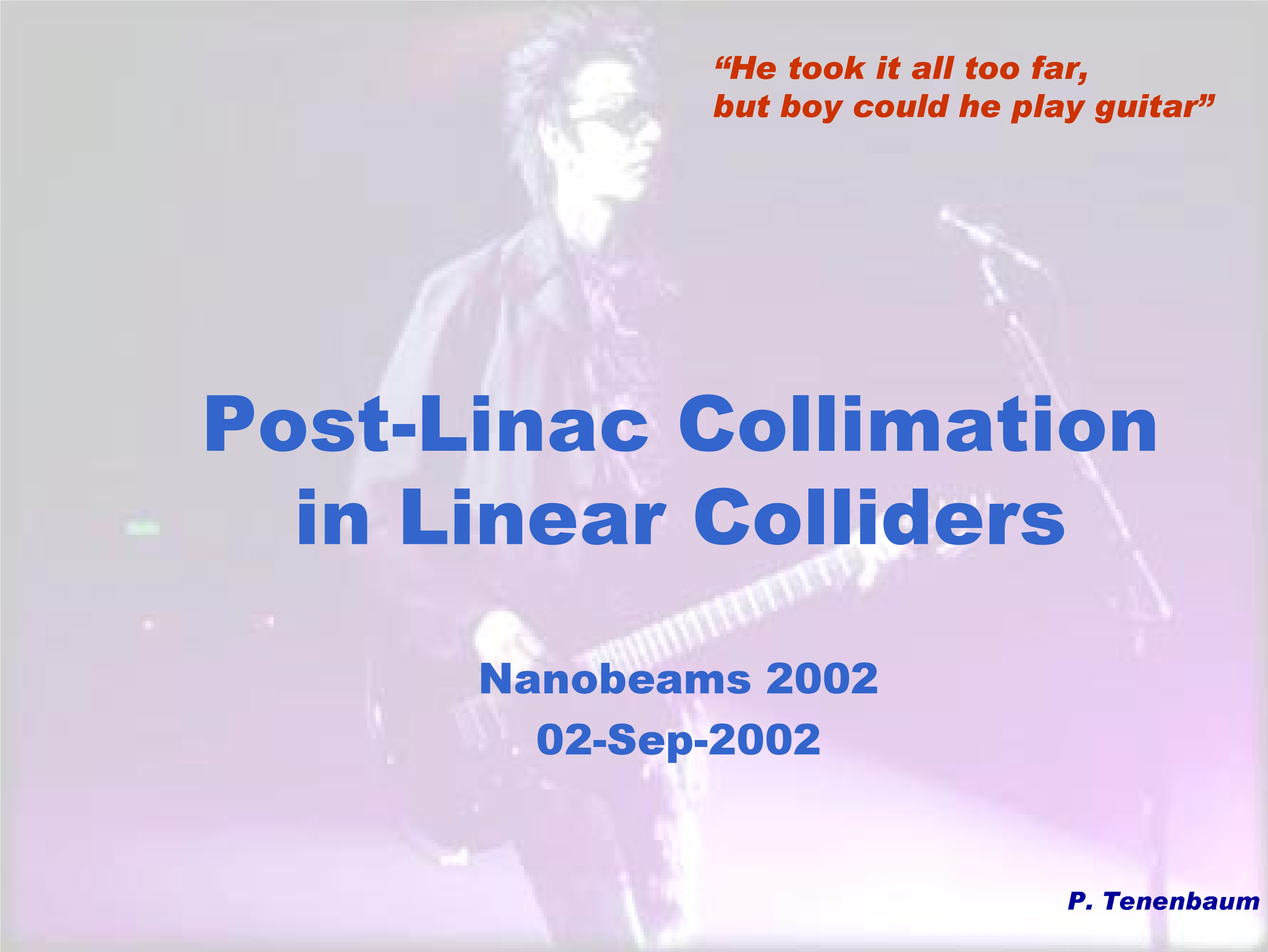


"He took it all too far,
but boy could he play guitar"

Post-Linac Collimation in Linear Colliders

Nanobeams 2002

02-Sep-2002

P. Tenenbaum

Images Provided By:

T. Maruyama, D. McCormick, M. Ross, PDG, Fernandes Guitars

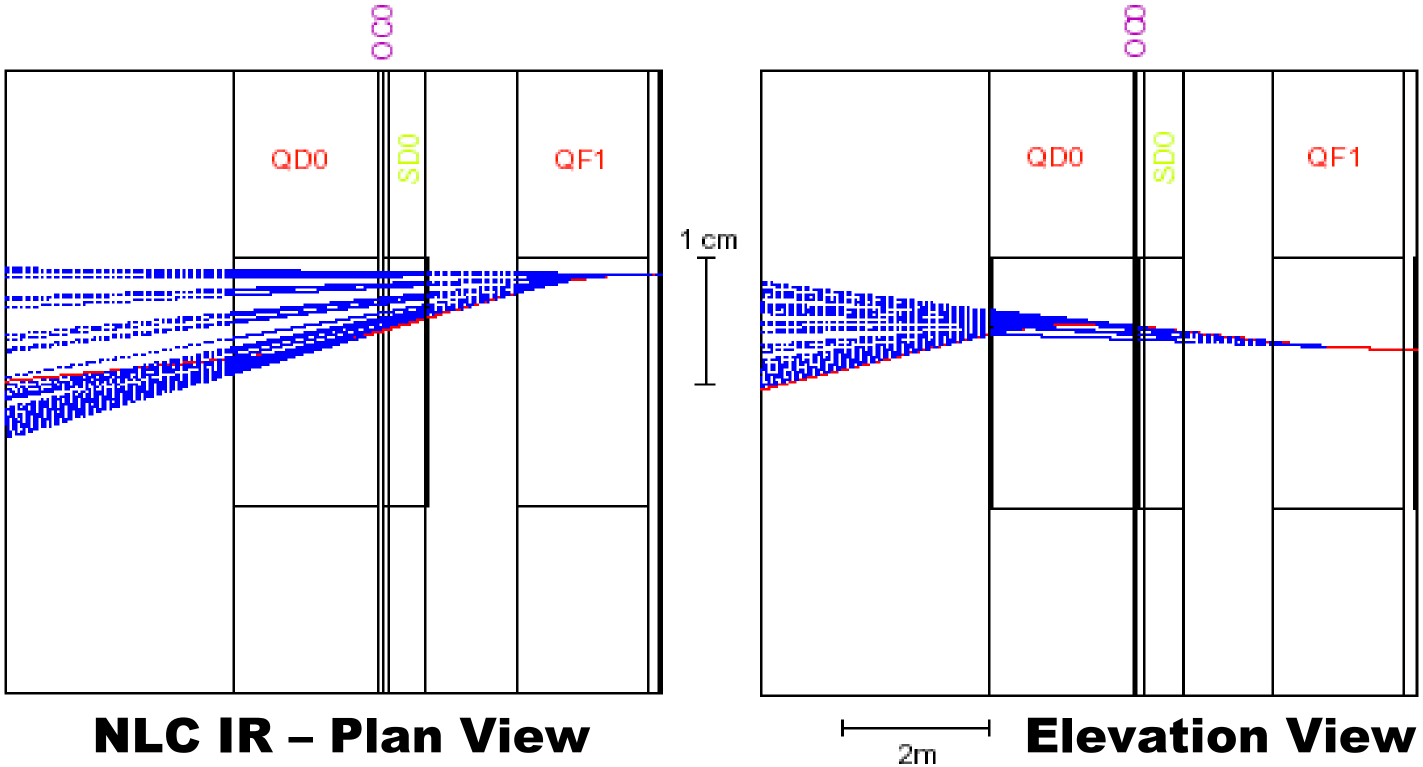
Requirements in Brief

- **Stop primary particles which would make unacceptable detector backgrounds**
- **Stop secondary particles which would make unacceptable detector backgrounds**
- **Protect detector and IR from beam core in event of large excursion**

- **Protect collimation system itself from beam core!**
- **Limit pathological beam dynamics from collimators (*wakefields*)**

Primary Particles

- **What sets the collimator apertures?**
  - **Primary beam hitting the vacuum chambers? NO!**
  - **SR from last quads hitting vertex detector? YES!**
- **Don't forget SR from bends in final focus…**

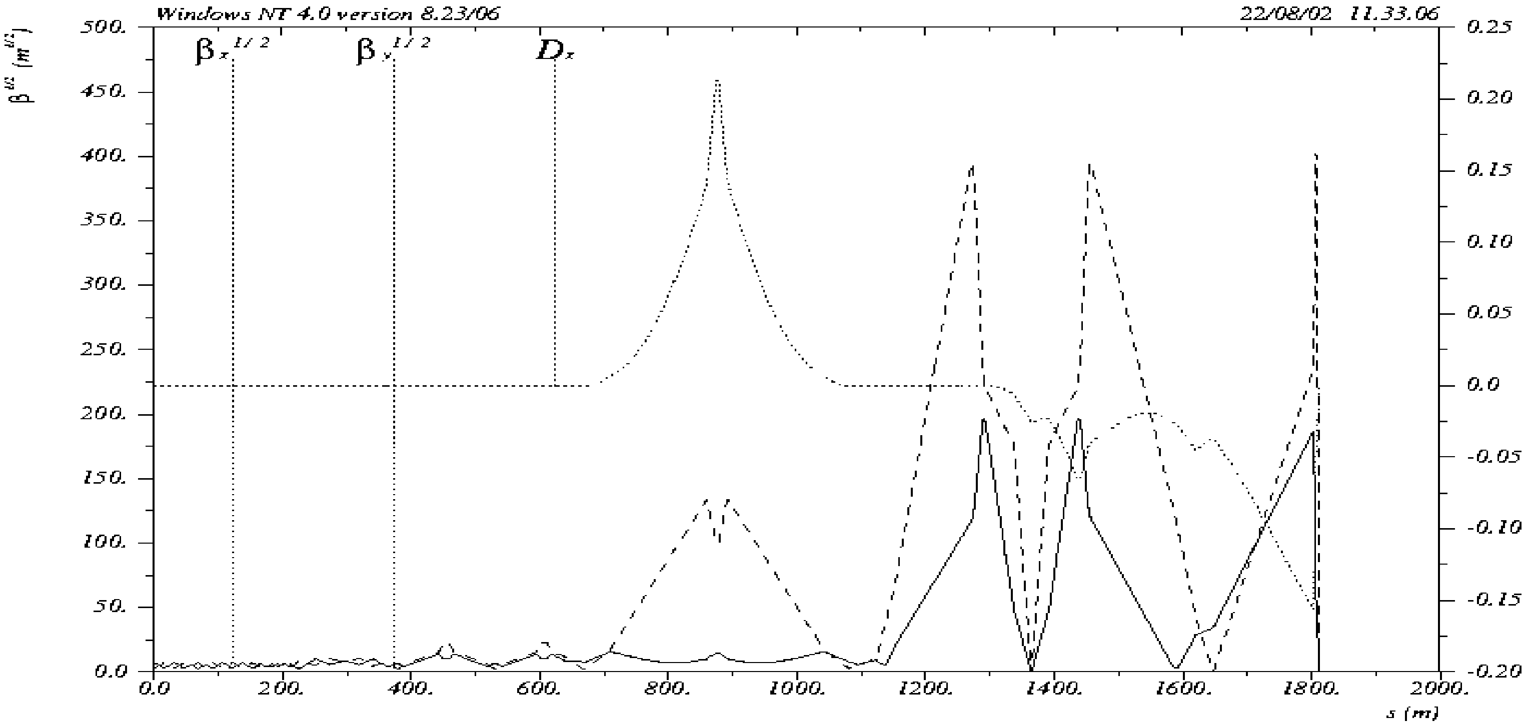


NLC IR – Plan View

Elevation View

Primary Particles (2)

- **What sets the gap of the *energy slit*?**
  - **FF $\eta_{x'}^{*}$ -- off-energy particles take up some of x aperture**
  - **FF optics – particles go out of control for some δ**
  - **Cleanup of collimated particles (energy slit downstream of beta slits, like NLC BDS)**



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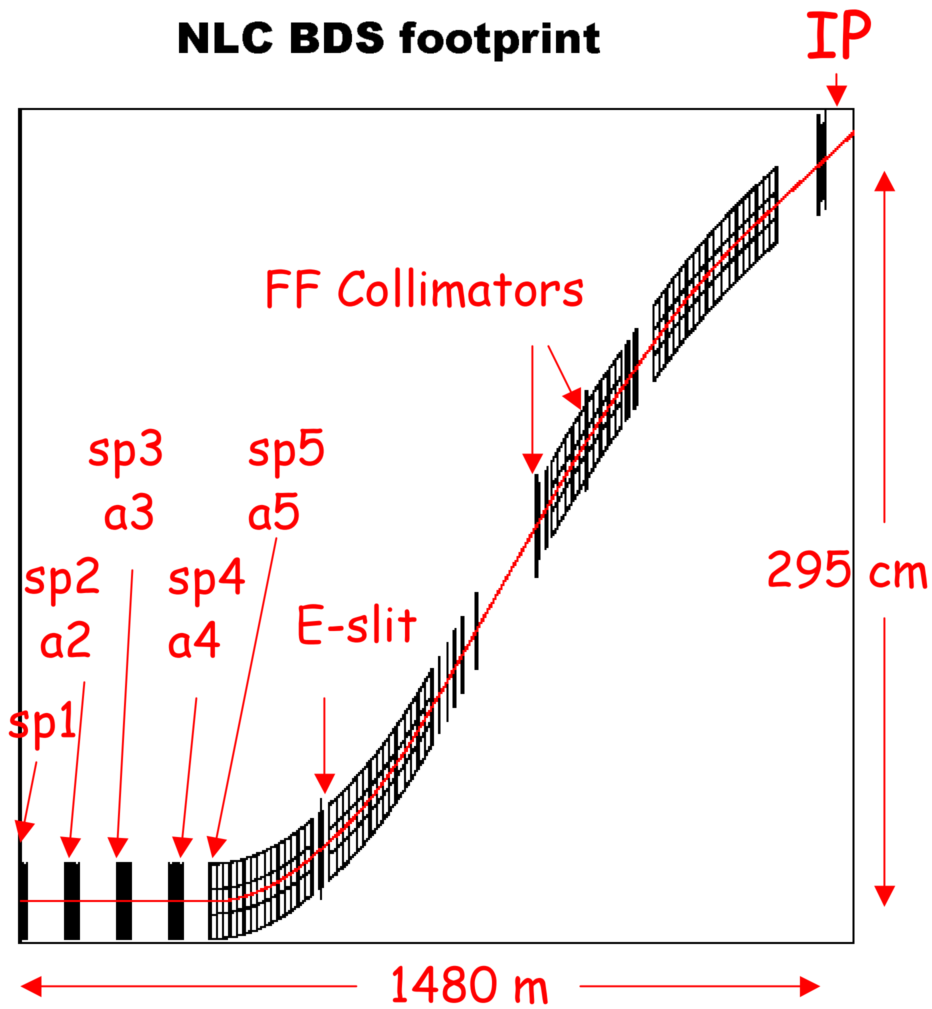
Primary Particles (3)

- **LC collimation a "layered defense"**
  - **upstream dedicated collimation system**
  - **More collimators in final focus**
    - **mainly stop primary beam particles which are *rescattered* in collimation system**

- **Why not do all collimation in FF?**

NLC BDS footprint



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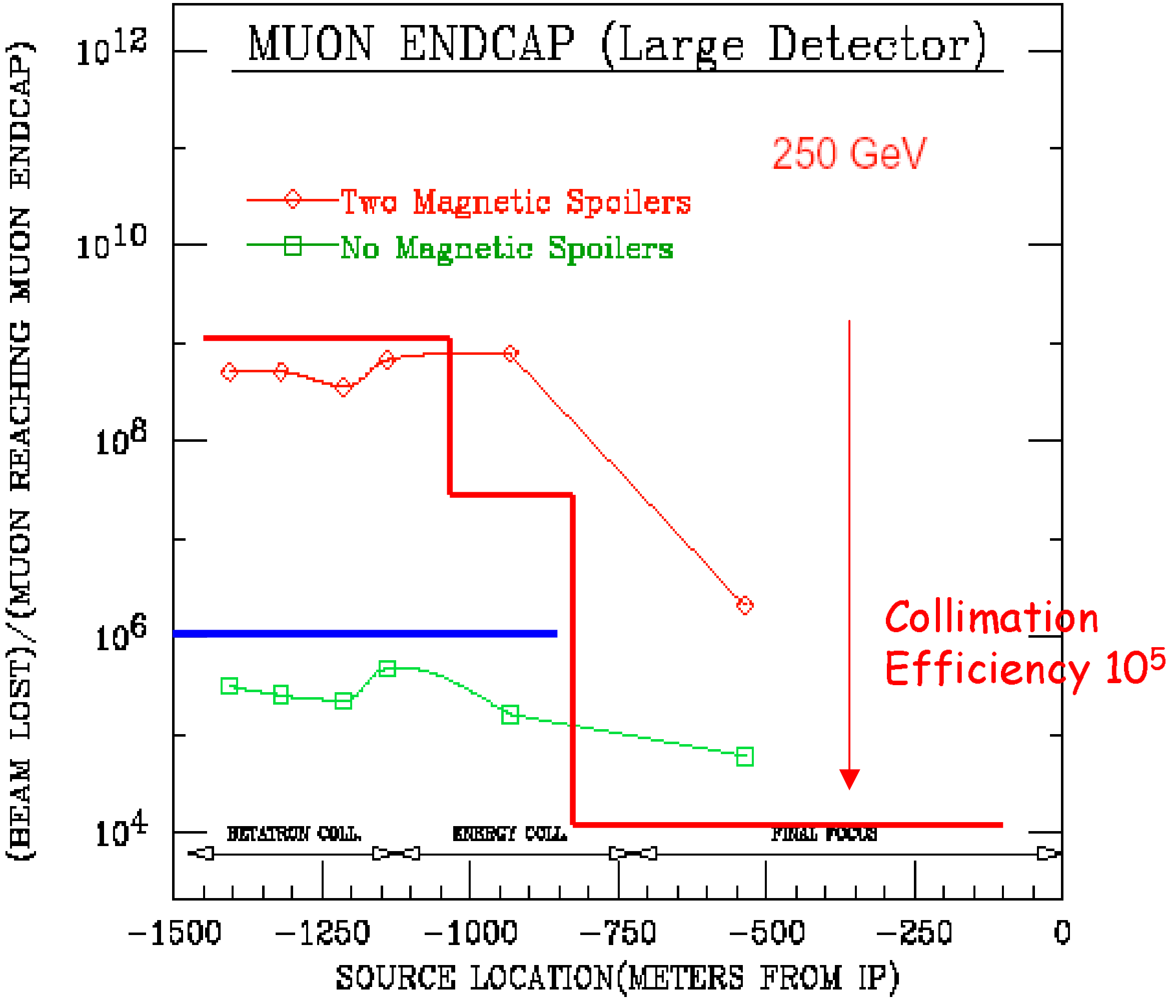
Secondary Particles

- **Biggest issue: muons**
  - **Produced when primary particles stopped**
  - **Go thru anything**
  - **Muon flux in detector sets**
    - **allowed halo (#/pulse)**
    - **attenuation of main collimation system**



Primary Particles: SLC Experience

Just How Bad was the SLC Experience with Primary Beam Halo Particles?

- Pretty bad -- ~10% of the beam in early days!
  - could see bunch charge drop downstream of main linac collimators
- Amenable to tuning
  - improved to 1%, then 0.1%, of primary beam over life of SLC
- Source *not* understood
  - Inadequate diagnostics, modeling
- Future LC collimation systems *attempt* to address shortcomings in SLC
  - Caveat emptor!

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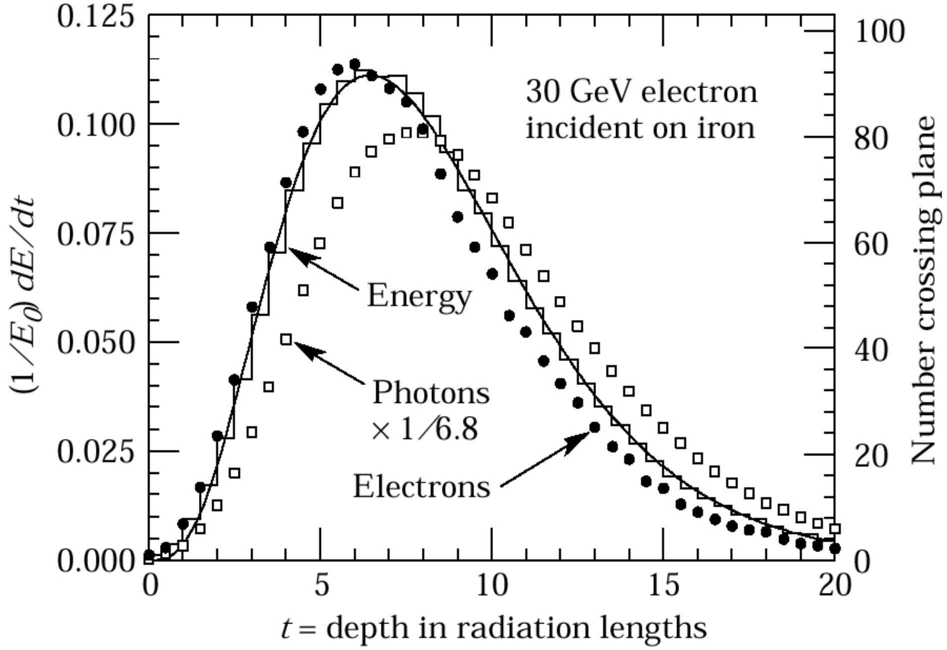
Self-Defense

- **Protecting detector easy**
  - **constraint on SR tighter than needed for machine protection**
- **Protecting collimators tougher**
  - **need >> 10 R.L. material to stop ~all power**
  - **Beam power density huge**
    - **direct hit on coll will demolish it!**



Material	X_0, cm	0.0 X_0	0.5 X_0 Target	1.0 X_0 Target	20 X_0 Target
Beryllium	37.5		185 μ		300 μ
Carbon	20.1	45 μ	76 μ	105 μ	123 μ
Titanium	3.7	120 μ	180 μ	300 μ	750 μ
Ti alloy	3.7	70 μ	100 μ	170 μ	440 μ
Copper	1.5	275 μ	470 μ	760 μ	2.7 mm
Iron	1.8	210 μ	360 μ	590 μ	2.1 mm
Steel	1.8	140 μ	230 μ	380 μ	1.3 mm

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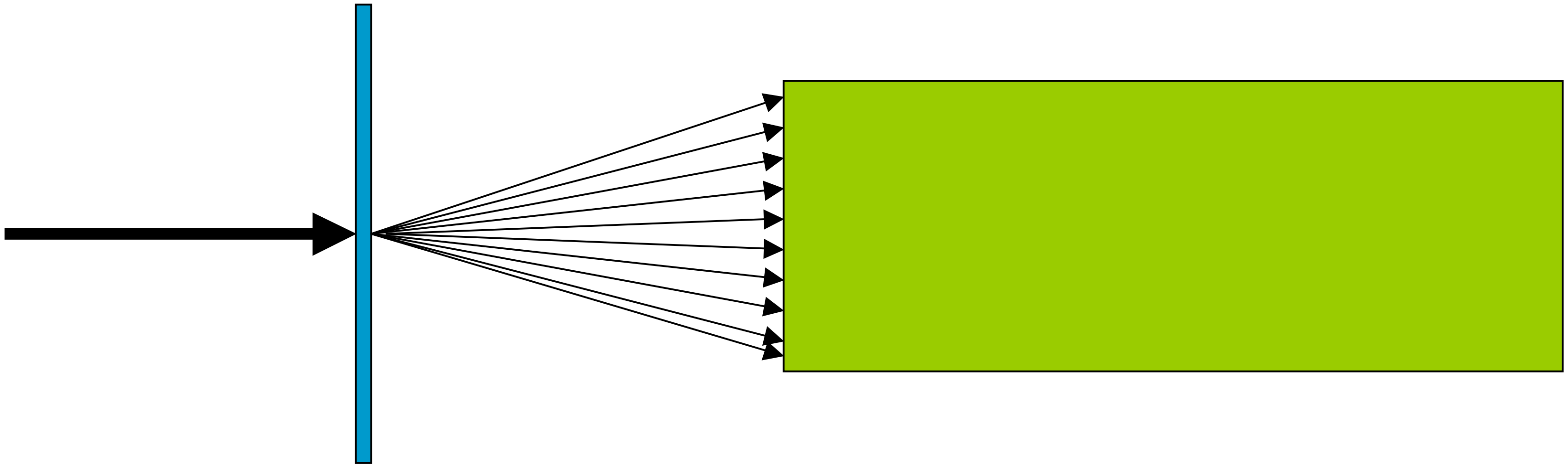
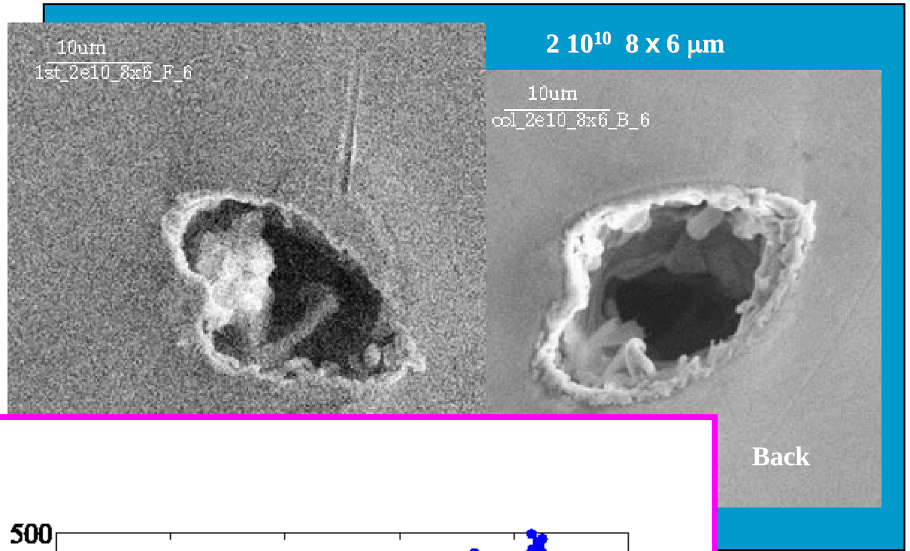
Self-Defense (2)

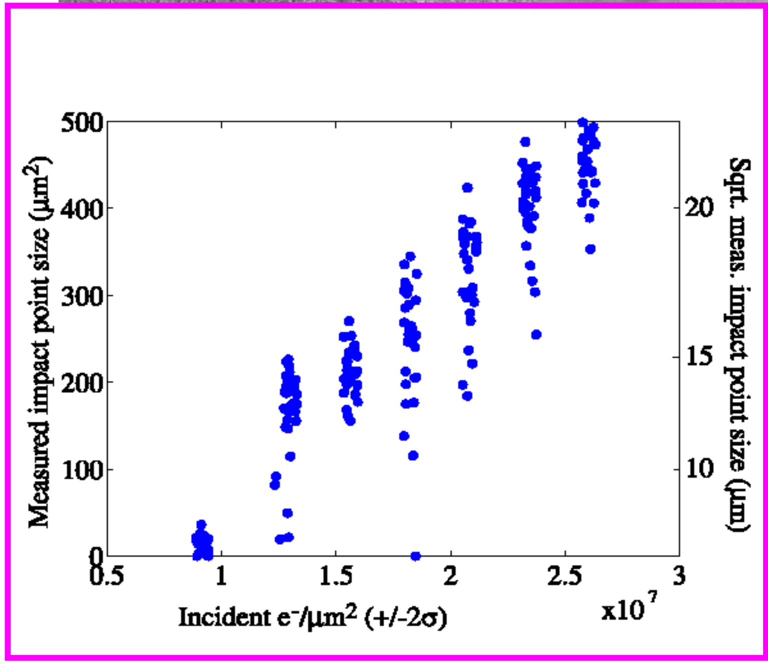
- **Solution: make the beam big at the thick collimator**
  - **use a thin collimator (*spoiler*) with multiple coulomb scattering**
  - **beam blows up downstream at thick collimator (*absorber*)**
- **Drawbacks**
  - **still need to make spoiler strong enough to survive**
  - **Reduces collimation efficiency – not every particle hitting spoiler hits the absorber!**



Self-Defense (3)

- How hard do you work to protect spoiler?
  - Thin: classical eqns for heating damage don't apply
    - situation is not as bad as you think
  - betatron oscillations can (maybe) be trapped
    - active MPS
  - Energy oscillations harder to trap



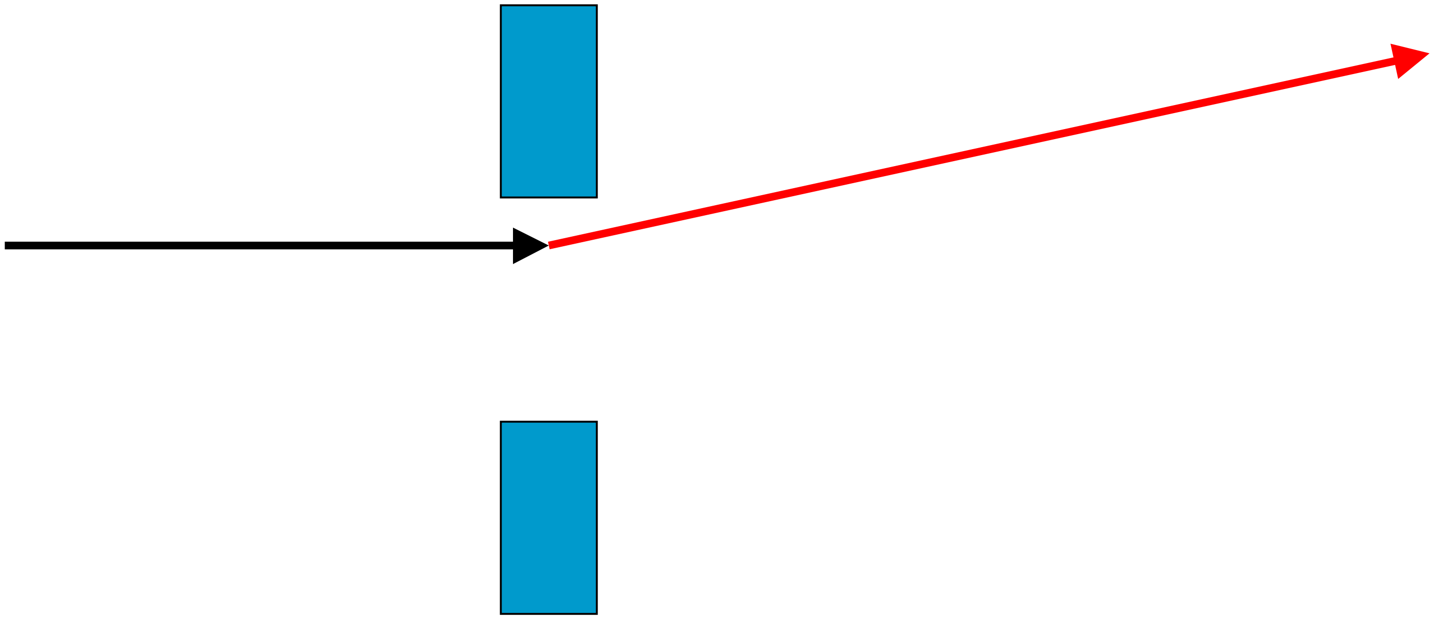


Self-Defense: Summation

- Blow beam up at energy spoilers
  - use β_y and η_x for this – spoiler must survive!
- Blow beam up at betatron spoilers
  - but not as much – hits will be rare
  - use "consumable spoilers" – can tolerate ~1000 hits/year (rotating wheels!)
- Use linear optics to ensure halo big at absorbers
  - so bunch train thru spoilers is big enough at absorbers to be stopped w/o damage
- Add absorbers in FF to clean up rescatters

Wakefields

- Introduce deflection and beam shape change when beam passes off-axis thru collimator
  - geometric wake: due to change in vacuum chamber x-section
  - Resistive: due to material with finite conductivity near beam



Wakefields (2)

- Near center of coll gap: linear effect
  - $\Delta y'$ α y in gap
  - jitter amplification: n sigmas jitter → $n(1+A^2)^{1/2}$ sigmas
  - Coll at doublet phase → angle at doublet phase → offset at IP phase (critical)
  - Also: energy colls couple energy jitter to x jitter of beam
    - $A_\delta \equiv$ # sigmas x jitter / % energy jitter
- Near-wall wakes: nonlinear (but saturating kick)
  - mainly machine protection issue – is nonlinear kick big enough to hit the wall?

Wakefields (3)

Summary of Wakefield Jitter Amplification Coeffs for LC Designs

Parameter	TESLA			NLC			CLIC		
	$\mathcal{A}_x$	$\mathcal{A}_y$	$\mathcal{A}_\delta$	$\mathcal{A}_x$	$\mathcal{A}_y$	$\mathcal{A}_\delta$	$\mathcal{A}_x$	$\mathcal{A}_y$	$\mathcal{A}_\delta$
δ Spoilers	0.0450	0.0890	0.3458	0.0010	0.0450	0.0530	0.0345	0.0	0.0
δ Absorbers	0.0063	0.0335	0.0582	0.0055	0.0163	0.0199	0.0477	0.	0.
β Spoilers	0.0845	1.3630	0	0.0819	0.7232	0	0.1721	0.9844	0
β Absorbers	0.0329	0.5145	0	0.0033	0.0140	0	0.0307	0.0388	0
FF Spoilers	0.0553	0.7248	0.0023	0	0	0	0	0	0
FF Absorbers	0.0255	0.3069	0.0372	0.0627	0.5392	0.0020	0	0	0
Total	0.2496	3.0318	0.4435	0.1543	1.3378	0.0748	0.2846	1.0231	0.

(the whole story is documented in LCC-Note-0101, on the NLC web site...)

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Wakefields (4) – Emittance Growth

- **Emittance growth eqn for near-center:**
  - $\Delta\varepsilon/\varepsilon \sim (0.4nA)^2$, where n = # sigmas jitter
  - for reasonable values of n (<1), should be no problem…