Post Collision Diagnostics Beamline
or
Post Collision Beamline Diagnostics?

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- **Motivation**
- **What comes out of the IP**
- **Separating the different beams**
- **Coherent Pair Diagnostic**
- **Beam Dump Calorimetry**
- **Conclusions**

Motivation

- Need to get rid of the beams after collisions.
- Make sure to minimize background to the experiment.
- Need to diagnose what happened in the collisions:
    - Luminosity, beam size and centering.
- Need to measure on fast time scales to counteract jitter.
- The post-collision beamline is the place to do it.
- Other considerations:
    - Operate at low and high intensity.
    - Time scales: bunch-to-bunch, within bunch-train, averaged

What comes out: Primary Beam

- Simulations done with Guinea_pig.
- E=1500 GeV, 60 x 0.7 nm, 4 x 10^9 particles/bunch.

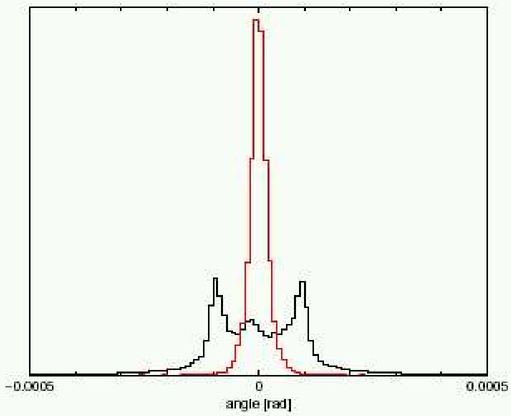


Figure 1: The horizontal (black) and vertical (red) angular divergence of the electron (or positron) beam.

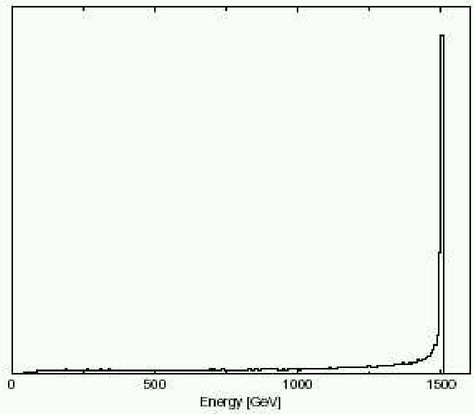


Figure 2: The energy distribution of the electron beam.

- Angular Distribution has rms 140 and 20 μm.
- Double peaked due to electric field of target beam.
- Energy Distribution has pronounced low-energy tail.

What comes out: Beamstrahlung

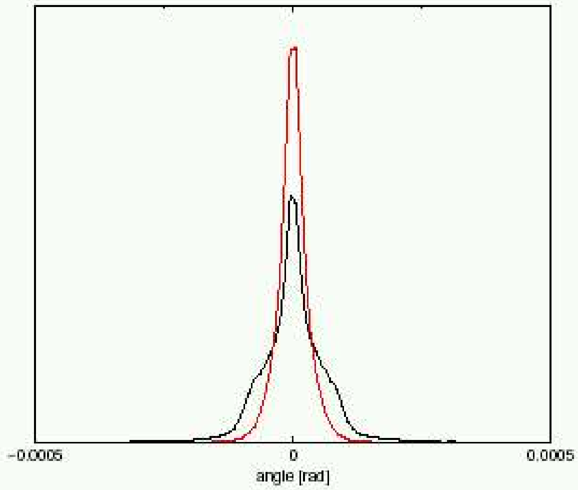


Figure 3: The horizontal (black) and vertical (red) angular distribution of the number of beamstrahlung photons.

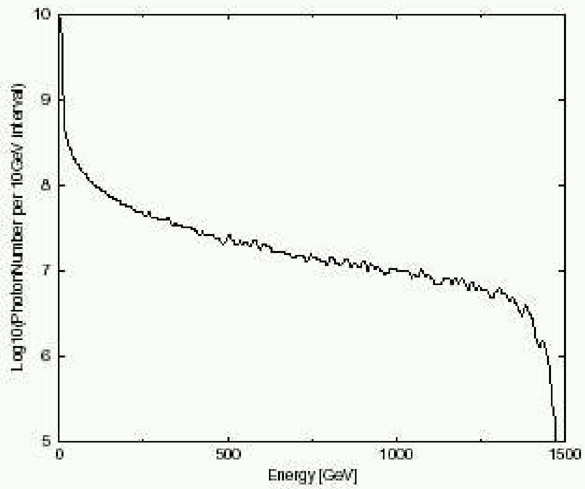


Figure 4: Relative number of beamstrahlung photons as a function of energy.

- Angular distribution has rms of 140 and 100 μm.
- Large number of low energy photons.
- Will not consider this further for the time being.

What comes out: Coherent Pairs

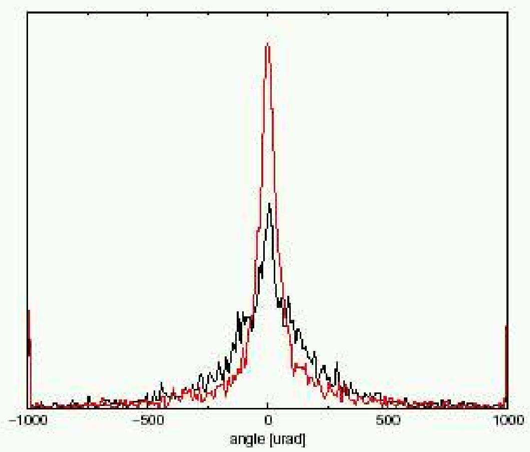


Figure 5: The horizontal (black) and vertical (red) angular distribution of the number of coherent-pair leptons.

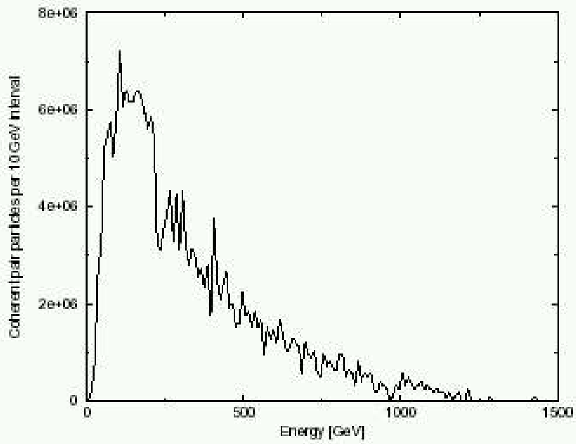


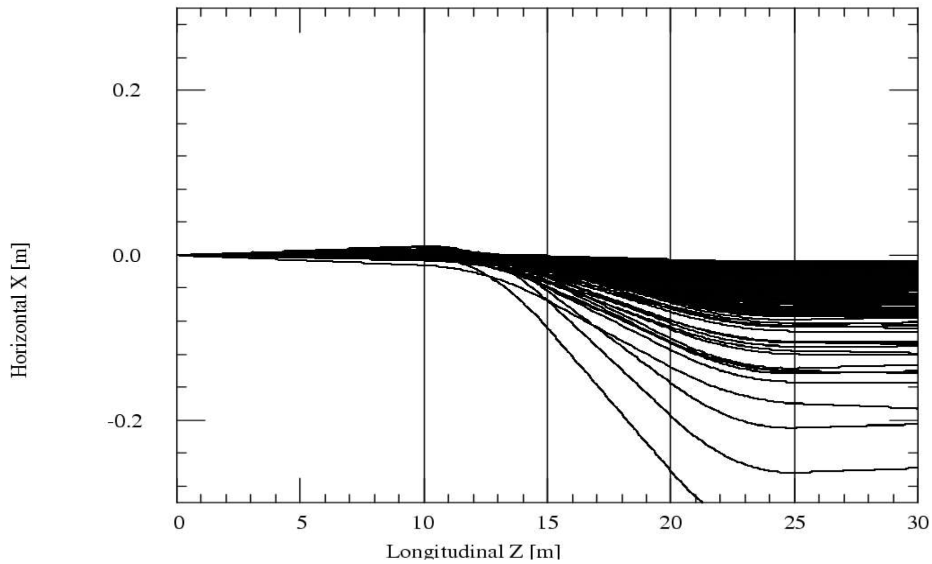
Figure 6: Number of particles in coherent pairs in a 10 GeV interval as a function of energy. Note that only half of the particles are positrons.

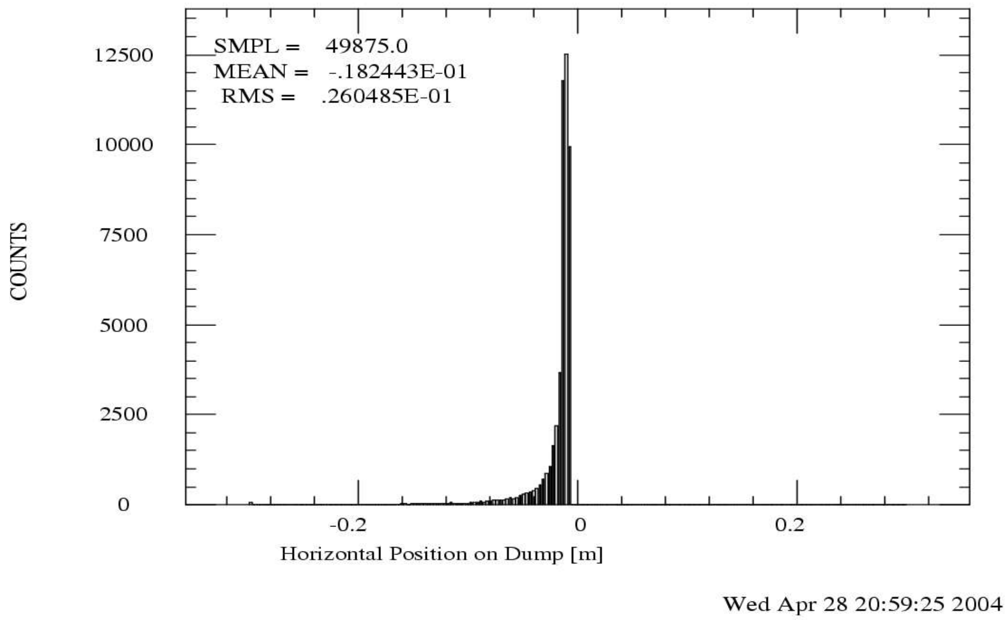
- Angular Distribution has rms of 330 and 390 μm.
- Energy Distribution is peaked at 1/10 times the energy of the primary beam.
- But goes up to almost the beam energy.

Separating the different beams

- Need to separate the beams to diagnose the constituitive parts.
- Probably need a chicane?
- Horizontal or vertical?
- (+1, -1) or (+1,-2,+1)?
- Gradient in the dipoles to blow up the beam size to alleviate the stress on the beam dump.
- Chicane generates synchrotron radiation, extra stress.
  - Critical photon energy is about 1.5 GeV.
  - Emit about 9 J/bunch/magnet → 180 kW average total load.
- Blow up the vertical or horizontal beam size?
- Need simulation package.
- Large energy spread makes direct integration of Lorentz-force equations necessary.
- Easy to define magnetic fields in space regions and aperture restrictions (e.g. detector solenoid and beam pipes).
- Use guinea_pig output files and pipe them through a simple first order integrator and plot trajectories and distribution on dump
- Example: IP + (10m) + (5m,1T) + (5m) + (5m,-1T) + (5m) + dump
- Primary beam is horizontally offset by 10 mm.

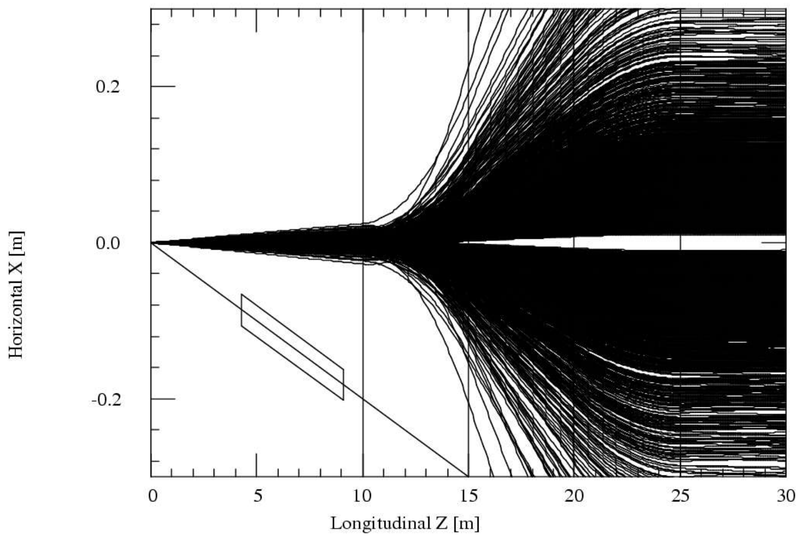
The Primary Beam in the Post Collision Beamline

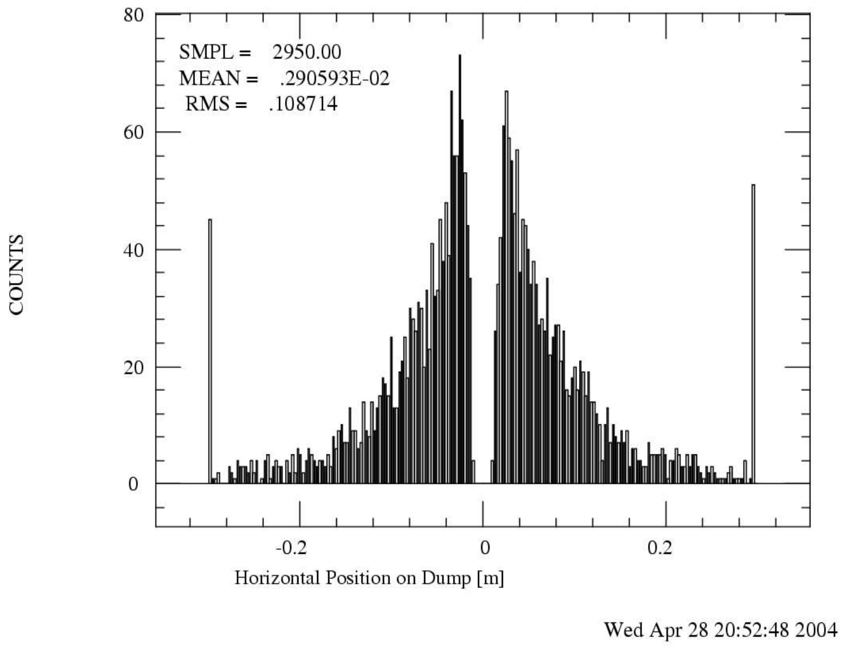




- Dump distribution mostly reflects the momentum distribution.
- Reduces direct back-shine.
- Separated from Beamstrahlung.

The Coherent Pairs in the Post Collision Beamline





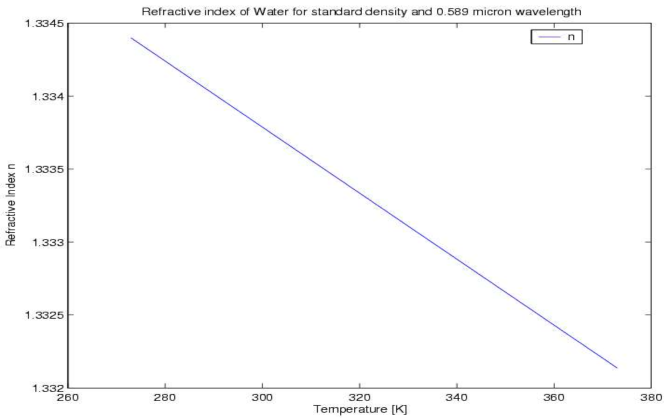
- Electron and positron pairs nicely separated.
- Coherent positrons on electron side are a unique echo of the luminosity generating process at the interaction point.
- There are a few flyers shown as the spikes at the histogram ends.
- Need to address losses.

Coherent Pair Diagnostics

- The anti-partner (positron in the electron beam line) of the coherent pairs is a unique indicator of the luminosity generating process.
- Coherent Pairs peak at about 150 GeV.
- Coherent beam is spread out, smeared due to angular spread.
- Number of positrons in peak value of coherent pair distribution is about 3×10^5 positrons/collision.
- Pulse duration is about 0.12 ps (35 μm bunch length).
- Bending radius for 1 T field is 330 m for 100 GeV.
- Peak power in a 1 m long magnet 5×10^6 W.
- Total Energy is 6×10^6 J or 3.6×10^{12} eV per pulse.
- Critical Energy of photons is 6.6 MeV
- About 0.5×10^6 photons are emitted in 1% energy bandwidth.
- Should be easy to detect.
- Signal carries the time structure of the luminosity, bunch-by-bunch.
- Use streak camera or diodes? Other?
- maybe use a magnetic horn to capture the positrons, similar to a positron source.

Beam Dump Calorimetry

- Beam Dump is an extremely hostile environment.
- Preferably non-invasive diagnostic equipment.
- Utilize the fact that the refractive index of water is temperature dependent. ($n = 1.341 - 2.262\times10^{-5}\ T$)



- Measure that with an interferometer.
- Assume area with rms width σ, where temperature differs with a gaussian profile and peak temepratur T_0.
- Number of wavelength change when traversing that area

$$\Delta m = 96.3\ \ \sigma[m]\ \ T_0[K]$$

- Temperature *variations* of the order of mm and fractions of K should be detectable.
- Temperature profiles by scanning.
- Tomographic reconstruction of 2D or 3D temperature distributions.
- Difficulties:
    - Rapidly flowing water
    - Turbulence in the water
    - Changing refractive index bends the rays.
    - Need at least one input window and a mirror.

Conclusions and Questions

- Chicane (type? orientation?)
- Coherent Pair Diagnostic (how? what detector?)
- Beam Dump Calorimetry
- Beamstrahlung Detector (Who? How? Where?)