstream mask apertures start to allow hits first on the cryostat beam pipes**
- **One then becomes sensitive to the high sigma transverse particle distribution in the beam bunch**

Summary

- **All the primary sources of SR look to be under good control**
- **Worth looking at secondary sources again to make sure they are (still) not a problem**
- **Important to try to model the non-ideal startup machine**