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CLIC Post-collision Diagnostics

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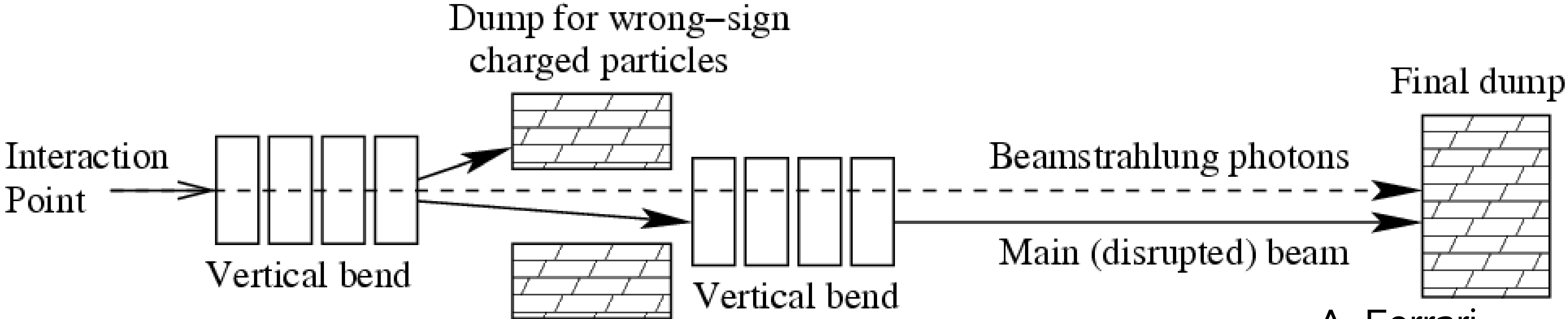
Overview

- Conceptual Design of the Beam line
- Beamstrahlung detector
- Opposite sign coherent pair partners
- Tail monitor or instrumented collimator
- Interferometric Dump Thermometer
- Image Current Monitor
- Beam-beam deflections
- Conclusions

CLIC Post-Collision Line for 1.5+1.5 TeV

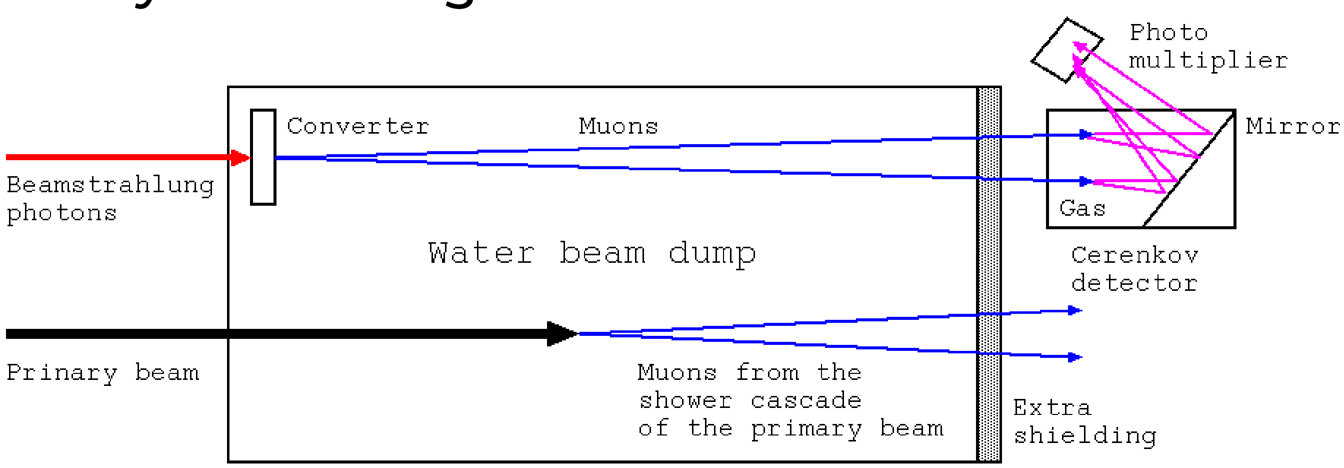
- A. Ferrari, et. al, PRSTAB 12 (2009) 021001
- Safely dispose of 14 MW beams after collision
  - when in collision (low-energy tail, losses)
  - when not in collision (drill hole in dump window)
- Simple, no quadrupoles to avoid overfocussing
- Integrated diagnostic *by design*
  - separate beamstrahlung and coherent pairs from primary beam



A. Ferrari

Beamstrahlung Detector

- Inspired by the SLC beamstrahlung detector
  - VZ: SLAC-PUB-5595 (1991), SLC-CN-379 (1990)
- The only signal from the high-energy beamstrahlung photons detectable behind th dump should be muon pairs.
- Use Cerenkov detector with a threshold to discriminate the synchrotron radiation from the chicane dipoles with ε_c=1.5 GeV.
- Fast luminosity-related signal



Muon Pair-production

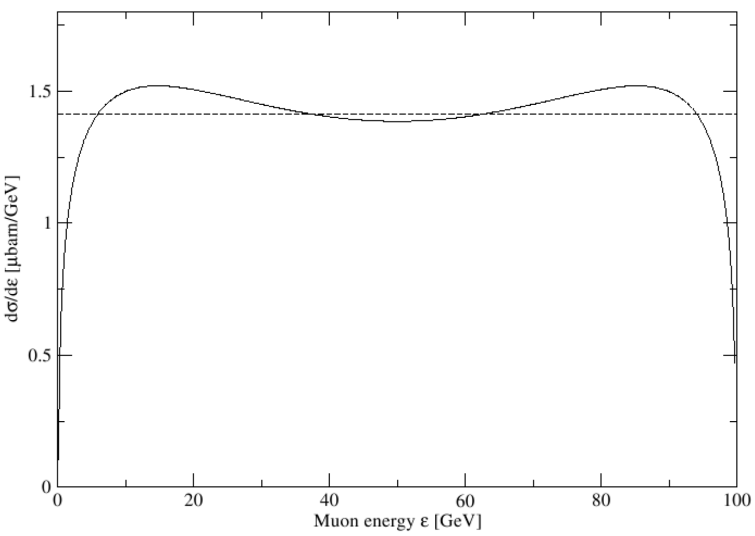
- Bethe-Heitler muon pair-production cross section

$$\sigma = \frac{28}{9} Z^2 \alpha r_\mu^2 \left(\ln \frac{2\hbar\omega}{m_\mu c^2} - \frac{109}{42} \right)$$

- Iron Z=26 and ħω=100 GeV → σ = 141 μbarn
- 1 mm iron converter plate
  - conversion rate of 1.2 10^{-6}
  - about the same for the composite carbon window

- Energy distribution of muon pairs

$$\frac{d\sigma}{d\varepsilon_+} = 4Z^2\alpha r_\mu^2 \frac{\varepsilon_+^2 + \varepsilon_-^2 + 2\varepsilon_+\varepsilon_-/3}{\hbar\omega} \left(\ln\left(\frac{2\varepsilon_-\varepsilon_+}{m_\mu c^2 \hbar\omega} \right) - \frac{1}{2} \right)$$



- Approximate: P(ε,ħω)=2/ħω

Cerenkov detector

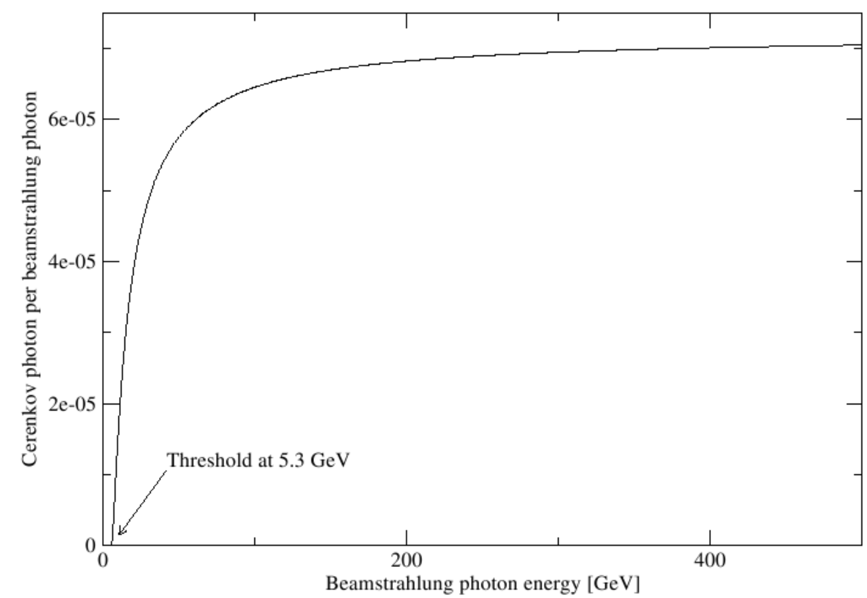
- Gas volume with 1/3 bar Ethylene: $n=1+2\ 10^{-4}$ $\rightarrow$ threshold 5.3 GeV
- Cerenkov production probability

$$\frac{dN}{d\nu} = \frac{2\pi\alpha l}{c}\left(1 - \frac{1}{\beta_\mu^2 n^2}\right) \approx \frac{2\pi\alpha l}{c}\left(1 - \frac{1}{n^2}\left(1 + \frac{1}{\gamma_\mu^2}\right)\right)$$

- Total production rate ($\gamma_B = \hbar\omega/m_\mu c^2$)

$$N = nd\sigma\int_{\gamma_0}^{\hbar\omega} 2P(\varepsilon_\mu,\hbar\omega)\frac{dN}{d\nu}\Delta\nu d\varepsilon_\mu \approx nd\sigma\frac{4\pi\alpha l\Delta\nu}{c}\left(\frac{1}{\gamma_0} - \frac{1}{\gamma_B}\right)^2$$

- with $\Delta\nu = 5\ 10^{14}$ Hz (visible range) and length of 1 m



- 1/20000 Cerenkov photons per beamstrahlung photon
- Approx. one beamstrahlung photon/electron
  - $2\ 10^5$ photons per bunch

Coherent Pair partners

- Opposite charge coherent pair partners are a clear signature of collisions
- Most of the work is already done by the design of the post-collision line
- Moderate power levels (kW scale)
- Robust drift-chamber with horizontal wires
  - momentum distribution of coherent pairs
  - has peak at 1/10 of the primary beam energy

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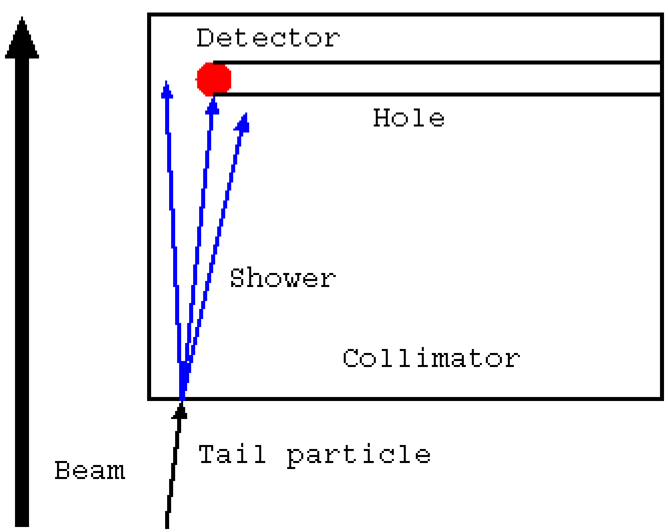
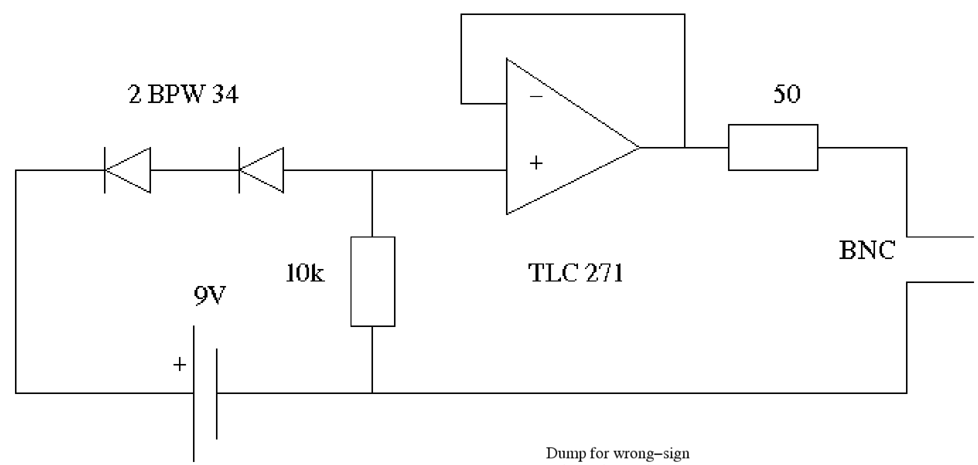
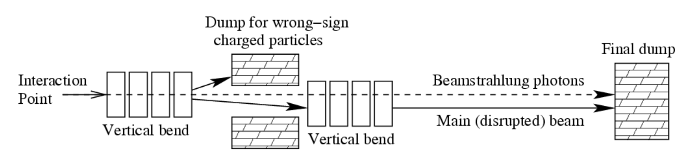
Tail Monitor or Instrumented Collimator

- Detect the particles that directly impact the collimators between the dipoles in the chicane
- Insert a detector in a hole into the collimator
- Borrow idea from HERA beam loss system
- based on PIN diodes
- Reverse biased diodes and impedance converter to 50 Ω





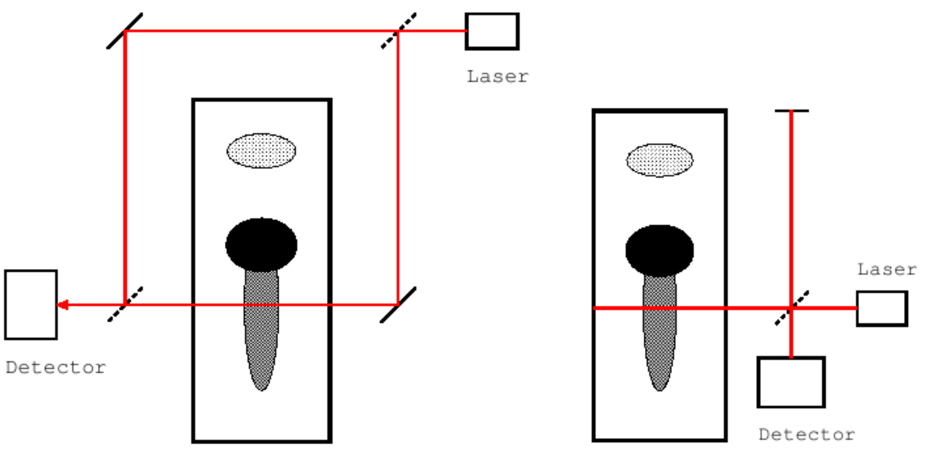


Dump Thermometer

- Refractive index of water is temperature dependent
  - $n = 1.341 - 2.262\ 10^{-5}\ T[K]$
- Use interferometer to determine changes
- Gaussian temperature distribution

$$\Delta m = \frac{1}{\lambda} \int \Delta n(x) dx \approx 96.3\, \sigma\, T_0$$

- 1 cm and 1 degree should be easily visible



- Michelson-Morley or Mach-Zehnder interferometer
- Needs testing
- Turbulence in the dump
- Windows are tricky

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Image current monitor

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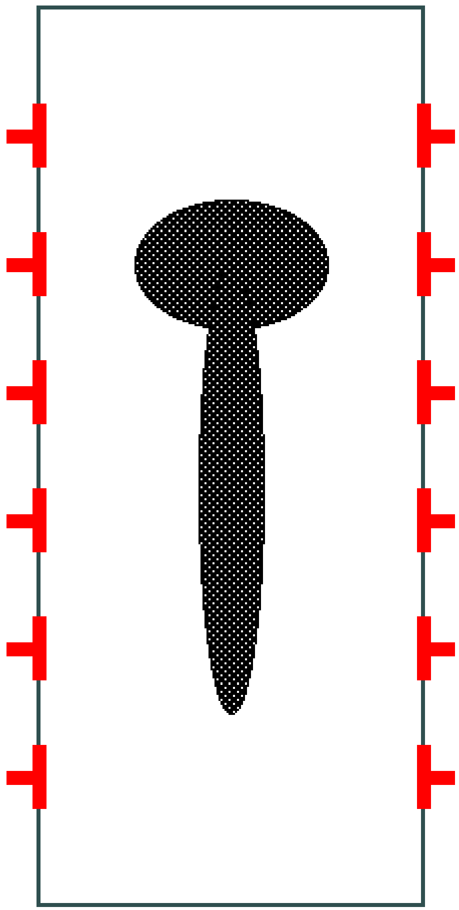
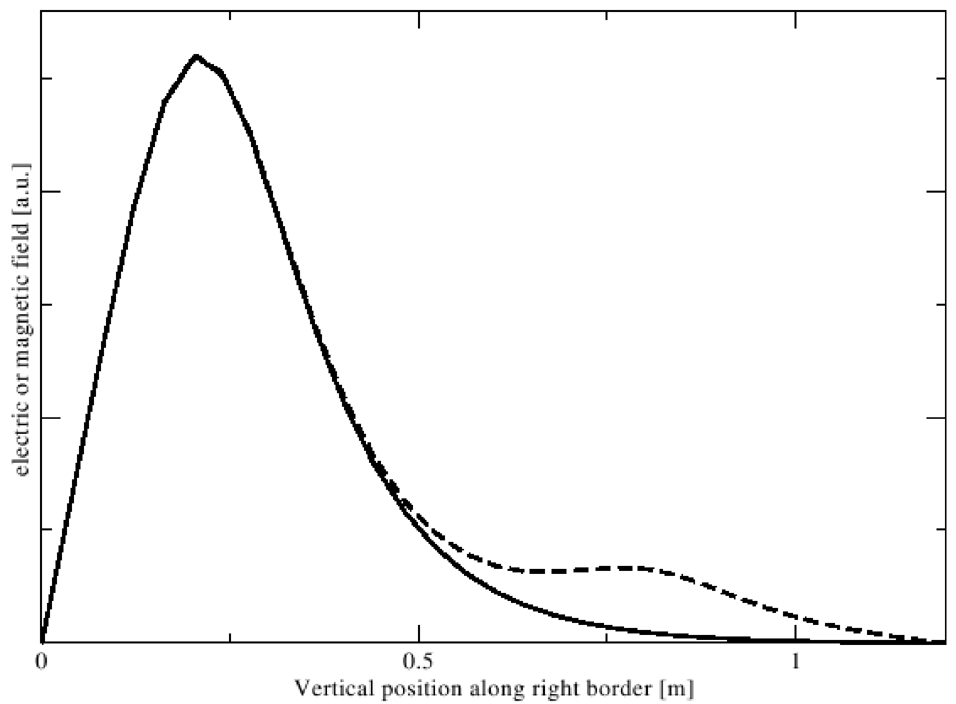
- Pick up image currents by BPM like device
- Not sensitive enough, because only a 10% tail can be detected due to wide beam pipe





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Beam-beam deflections 1

- Beam sizes should give indication of luminosity
- Show old unpublished (March '92) simulations for non-disruptive (low-current, large spots) regime
- Parameters: 500 GeV, 224x2 nm, 20 μrad, 10^{10}
- Angle reconstruction σ_{bpm}=1μm → σ(ε)=1 μrad
- $\Sigma_{x,y} = \sqrt{\sigma^2_{x,y}(e^-) + \sigma^2_{x,y}(e^+)}$
- Deflection angle
- Fit function

$$\varepsilon_y \approx -\frac{2Nr_e}{\gamma\Sigma_x}\left\{\sqrt{\frac{\pi}{2}}\,\mathrm{erf}\left(\frac{y}{\sqrt{2}\Sigma_y}\right) - \frac{y}{\Sigma_x}\right\}$$

$$\varepsilon_y = A + B\left\{\sqrt{\frac{\pi}{2}}\,\mathrm{erf}\left(\frac{y-D}{\sqrt{2}C}\right) - \frac{y-D}{\Sigma_x}\right\}$$

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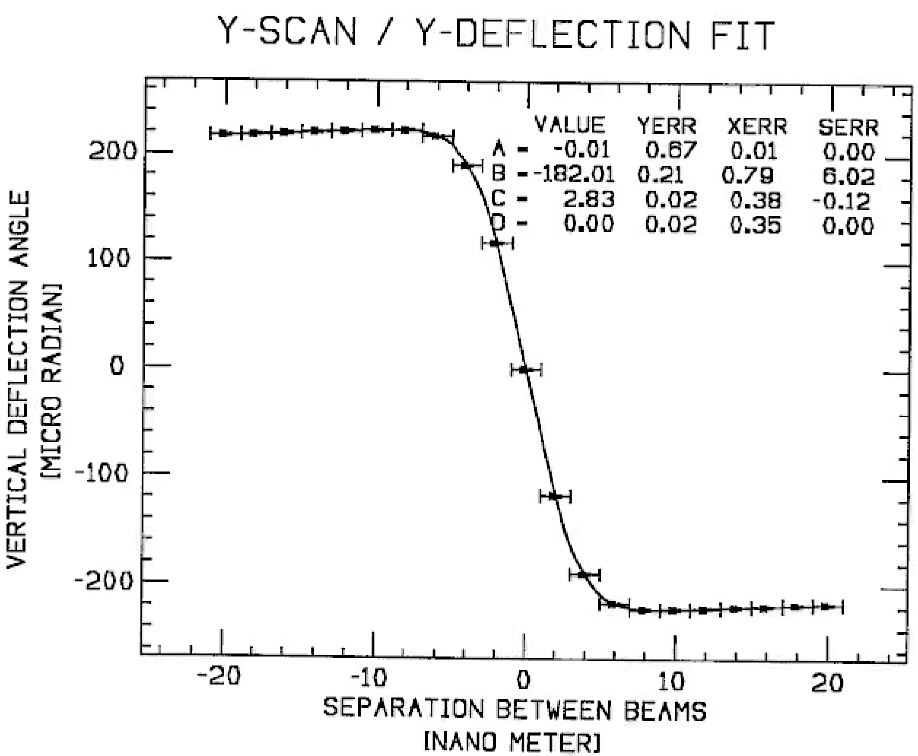
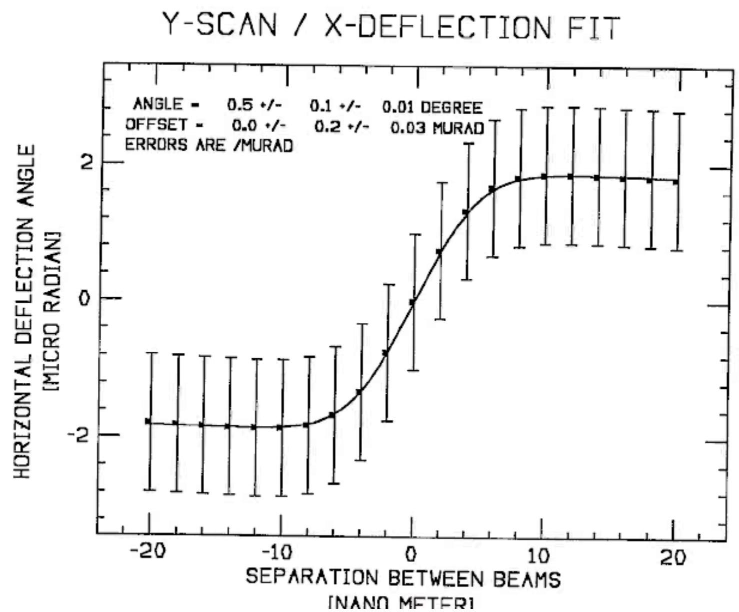
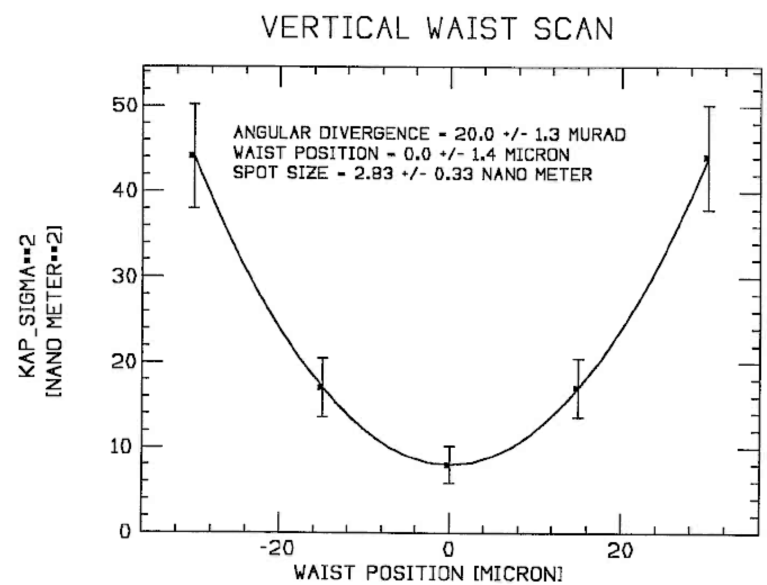
Beam-beam deflections 2

- Vertical scan
  - size and tilt angle, angular divergence







Conclusions

- Looked at several non-standard diagnostic devices for the CLIC post-collision line
  - Beamstrahlung detector most promising
  - Coherent pair detector built-in
  - Tail monitor needs GEANT simulations
  - Dump thermometer needs testing
  - Image current monitor too insensitive
  - Beam-beam deflections for initial tuning
- More detailed studies needed (as always).