Symposium in Memory of Robert H. Siemann
and ICFA Mini-Workshop on Novel Concepts for Linear Accelerators and Colliders

Collimation & Focusing concepts

Rogelio Tomas, Andrei Seryi

WG5 summary

July 7-10, 2009

SLAC NATIONAL ACCELERATOR LABORATORY

PPA Particle Physics & Astrophysics

- Thursday 7/9, 2:00 - 3:30, Orange room
  - Joint with WG3 (Plasma)
    - 2:00 Discussion of program and challenges
    - 2:10 Plasma focusing Johnny Ng
    - 2:50 Discussion of ultimate IP parameters and path to 100pm beam and IP parameters of plasma (beam and laser driven) collider concepts
- Friday 7/10, 9:00 - 10:30, ROB
  - Joint with WG1 (Microwave)
    - 09:00 RF linac and 100pm IP beam Sami Tantawi et al
    - 09:40 Discussion of parameter and cost optimization
- Friday 7/10, 11:00 - 12:30, Yellow room
  - Joint with WG2 (Dielectric)
    - 11:00 Discussion of program & challenges
    - 11:10 Dielectric collimators Alexej Grudiev
    - 11:50 Crystal Collimation Bob Noble

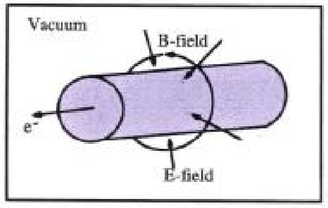
Plasma Focusing:
Opportunities and Challenges

Johnny S.T. Ng
SLAC National Accelerator Center

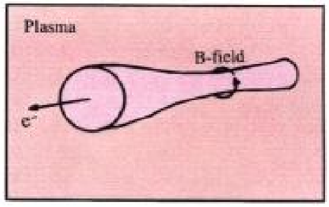
ICFA Workshop on Novel Concepts for Linear Accelerators and Colliders
SLAC, July 8, 2009

Plasma lens focusing for linear colliders

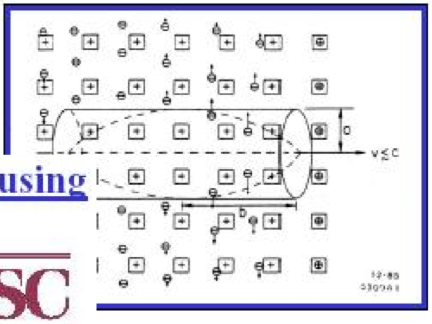
[Pisin Chen, Part. Accel., **20**, 171 (1987)]



In vacuum, there is no net Lorentz force on the beam



In a plasma, E-field is neutralized; B-field pinches the beam.



An electron beam traversing a plasma

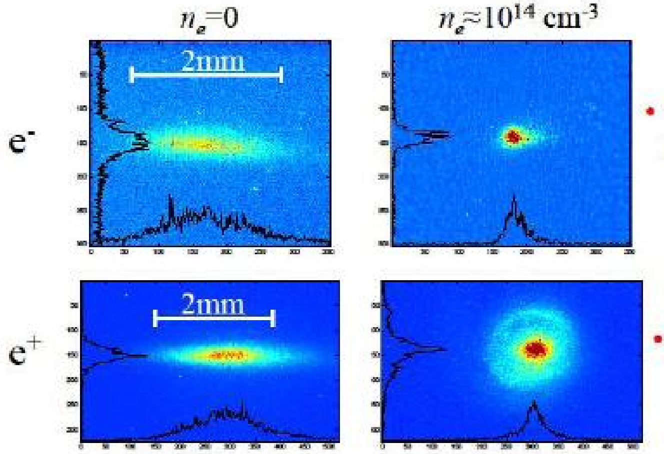
The plasma electron density relative to the beam electron density will determine the location of the return current.

SLAC E157, E162, E164X: Plasma Acceleration and Focusing

[P. Muggli, 2003]

FOCUSING OF e^-/e^+

- OTR images ≈1m from plasma exit ($\varepsilon_x \neq \varepsilon_y$)



- Ideal Plasma Lens in Blow-Out Regime
- Plasma Lens with Aberrations

P. Muggli, SLAC-DoE, 04/10/03

Background Study for NLC-Type Detector

[A. Weidemann et al., SLAC-PUB-9207, 2002]

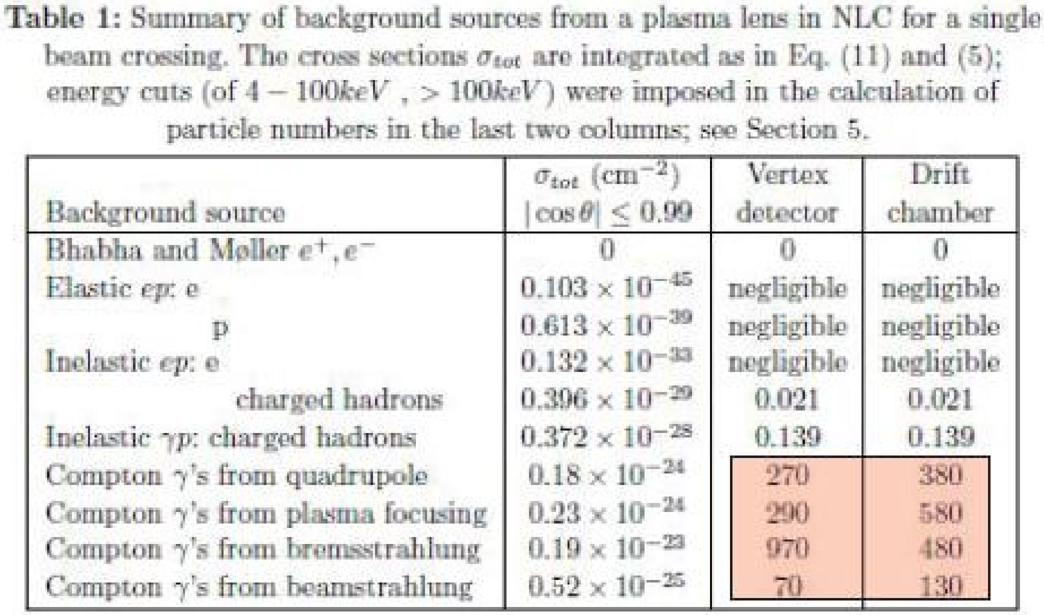


Table 1: Summary of background sources from a plasma lens in NLC for a single beam crossing. The cross sections σ_{tot} are integrated as in Eq. (11) and (5); energy cuts (of $4 - 100 keV$, $> 100 keV$) were imposed in the calculation of particle numbers in the last two columns; see Section 5.

Background source	σ_{tot} (cm^{-2}) $\lvert\cos\theta\rvert \leq 0.99$	Vertex detector	Drift chamber
Bhabha and Møller e^+, e^-	0	0	0
Elastic ep: e	0.103×10^{-45}	negligible	negligible
p	0.613×10^{-39}	negligible	negligible
Inelastic ep: e	0.132×10^{-33}	negligible	negligible
charged hadrons	0.396×10^{-29}	0.021	0.021
Inelastic γp: charged hadrons	0.372×10^{-28}	0.139	0.139
Compton γ's from quadrupole	0.18×10^{-24}	270	380
Compton γ's from plasma focusing	0.23×10^{-24}	290	580
Compton γ's from bremsstrahlung	0.19×10^{-23}	970	480
Compton γ's from beamstrahlung	0.52×10^{-25}	70	130

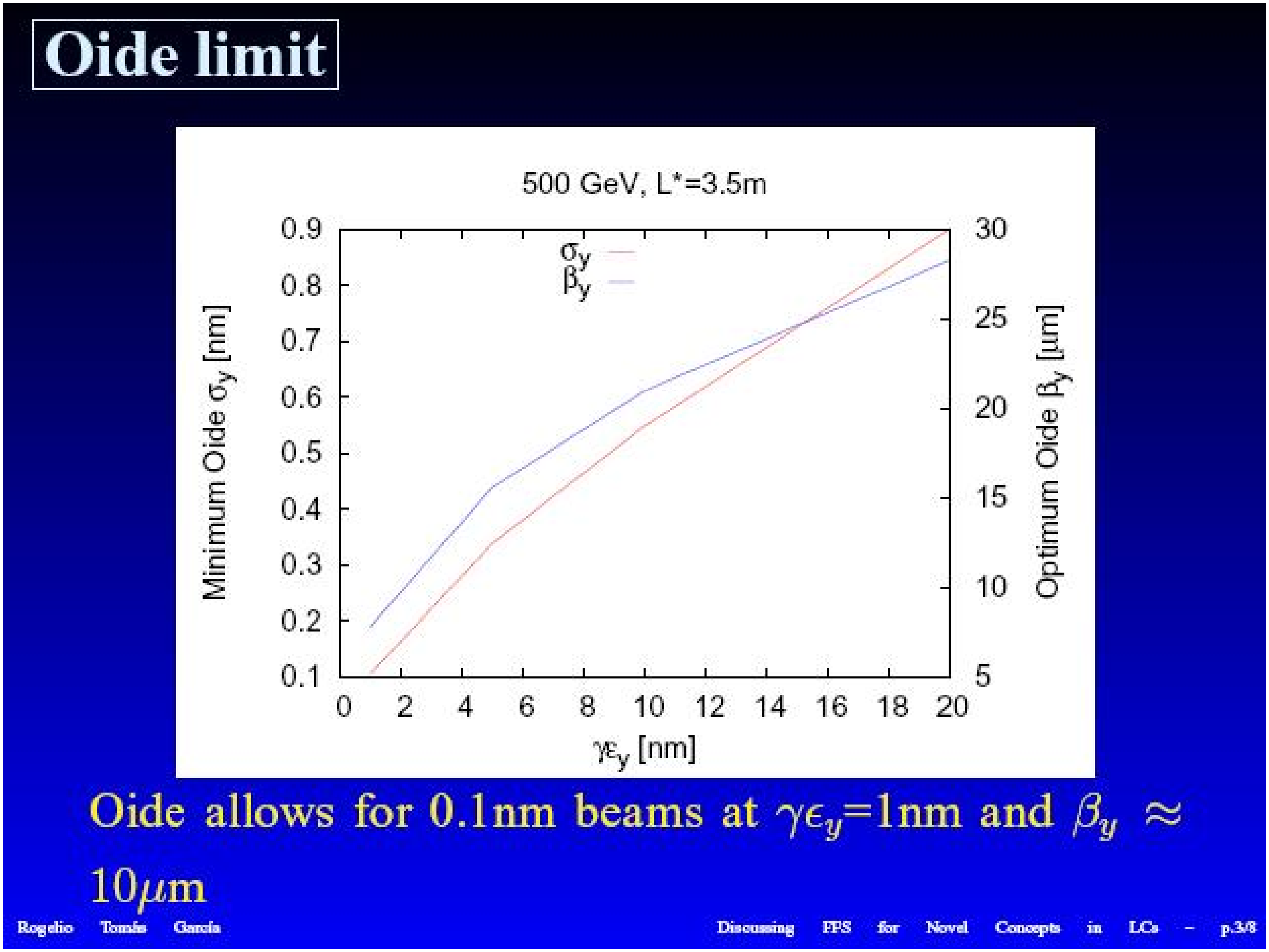
•NLC beam parameters

•Plasma lens: overdense $n_p = 2 \times 10^{18}$ cm^{-3}, 3mm thick

Summary and Outlook

- Strong plasma focusing of e$^-$ and e$^+$ has been demonstrated for collider parameters; underdense plasma lens advantageous.
- Further experiments needed to study emittance preservation/growth mitigation: FACET, NLCTA, …
- Plasma-induced detector background requires further study

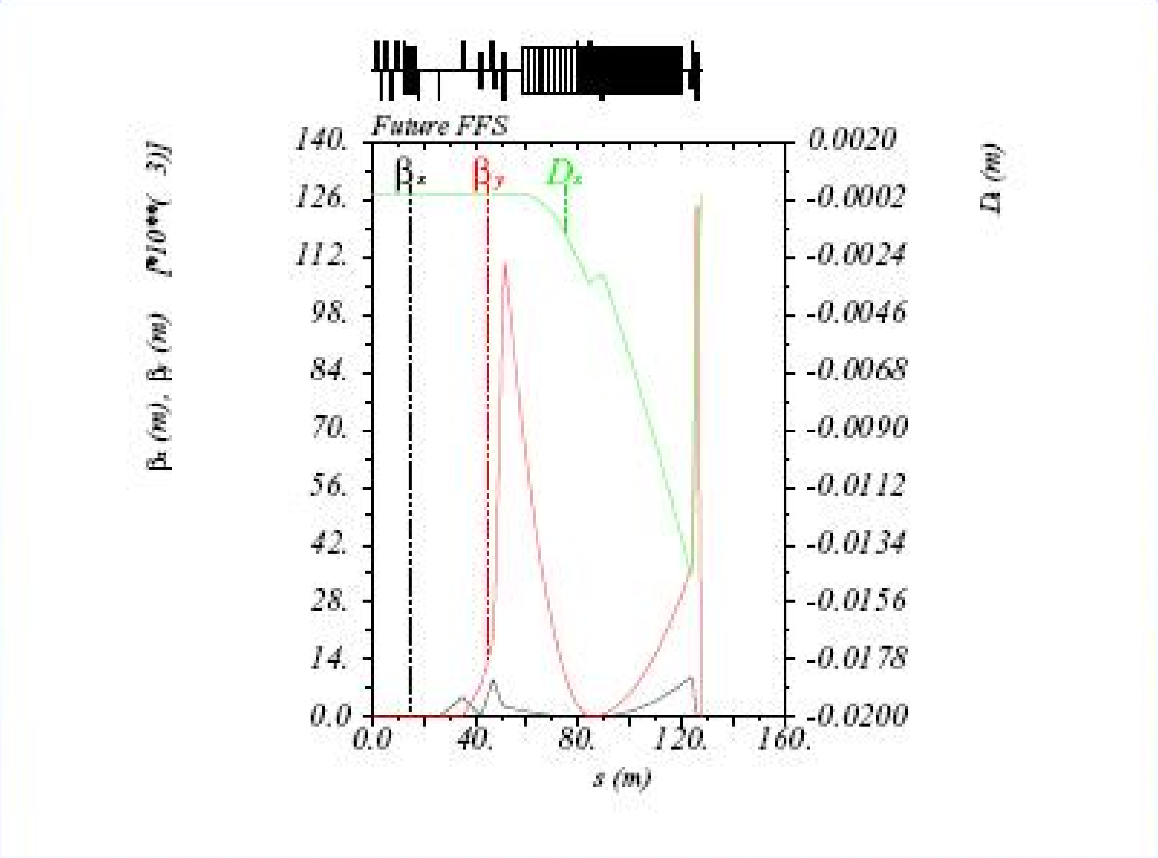
Versions		100pm v1	100pm v2	100pm v3
Ecms [GeV]		1000	1000	1000
N		1.0E+09	1.0E+09	1.0E+08
nb		1200	120	120
Tsep in Linac [ns]		480.0	1.0	1.0
Iave in train [A]		0.0003	0.1600	0.0160
f rep [Hz]		5	50	500
Pb [MW]		0.5	0.5	0.5
IP Parameters:				
gamepsX [m]		1.0E-06	1.0E-06	1.0E-07
gamepsY [m]		1.0E-10	1.0E-10	1.0E-10
bx [m]		1.0E-02	1.0E-02	1.0E-03
by [m]		1.0E-04	1.0E-04	1.0E-04
sigx_geom [m]		1.0E-07	1.0E-07	1.0E-08
sigy_geom [m]		1.0E-10	1.0E-10	1.0E-10
sigz [m]		5.0E-05	5.0E-05	5.0E-05
Dx		0.03	0.03	0.28
Dy		28.5	28.5	28.2
Uave		0.179	0.179	0.178
delta_B		0.019	0.019	0.019
ngamma		0.38	0.38	0.38
Hd		1.95	1.95	2.04
Geom Lumi [cm-2 s-1]		4.67E+33	4.67E+33	4.67E+33
Lumi [cm-2 s-1]		9.12E+33	9.12E+33	9.54E+33



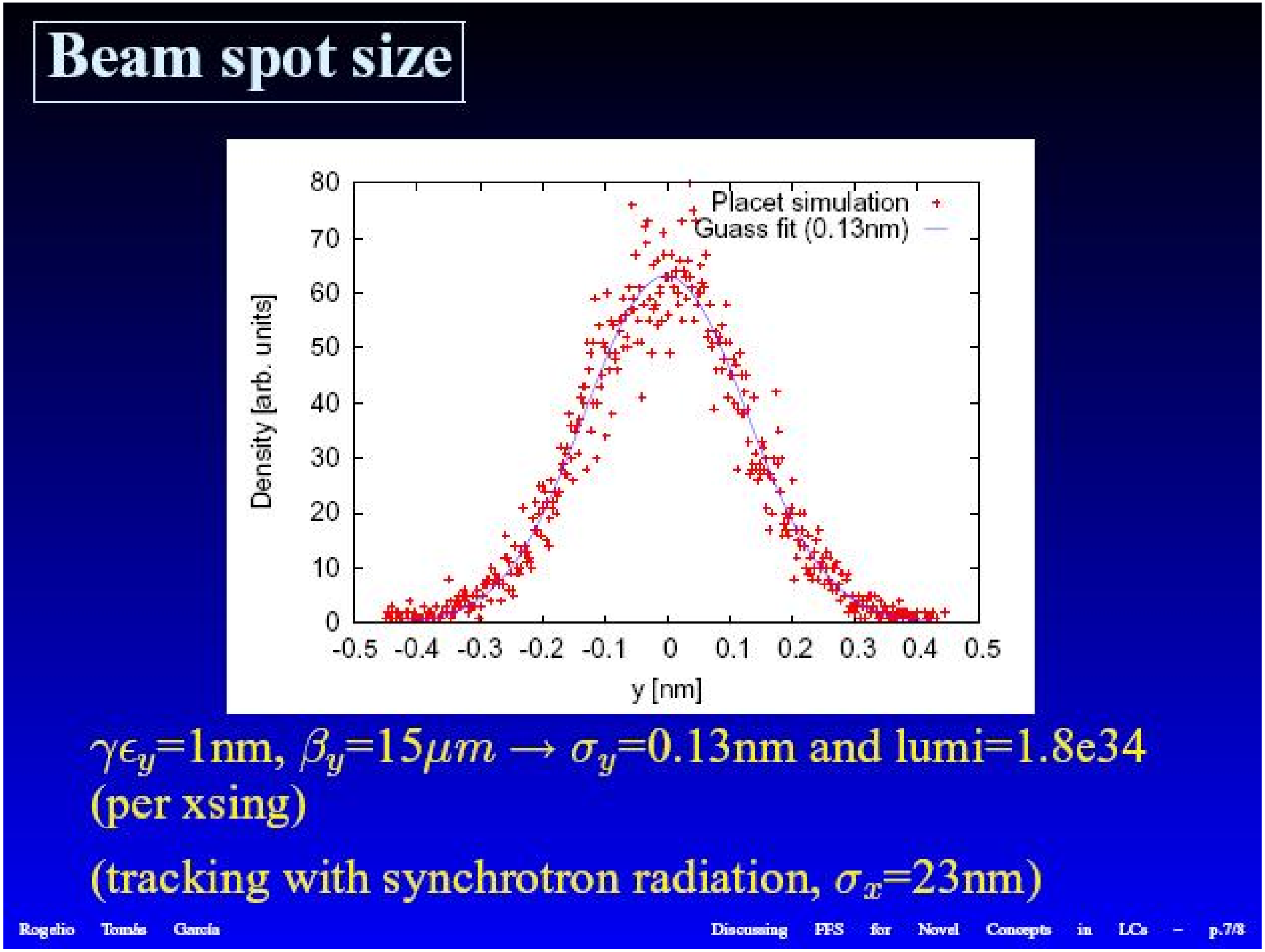
Oide limit

Oide allows for 0.1nm beams at $\gamma\epsilon_y$=1nm and $\beta_y \approx$ 10μm

Optics for L*=1m, β_y=15μm



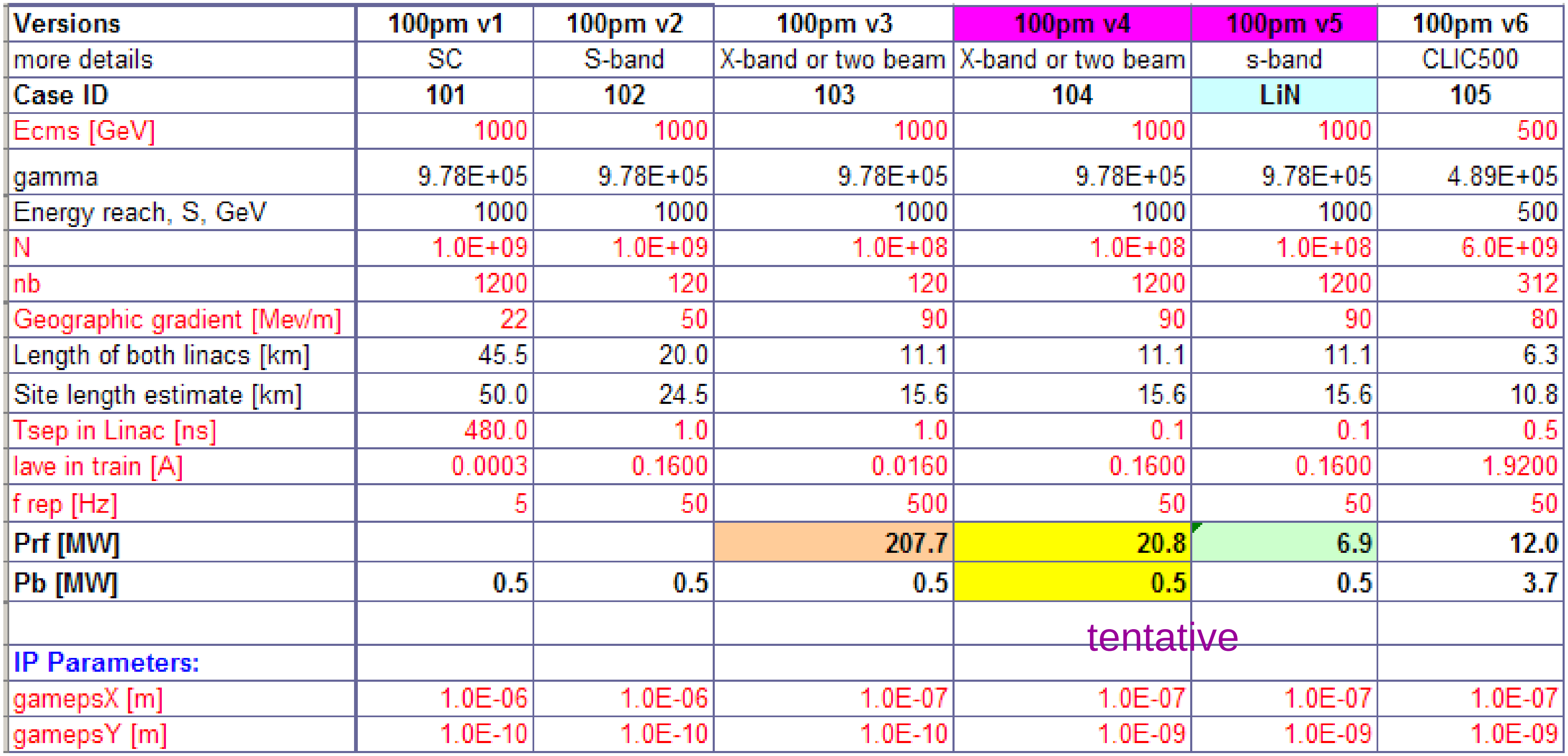
Scaled from CLIC FFS and re-optimized with MAPCLASS



Beam spot size

$\gamma\epsilon_y$=1nm, β_y=15μm → σ_y=0.13nm and lumi=1.8e34 (per xsing)

(tracking with synchrotron radiation, σ_x=23nm)



Versions	100pm v1	100pm v2	100pm v3	100pm v4	100pm v5	100pm v6
more details	SC	S-band	X-band or two beam	X-band or two beam	s-band	CLIC500
Case ID	**101**	**102**	**103**	**104**	**LiN**	**105**
Ecms [GeV]	1000	1000	1000	1000	1000	500
gamma	9.78E+05	9.78E+05	9.78E+05	9.78E+05	9.78E+05	4.89E+05
Energy reach, S, GeV	1000	1000	1000	1000	1000	500
N	1.0E+09	1.0E+09	1.0E+08	1.0E+08	1.0E+08	6.0E+09
nb	1200	120	120	1200	1200	312
Geographic gradient [Mev/m]	22	50	90	90	90	80
Length of both linacs [km]	45.5	20.0	11.1	11.1	11.1	6.3
Site length estimate [km]	50.0	24.5	15.6	15.6	15.6	10.8
Tsep in Linac [ns]	480.0	1.0	1.0	0.1	0.1	0.5
Iave in train [A]	0.0003	0.1600	0.0160	0.1600	0.1600	1.9200
f rep [Hz]	5	50	500	50	50	50
Prf [MW]			**207.7**	**20.8**	**6.9**	**12.0**
Pb [MW]	**0.5**	**0.5**	**0.5**	**0.5**	**0.5**	**3.7**
IP Parameters:						
gamepsX [m]	1.0E-06	1.0E-06	1.0E-07	1.0E-07	1.0E-07	1.0E-07
gamepsY [m]	1.0E-10	1.0E-10	1.0E-10	1.0E-09	1.0E-09	1.0E-09

tentative

Original ←→ Improved ←→ Ref.

- Parameters resulted from joint meeting with WG1
- Optimized to get higher RF-beam efficiency
- Further optimization of RF-beam efficiency drives the parameters to higher frequency and possibly using liquid nitrogen cooled Copper structures

Dielectric Collimators
for the CLIC Beam Delivery System?

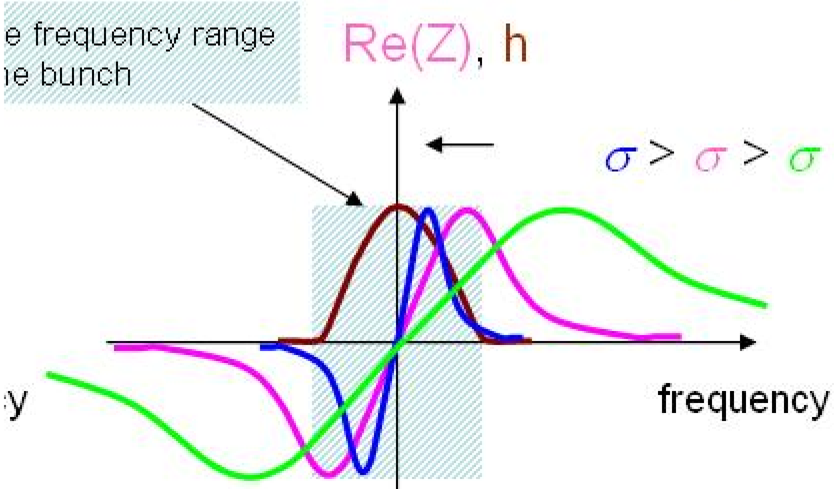
First ideas from studies for the LHC collimators

E. Métral, A. Grudiev, G. Rumolo, B. Salvant *(also at EPFL, Lausanne)*, R. Tomàs
CERN, Geneva

Many thanks for their help and advice to

E. Adli, R. Calaga, F. Caspers, A. d'Elia, A. Latina, F. Roncarolo, D. Schulte, C. Simon

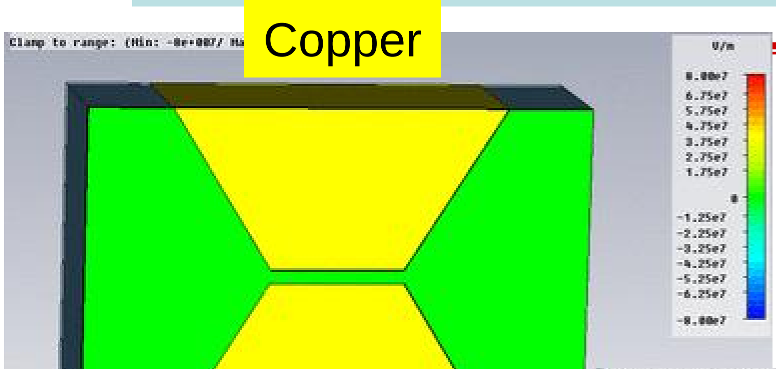
"New" formalisms
(Zotter/Metral, Burov/Lebedev)



In this case, it really depends on the frequency and bandwidth of the impedance peak

Vertical Electric field simulated by particle studio

Copper



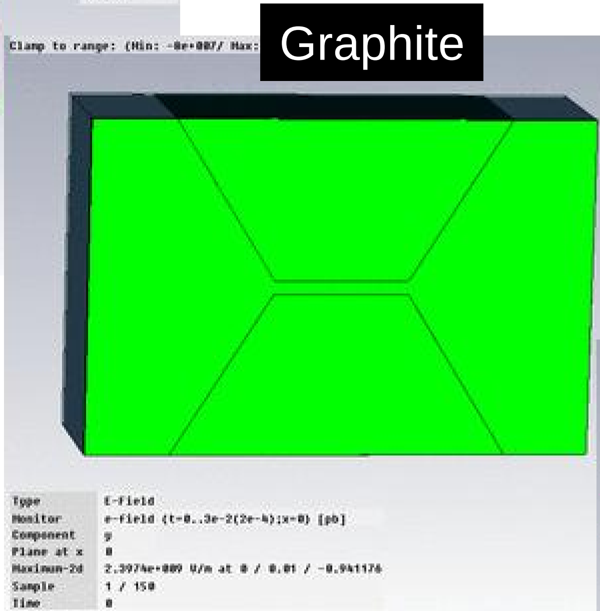
Type	E-Field
Monitor	e-field (t=0..3e-2(2e-4);x=0) [pb]
Component	y
Plane at x	0
Maximum-2d	2.5418e+009 V/m at 0 / 0.01 / -0.970496
Sample	1 / 151
Time	0

No relaxation time

Angle of the shock wave agrees with cerenkov effect

$$\sin(\vartheta)=\frac{1}{\beta n}=\frac{1}{\sqrt{\varepsilon_r}}$$

Graphite



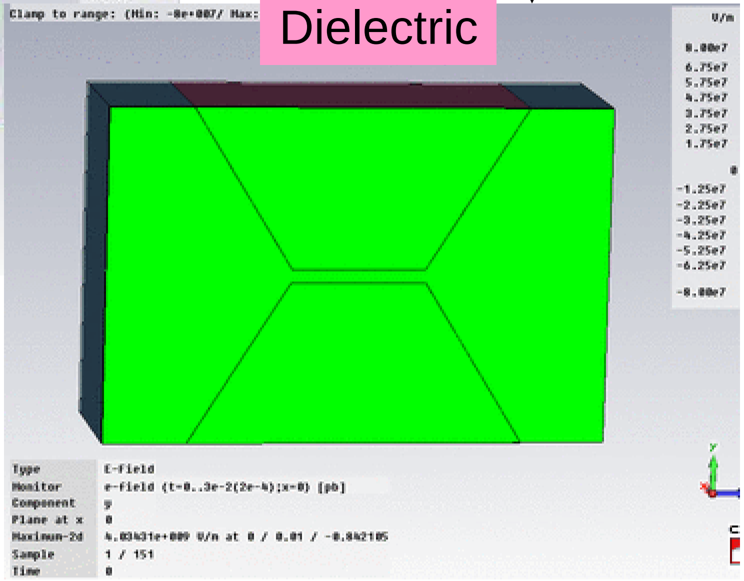
Type	E-Field
Monitor	e-field (t=0..3e-2(2e-4);x=0) [pb]
Component	y
Plane at x	0
Maximum-2d	2.3974e+009 V/m at 0 / 0.01 / -0.941176
Sample	1 / 150
Time	0

No relaxation time

$\varepsilon_r=5$

$\rho=1\ \Omega\mathrm{m}$

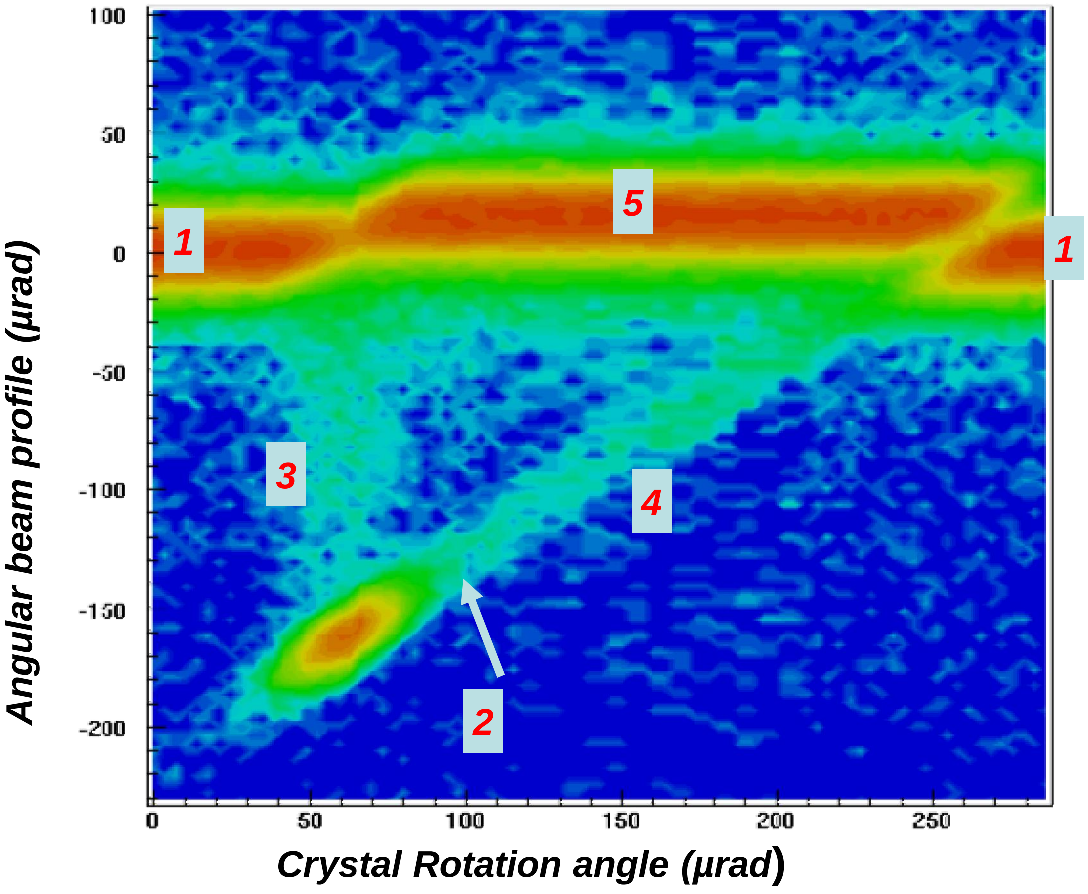
Dielectric

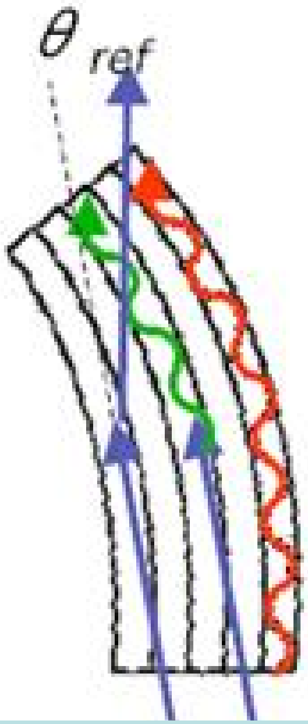


Type	E-Field
Monitor	e-field (t=0..3e-2(2e-4);x=0) [pb]
Component	y
Plane at x	0
Maximum-2d	4.03431e+009 V/m at 0 / 0.01 / -0.842105
Sample	1 / 151
Time	0

→ Less reflections with a dielectric taper?

Effects in bent crystals

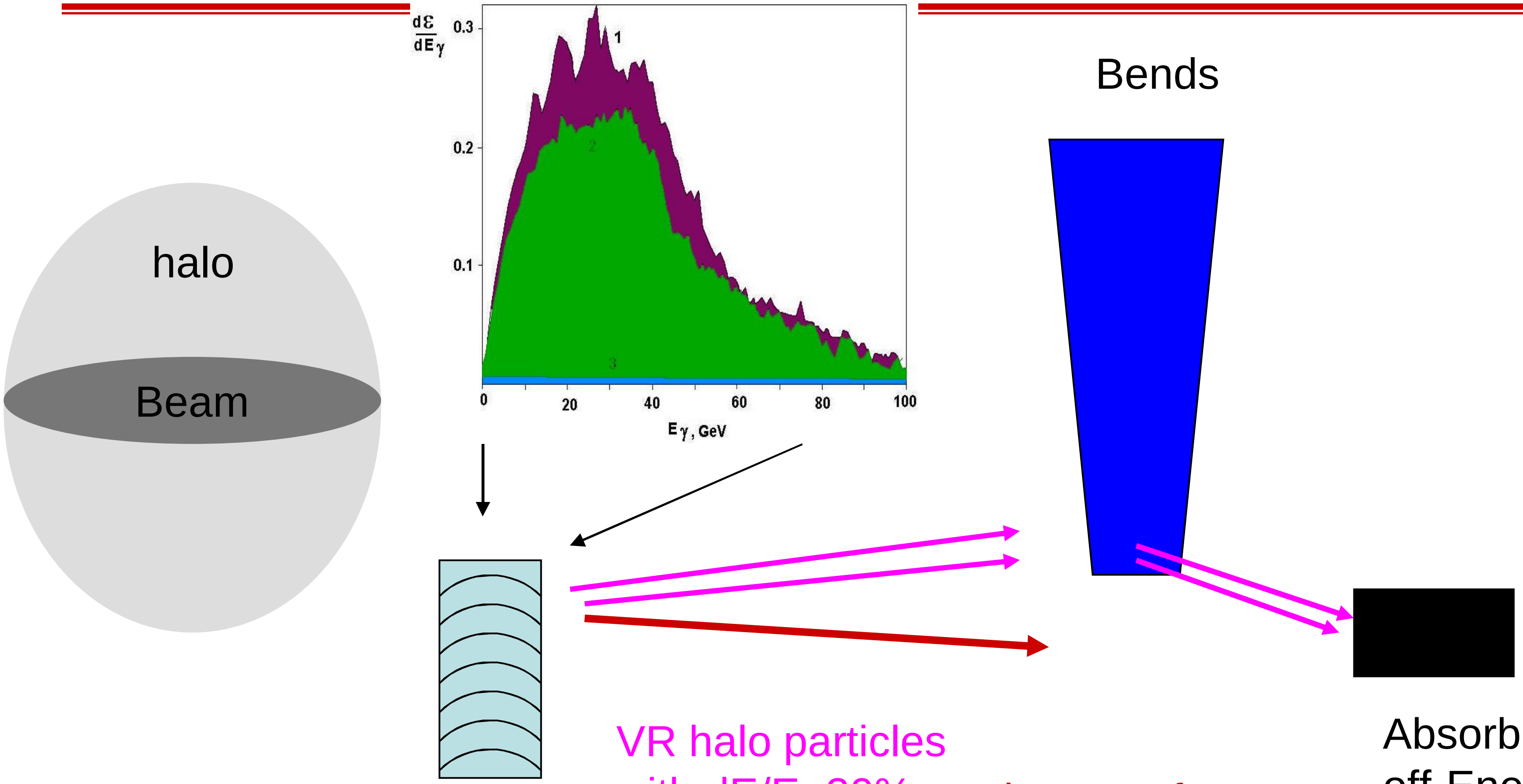




1 - “amorphous” orientation
2 - channeling
3 - de-channeling
4 - volume capture
5 - volume reflection

Angle of beam after passing the crystal, vs crystal orientation
Data plot from Walter Scandale et al

LC Collimation concept based on VR radiation



Bends

halo

Beam

Crystal
with Volume
Reflection

VR halo particles
with dE/E~20%
loss due to VR
radiation

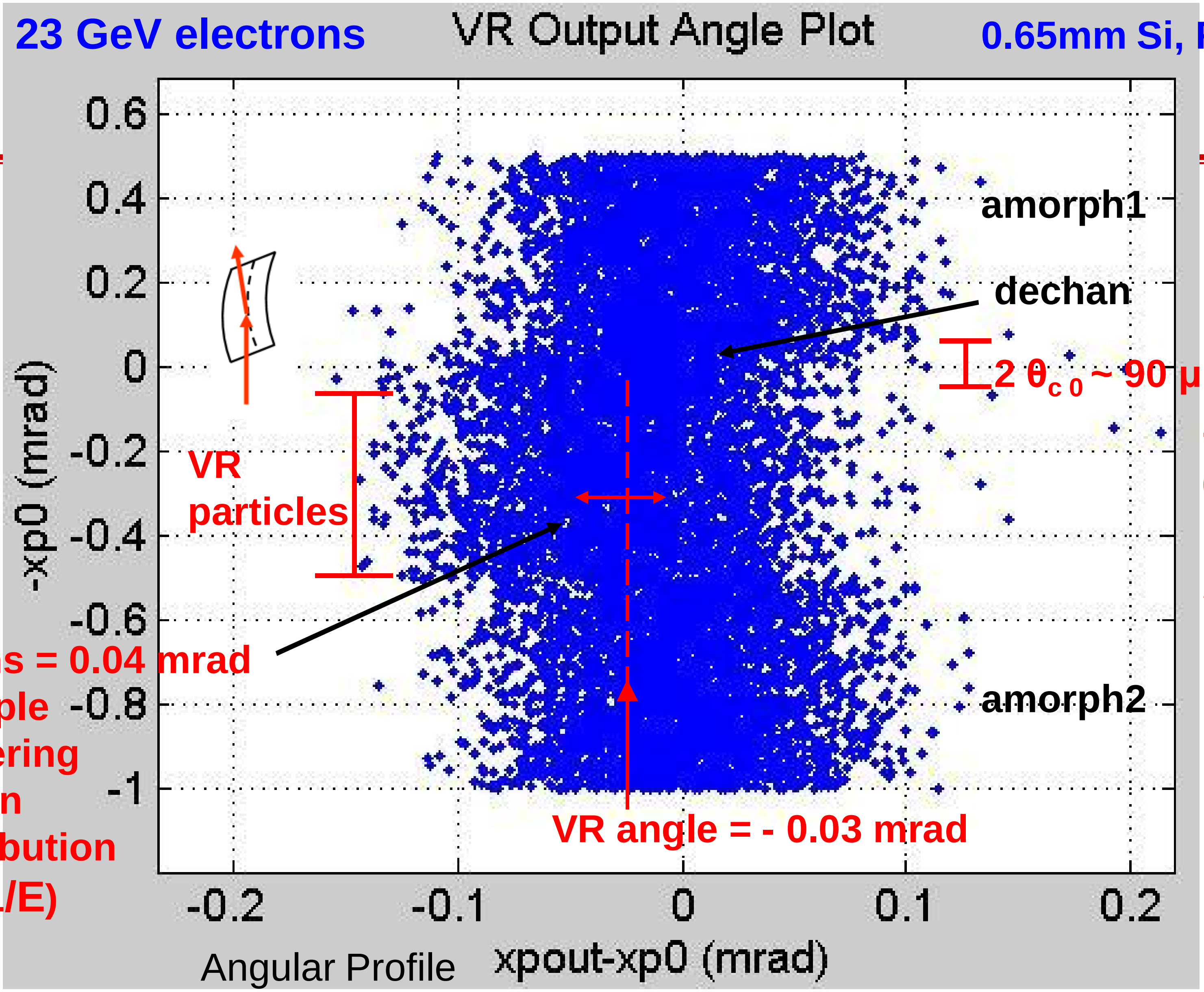
photons of VR
radiation (to be
absorbed in
dedicated places)

Absorb
off-Energy
particles

FACET 23 GeV electrons

0.65mm Si, R=1.3 m

Crystal Rotation Angle



Angular Profile

VR particles

$2\,\theta_{c\,0} \sim 90\ \mu\text{rad}$

VR angle = - 0.03 mrad

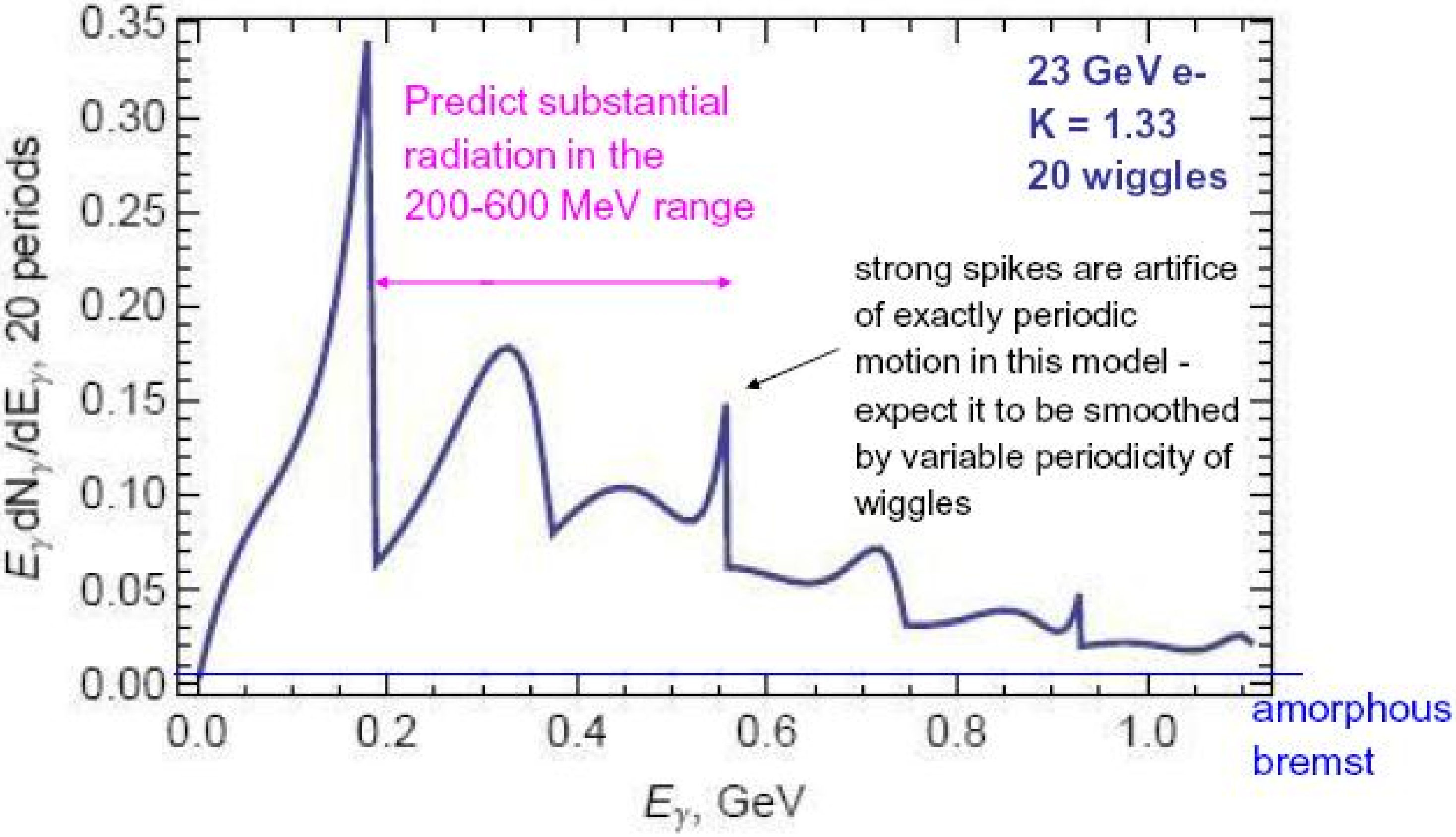
VR rms = 0.04 mrad (Multiple Scattering is main contribution $\theta_{MS} \sim 1/E$)

~FACET θ_{rms} for 10 μm spot

23 GeV: $\theta_{c\,0}$ ($\sim E^{-1/2}$)=0.044 mrad, R_{crit} ($\sim$ E)=0.05 m, L_{dech} ($\sim$ E)=0.75 mm

Wiggler Model Estimate of 23 GeV e- VR Radiation

G. Stupakov



Predict substantial radiation in the 200-600 MeV range

23 GeV e-
K = 1.33
20 wiggles

strong spikes are artifice of exactly periodic motion in this model - expect it to be smoothed by variable periodicity of wiggles

amorphous bremst

4. The VR radiation spectrum for this case is estimated to have photons in the range 200 – 600 MeV using a simple wiggler model, with about 20 channel wiggles providing most of the radiation.

Summary of WG5

- We had fruitful and enjoyable discussions
- It is good that there are parameters sets for all options that allow comparison and further optimization
- Discussion of paths to 100pm beam started and resulted in some interesting ideas
- Hope that some of these ideas will find their way to a machine that will be constructed