CORNELL UNIVERSITY LEPP

LABORATORY FOR ELEMENTARY-PARTICLE PHYSICS

First observation of large Angle Beamstrahlung

Giovanni Bonvicini

WAYNE STATE UNIVERSITY

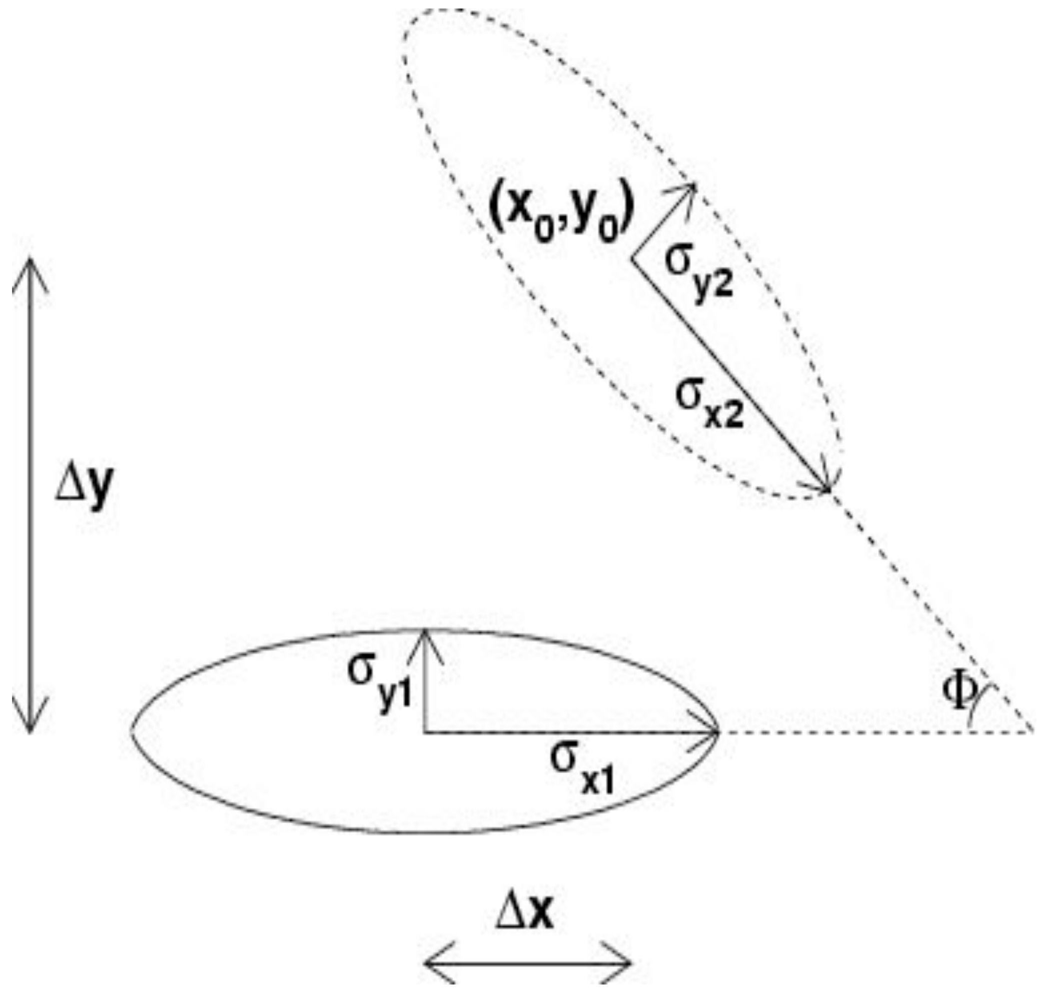
National Science Foundation

WHERE DISCOVERIES BEGIN

What is beamstrahlung

- The radiation of the particles of one beam due to the bending force of the EM field of the other beam
- Many similarities with SR but
- Also some substantial differences due to very short "magnet" ($L=\sigma_z/2\sqrt{2}$),very strong magnet (3000T at the ILC). Short magnets produce a much broader angular distribution

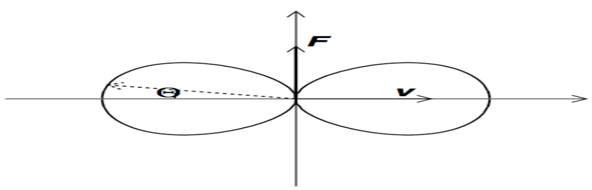
Beam-beam interaction (BBI) d.o.f. (gaussian approximation)

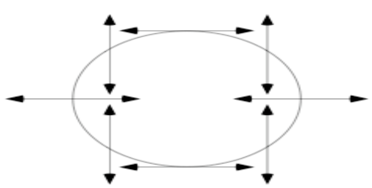


BBI d.o.f. counting at the ILC

- 7 gaussian transverse d.o.f.
- 2 beam lengths
- At least 4 wake field parameters, and possibly 2 longitudinal
- Total 13-15 BBC parameters that may affect the luminosity

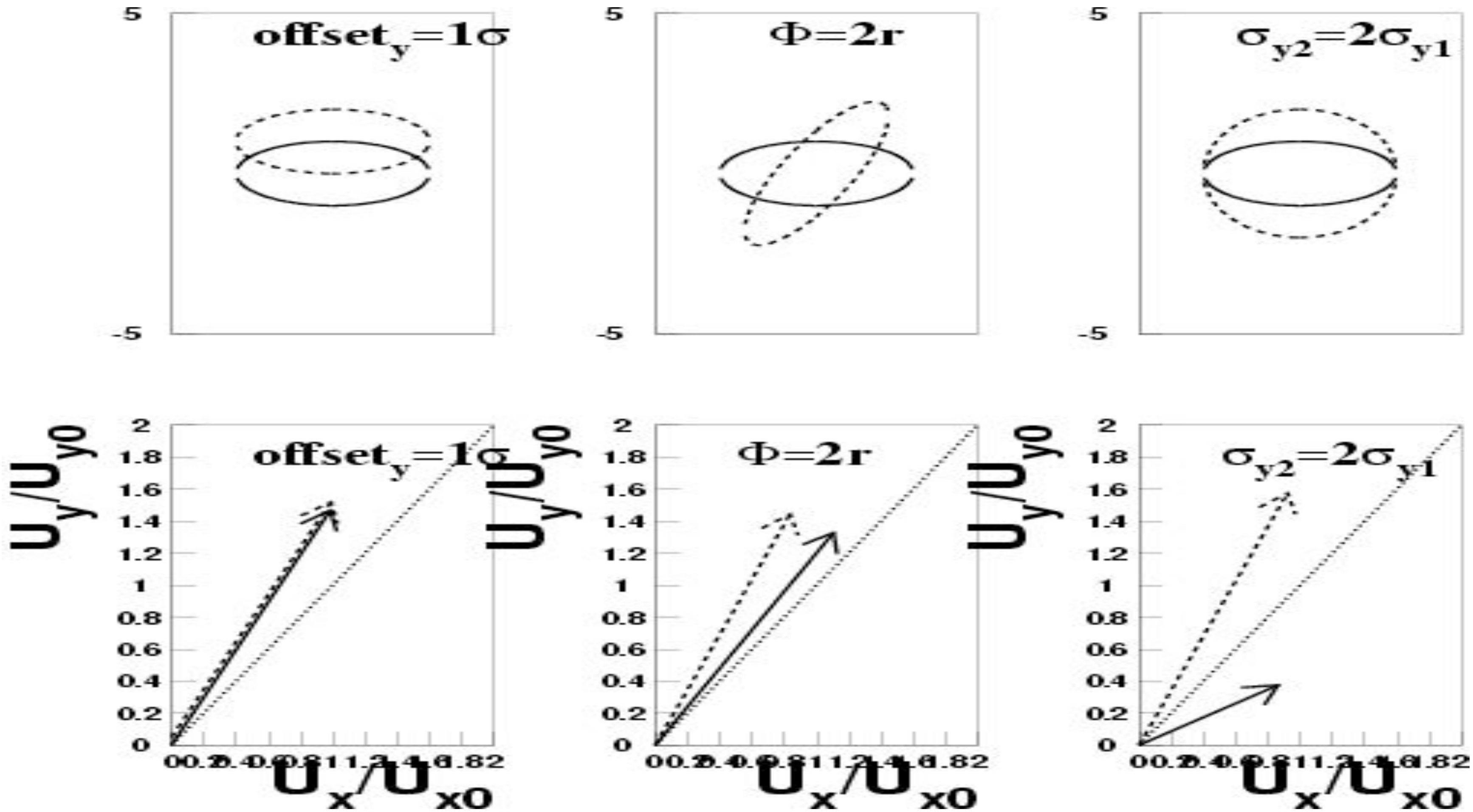
Properties of large angle radiation





- It corresponds to the near backward direction in electron rest frame (5 degrees at CESR, 2-4 degrees at KEKB/SuperB, 7 degrees at DAPHNE)
- Lorentz transformation of EM field produces a 8-fold pattern, unpolarized as whole, but locally up to 100% polarized according to $\cos^2(2\phi)$, $\sin^2(2\phi)$ with respect to direction of bending force (Bassetti et al., 1983)

Some examples of Large Angle BMST pattern recognition

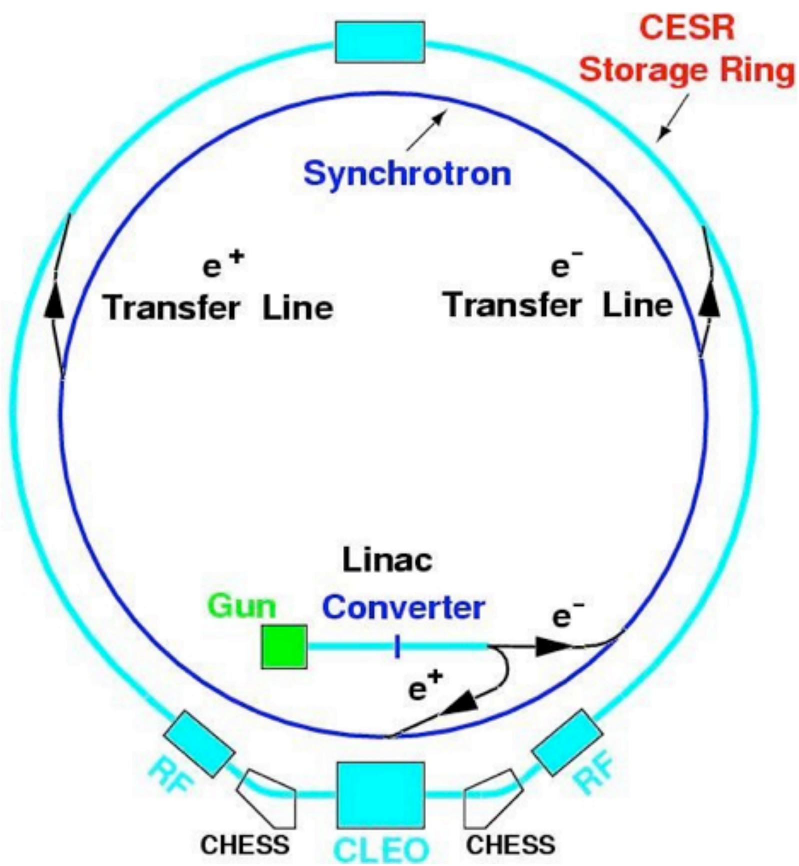


Large angle beamstrahlung power

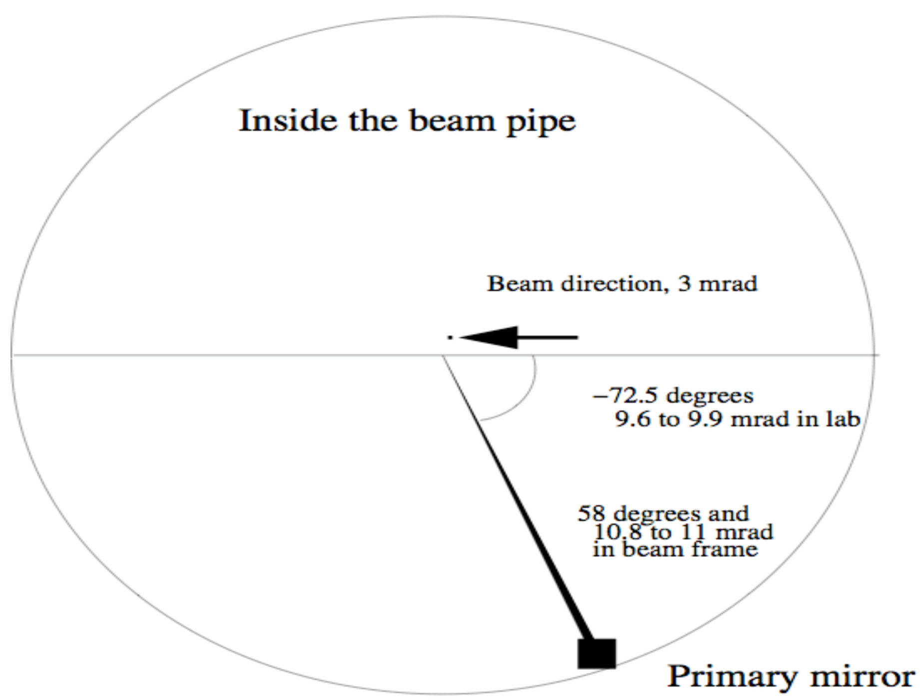
- Total energy for perfect collision by beam 1 is: $P_0 = 0.11\gamma^2 r_e^3 mc^2 N_1 N_2^2/(\sigma_x^2\sigma_z)$
- Wider angular distribution (compared to quadrupole SR) provides main background separation
- CESR regime: exponent is about 4.5
- ILC regime: exponent is very small
- KEKB: exponent is small

$$\frac{d^2 I}{d\Omega d\omega} = \frac{3\sigma_z}{4c\pi\sqrt{\pi}} P_0 \frac{1}{\gamma^4\theta^4} \exp\left(\frac{-\omega^2\theta^4\sigma_z^2}{16c^2}\right)$$

CESR location

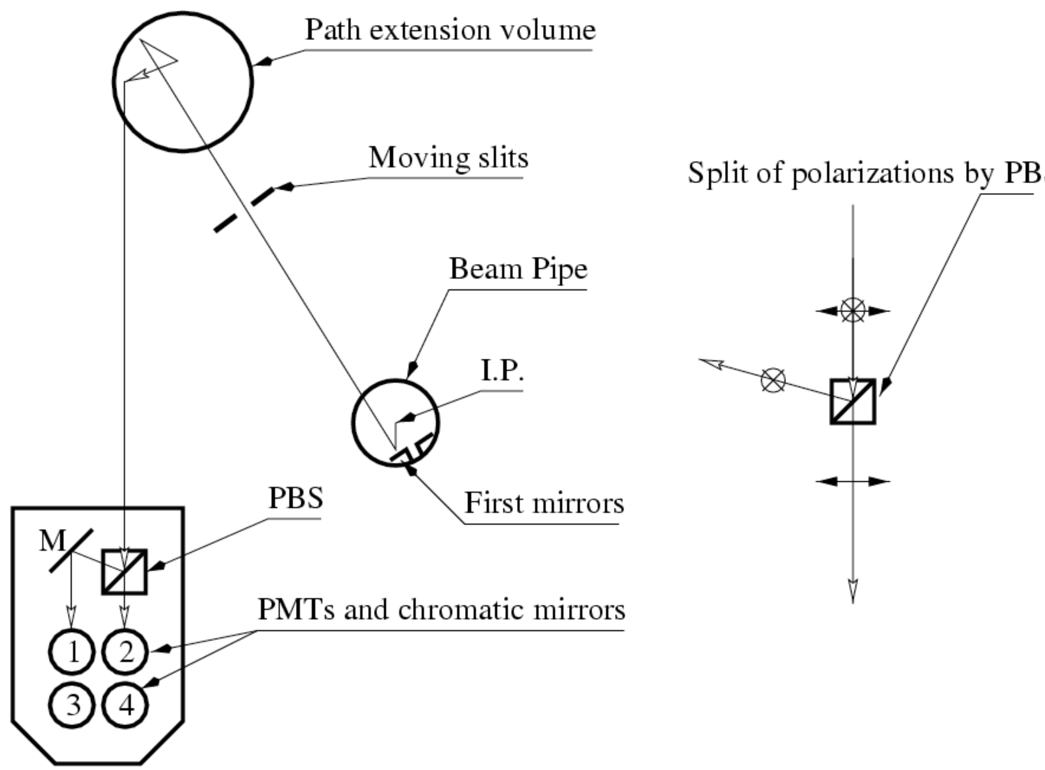


Beam pipe and primary mirror



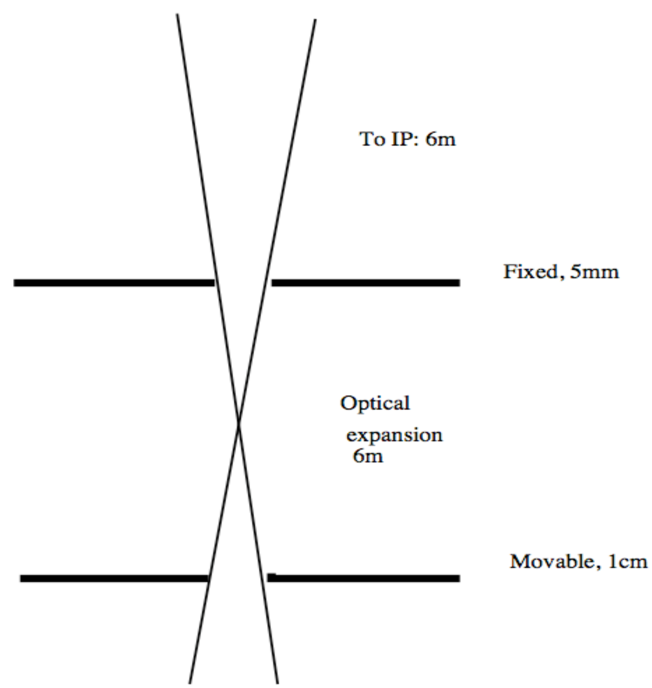
¼ Set-up principal scheme

- Transverse view
- Optic channel
- Mirrors
- PBS
- Chromatic mirrors
- PMT numeration



Detector parameters of interest

- Diffraction limit is 0.1 mrad. Sharp cutoff can be assumed
- Optics is double collimator. Has triangular acceptance with max width of 1.7mrad
- At IP, accepted spot is about 1cm



Set-up general view

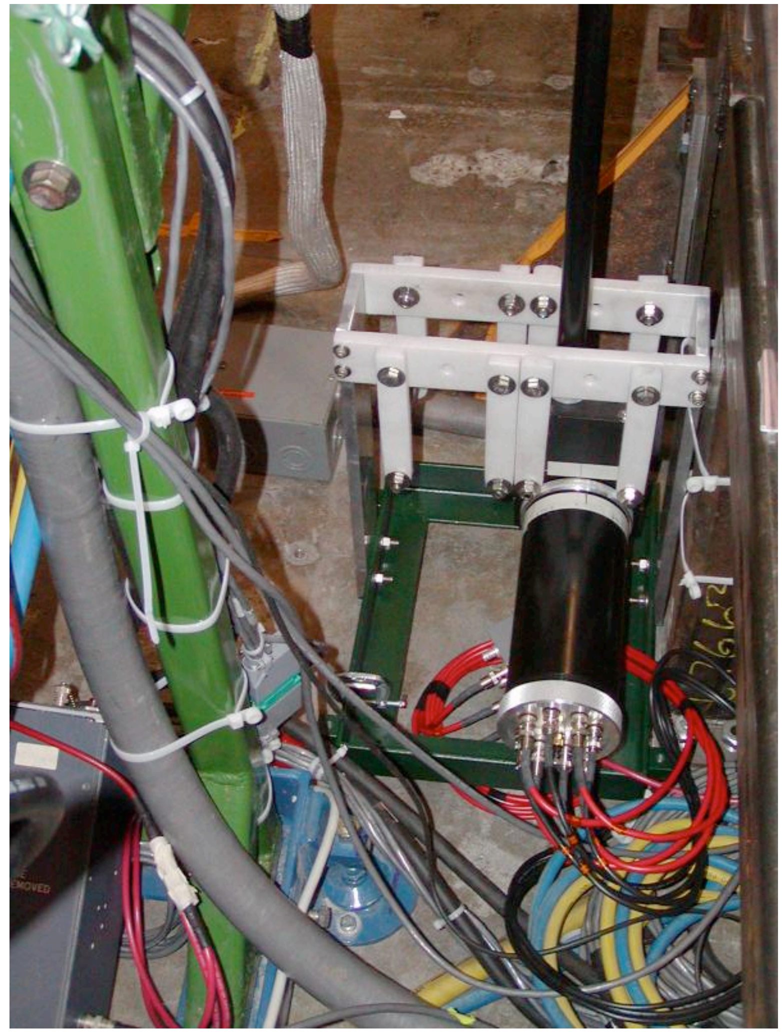
- East side of CLEO
- Mirrors and optic port ~6m apart from I.P.
- Optic channel with wide band mirrors

On the top of set-up

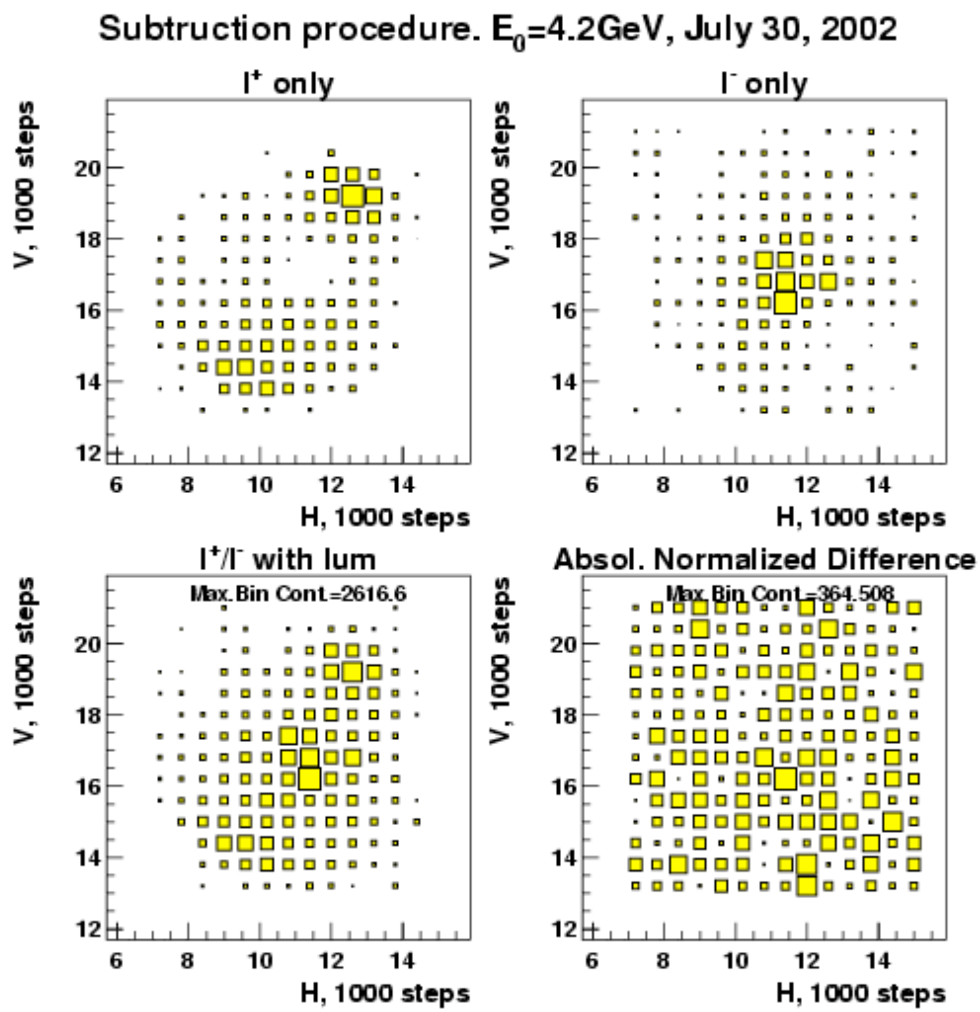
- Input optics channel
- Radiation profile scanner
- Optics path extension volume

The ¼ detector

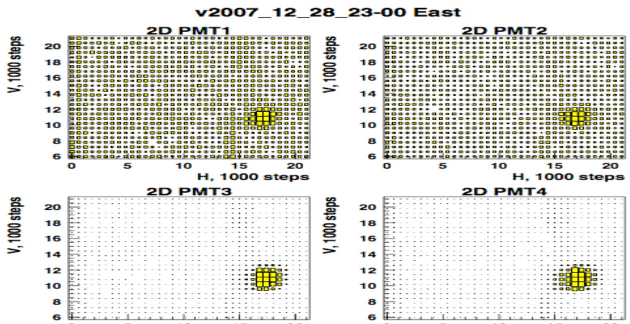
- Input channel
- Polarizing Beam Splitter
- Dichroic filters
- PMT's assembly
- Cooling…

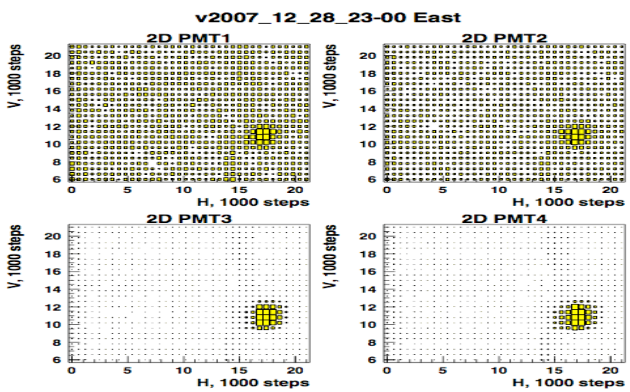


Check for alignment @ 4.2GeV



Directionality

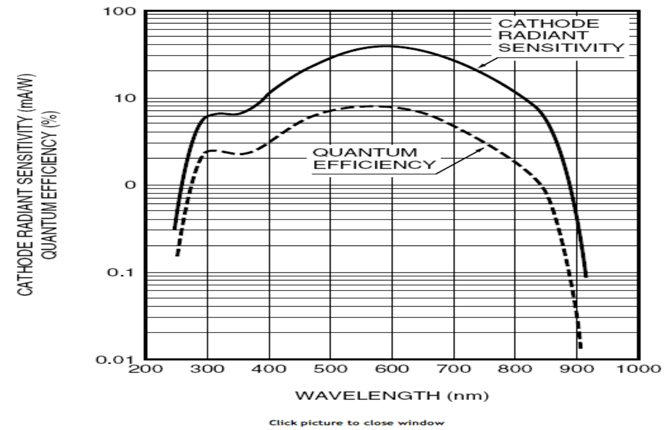


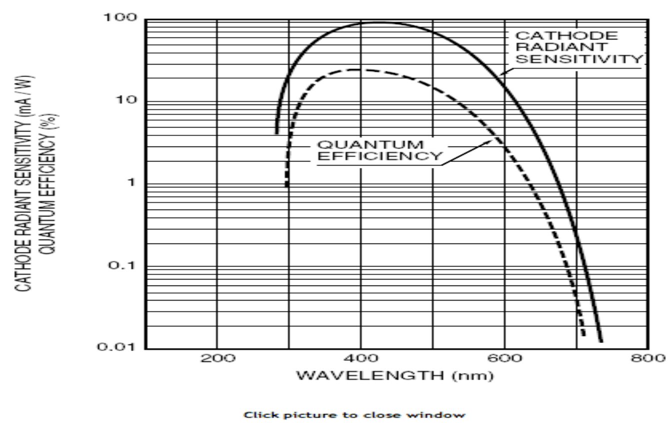


- Scanning is routinely done to reconfirm the centroid of the luminous spot.

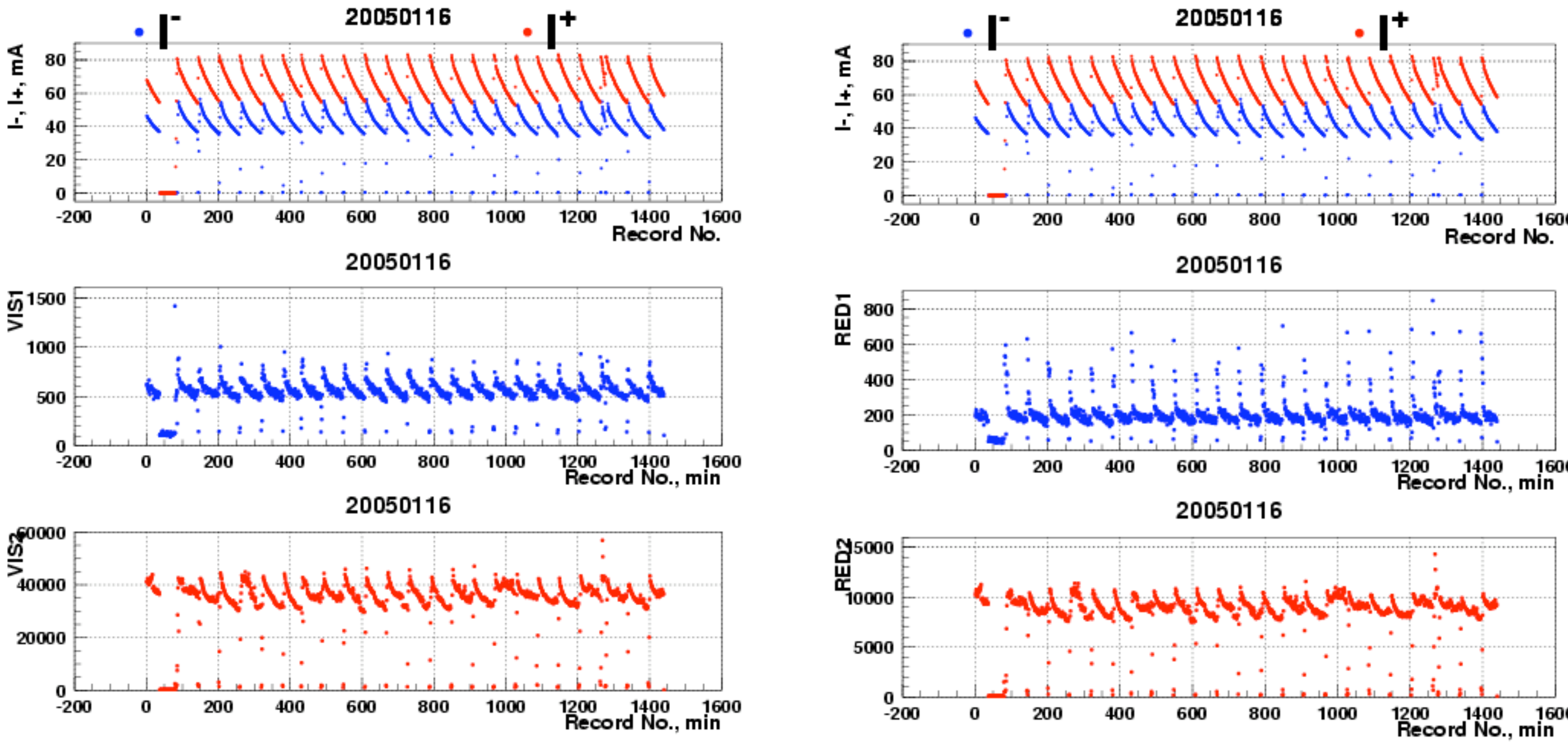
Photomultipliers

- IR: R2228, has relatively high noise (3-5 kHz). Has filter at 775 nm
- VIS: R6095, almost noise-free, has no filter
- Previous IR PMTs R-316-02 were discontinued





PMT rate correlations with beam currents



Typical rates

- At HEP conditions, VIS PMTs (West) will have a rate of about 300kHz (0.1Hz channels are used) and IR PMTs about 6kHz.
- In the East, 60kHz and 2kHz.
- Expected BMST rates are about 500Hz at the nominal theta

Detector systematics detail

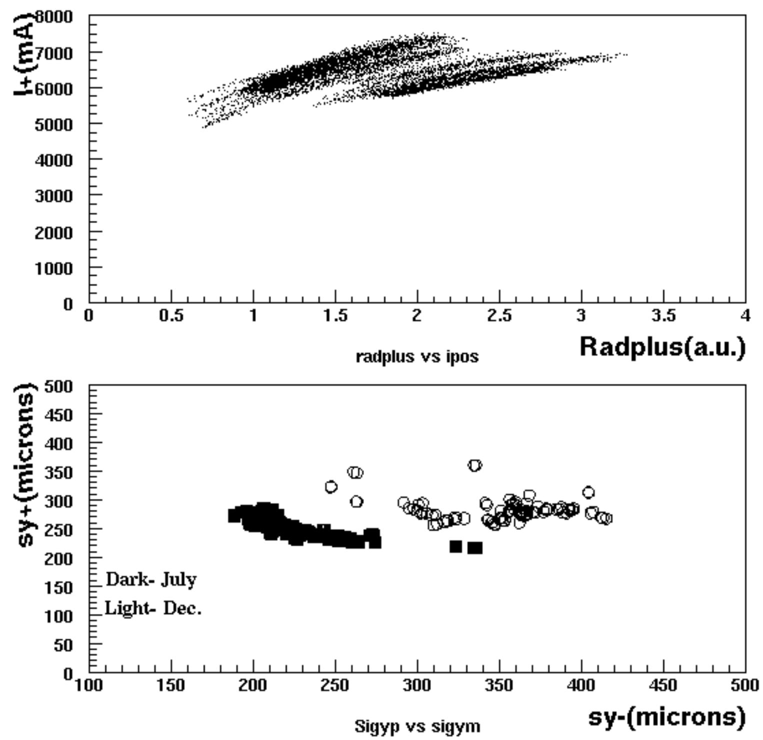
- Flashlight calibration measures all relative efficiencies to about 0.3%. Absolute efficiencies of VIS PMT >90%, optical channels assumed to be 75+-25%.
- Recurrent electronic noise problems on East side (electrons)
- Two major data taking periods in July and December 2007 (about 120 good fills each), with dark noise measured every 8 hours.

Data analysis method

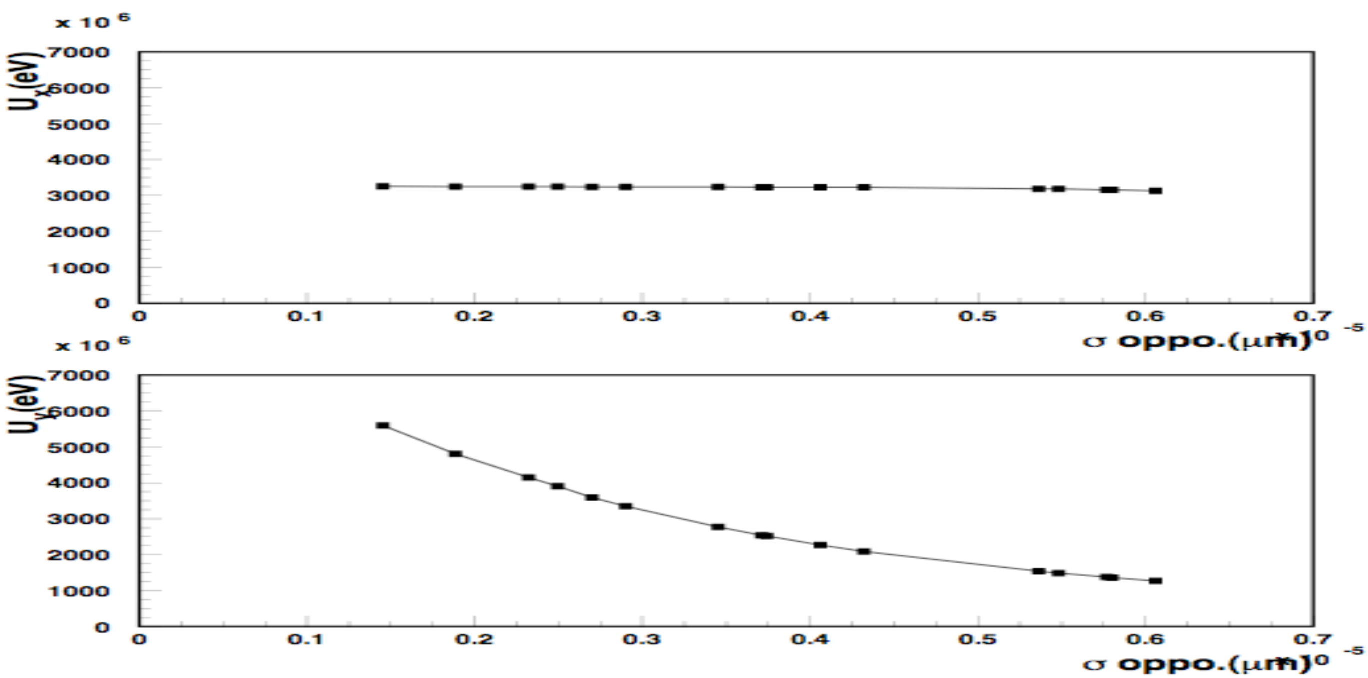
- The signal sought ought to increase IR light w.r.t. VIS light when a strong beam is opposite, so $IR/VIS=k_1+k_2I_{oppo}^2$
- The method also takes into account possible small variations of the bkg through normalization with VIS light
- The expected signal in VIS light is of the order of 10^{-4} of the rate and can be safely ignored
- Runs are minimally selected (continuous beams for at least 600 seconds) with chi square and dark noise (cleaning) cuts later to take care of noisy ones

Natural variability of machine provided crucial evidence

- In July, relatively high e+ current and relatively low e- current. In December, currents are more balanced, providing a stronger expected BMST signal
- In July, e- beam was smaller than e+. In December, the reverse was true. Differing polarizations expected

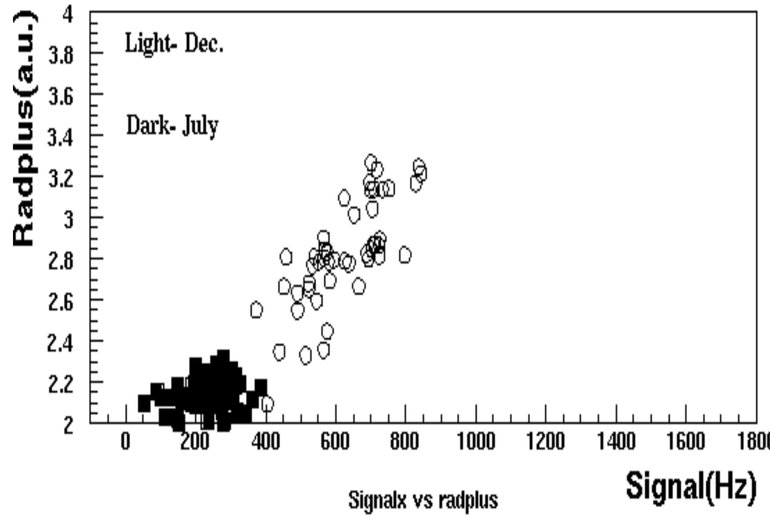


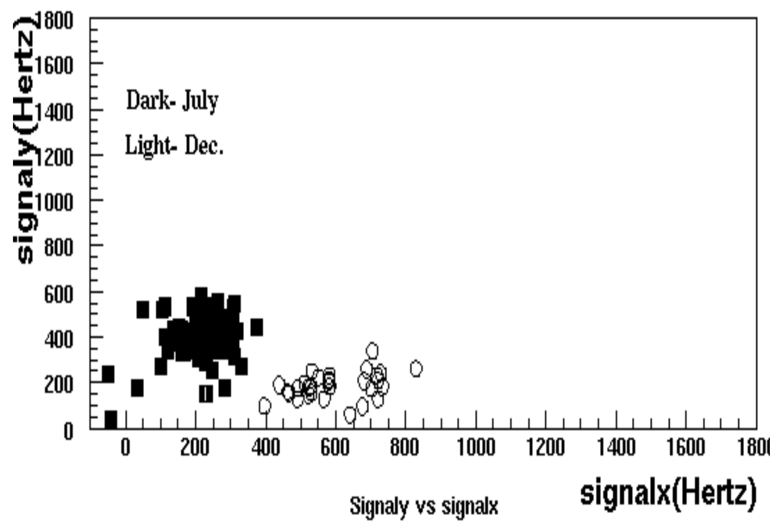
Variation of polarized components versus σ_{yoppo}



Main results page

- Signal(x) strongly correlated to $I_+I_-^2$
- Signal strongly polarized according to ratios of vertical sigmas
- Total rates consistent with expectations at 10.3 mrad





Numerous cross checks

- For those runs where the electron tail did not vary, positive signals are always seen
- Angle scans show a signal pattern consistent with point-like source. Background pattern is sloping
- Signal scatter decreases for low noise runs
- Signal scatter decreases when selecting bands of delta_VIS
- Signal is negatively correlated with sigma_x, sigma_z as measured by CLEO

Summary

- The first generation Large Angle Beamstrahlung detector was successful, but…
- This technique is dominated by systematic errors, therefore its only figure of merit is S/B

- In order to make this technique into a 1% BBI monitor, three conditions must be met:
- - S/B >>1 (it was 0.02-0.07 at CESR). We can tolerate lower S/B if the tails are proven to be constant during a fill
- -Much better control over systematics

Conclusions

- Large angle Beamstrahlung seen at CESR
- Its main features confirmed - in particular, polarization effects
- Major sources of systematics found
- Interesting for future accelerators in an area of strong need