The DØ Run II Luminosity Monitor

- **Introduction**
- **Counter Design**
- **Performance**
- **Multiple Interaction Flags**
- **Readout Electronics**
- **Summary**

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by

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for

The DØ Collaboration

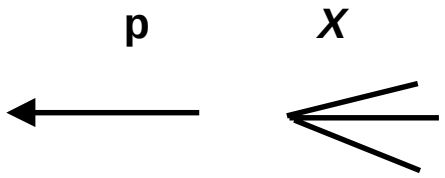
- **Using a Measured Cross Section**
  - **The total $p\bar{p}$ cross section:**

    Elastic cross section: (~20mb)

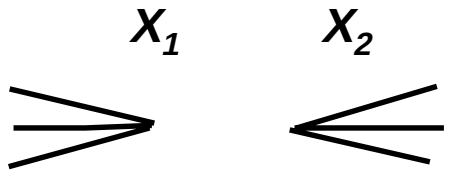
    - ▲ $p\bar{p} \rightarrow p\bar{p}$

    Inelastic cross section: (~ 59mb)

    - ▲ $p\bar{p} \rightarrow pX$ (single diffractive): (~9.5mb)



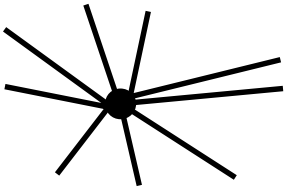
    - ▲ $p\bar{p} \rightarrow X_1X_2$ (double diffractive)



$\sigma_{DD} \sim \sigma_{SD}^2 / 4\sigma_{EL}$

~ 1.2 mb (est.)

    - ▲ $p\bar{p} \rightarrow X$ (hard scattering)



~ 48 mb (est.)

Run I (1992-96)
Luminosity Measurement

- **Count the interaction rate (R_{LM})**
  - Two arrays of plastic scintillation counters with PMT readout
    - with high efficiency and maximal acceptance for non-diffractive inelastic collisions

- **σ_{LM} : visible cross section**

$$= \varepsilon_{LM} (A_{SD}\sigma_{SD} + A_{DD}\sigma_{DD} + A_{HC}\sigma_{HC})$$

  - ε_{LM} : counter efficiency
  - A: acceptance (A_{SD} =0.15, A_{DD} =0.72, A_{HC} =0.97)
  - Fermilab TM-1930, 1995, 2000

- **Luminosity = $- \ln (1 - R_{LM}\tau) / \sigma_{LM}\tau$**
  - Use Poisson statistics to correct for multiple interactions
  - Uncertainties: 5.3%
    - DØ related: 2.6%, non-DØ related: 4.6%
    - Goal for Run II: DØ related $\leq$ 2%

Luminosity Monitor Secondary Goals

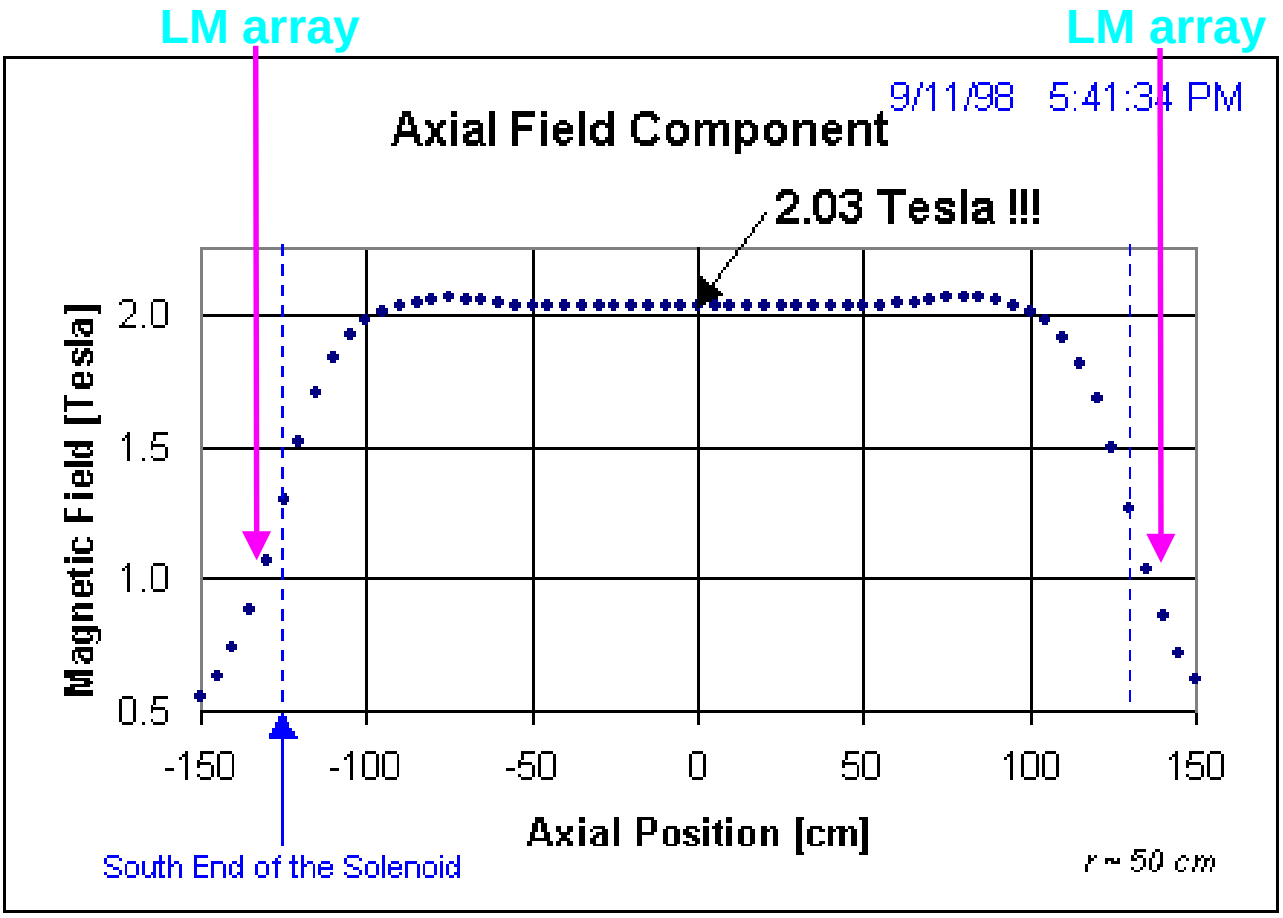
⇒**Require a good time-of-flight resolution (~250 ps)**

- **Secondary goals:**
  - **Accelerator diagnostic information**
    - **Vertex position: $Z_{vertex} = ½ \bullet (t_{-z} - t_{+z})c$ (σ_Z = 3.5cm in run I)**
    - **Beam halo rate: Z_{vertex} ~ LM location**
    - **Beam optics(interaction region lattice and beam size…)**

      (FERMILAB-CONF-97-184-E, Jun 1997)
  - **Multiple interaction tools**
    - **S/B ratio = 10 @ 90% efficiency**
  - **Large η trigger coverage for diffractive and rapidity gap triggers**

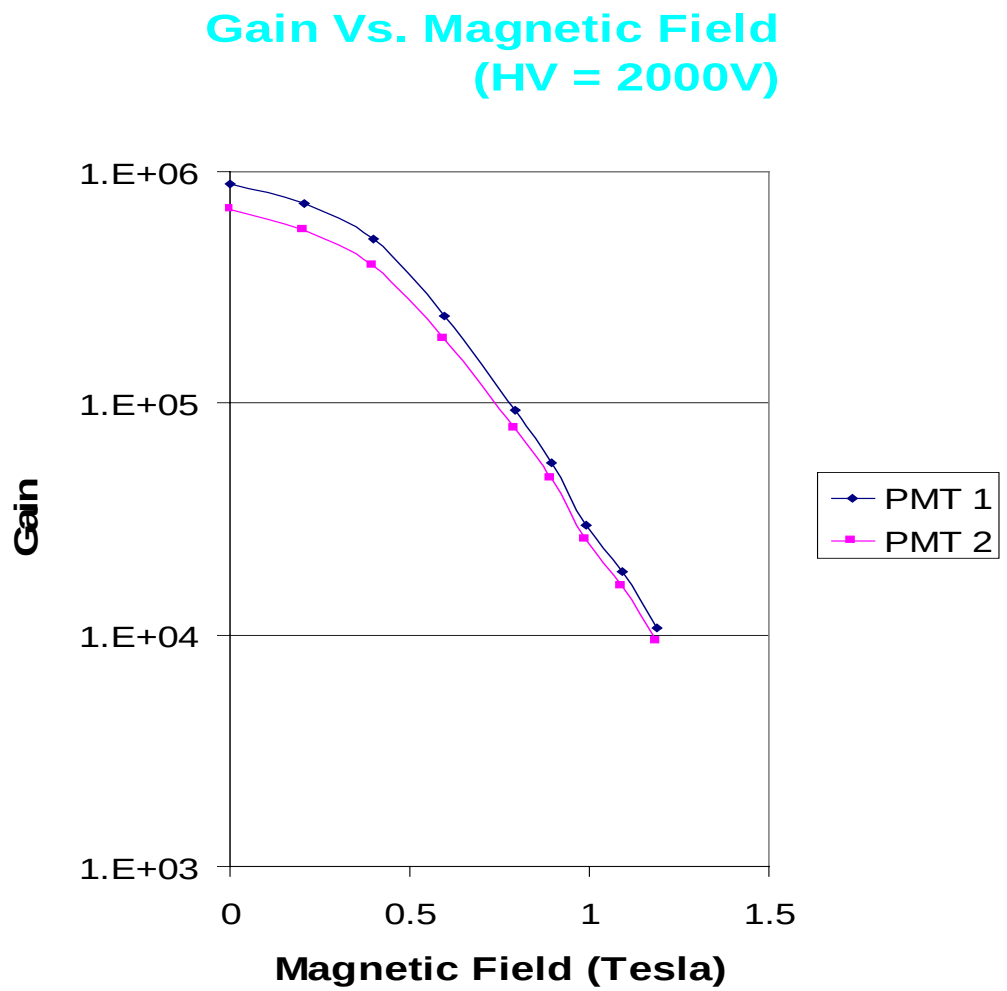
DØ Magnetic Field (Run II)

- **The DØ magnet will provide 2T field**
- **LM will be located at Z = ± 135cm from the center of the D0 detector**
- **Axial magnetic field of ~1 Tesla**



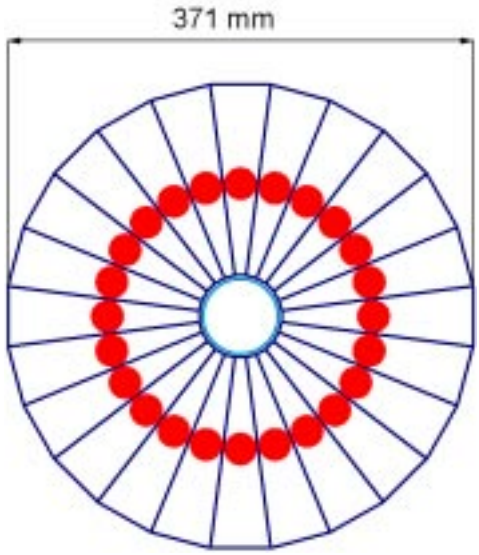
Magnetic Field Effect on PMT Gain

- **Hamamatsu 1″ (26 mm) diameter fine-mesh photomultiplier (R5505) tubes**
- **Gain of > 10,000 @ 1 Tesla measured**

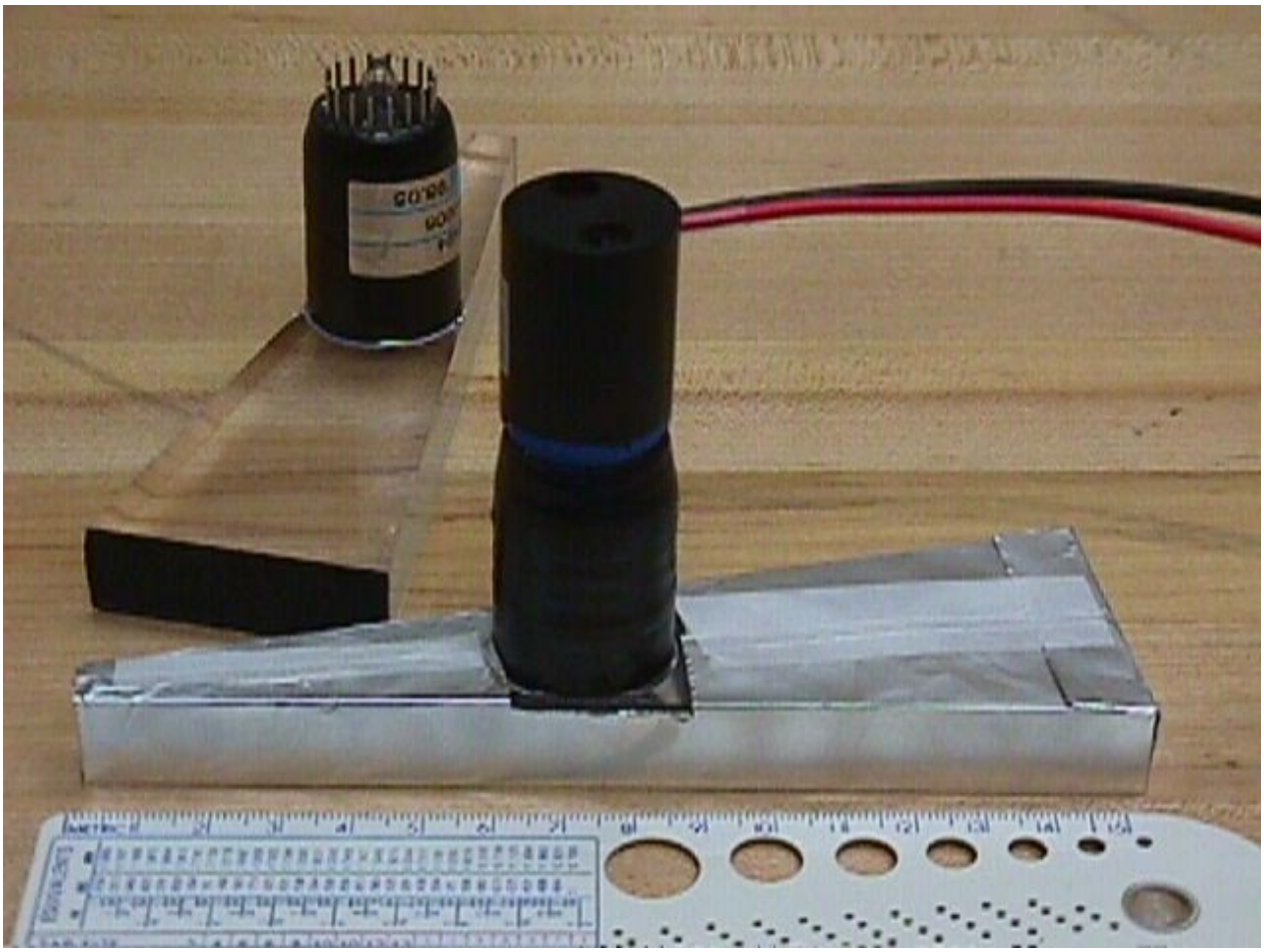


Run II Counter Design

- **Two arrays of 24 identical 1.6 cm thick BC-408 scintillator wedges**
  - **arranged symmetrically about the beam axis (inner edge 3.3 cm from the beam axis)**
  - **mounted on the end cryostats**
- **PMT′s mounted directly on the face of each scintillator wedge**
- **Special geometry due to detector constraints**

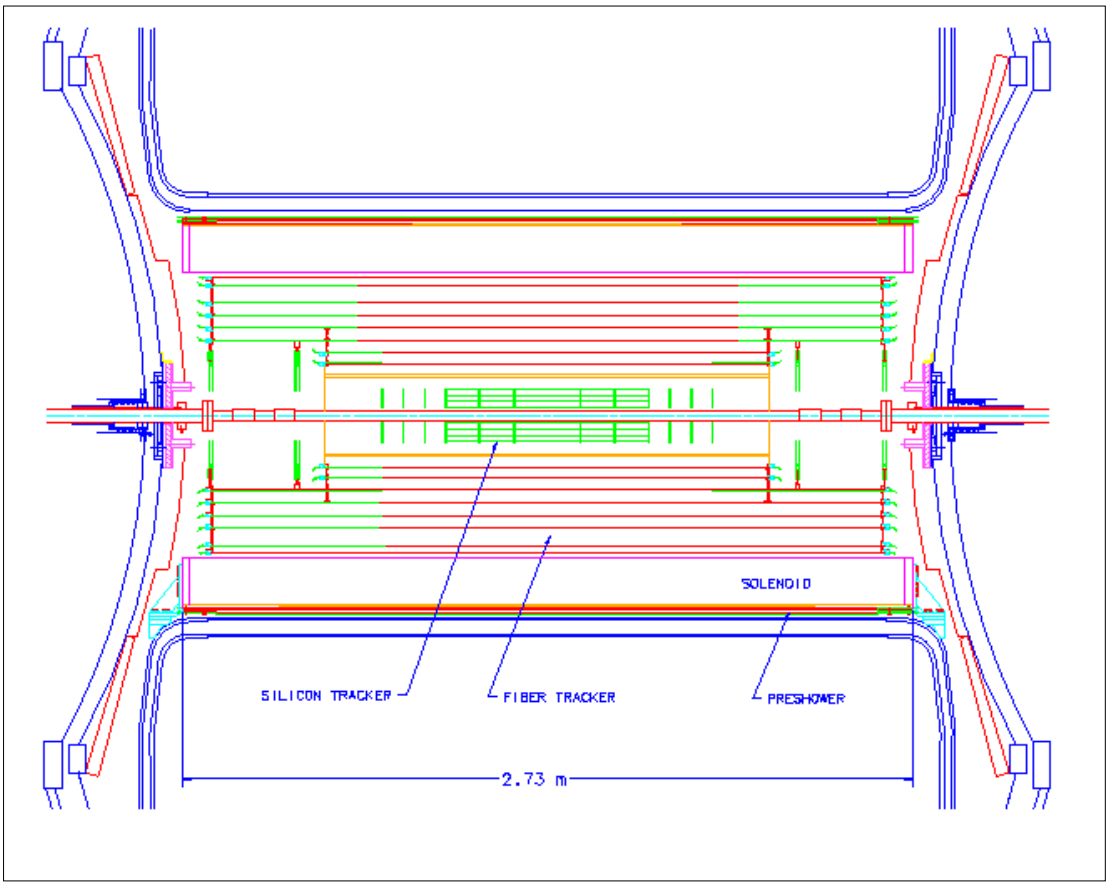


Picture of the Wedge Counters



Luminosity Monitor Location

- **Located between the beam pipe and the Forward Preshower Detector**
- **Providing coverage over the region $2.7 < |\eta| < 4.4$ ($\eta = -\ln \tan(\theta/2)$)**
  - **Acceptance 98 $\pm$ 1% (MC hard scattering)**

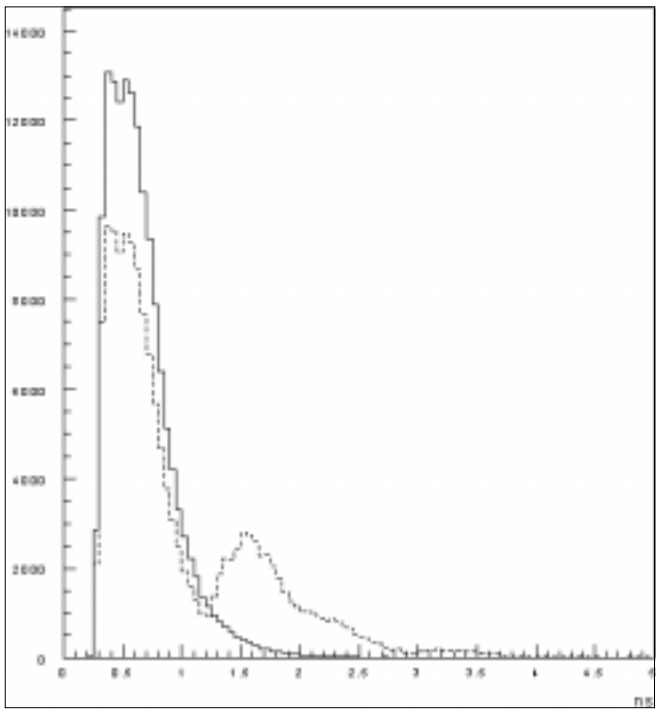


Single Wedge Counter Simulation

- **Model the charged particle response**
- **Ray trace of the scintillation photons**
- **Simulation studies:**
  - **photon collection efficiency as a function of the charged particle hit position**
  - **photon propagation time as a function of the charged particle hit position**
  - **Simulation results compared to prototype test on a cosmic ray test stand**

Simulation Studies

- **Absorber or reflector on the wider scintillator edge?**
  - **Distribution of photon propagation time for charged particles hitting the counter close to the narrow edge of the scintillator**

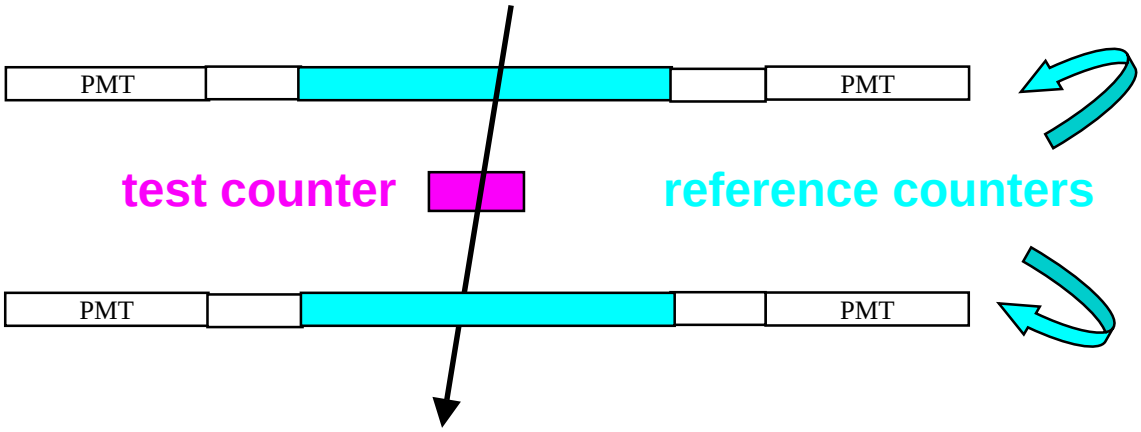


solid line: absorber
dash line: reflector
(shown in equal area)

- ▲ **Improve time resolution**
- ▲ **tradeoff: light collection efficiency reduced**

Cosmic Ray Test Stand

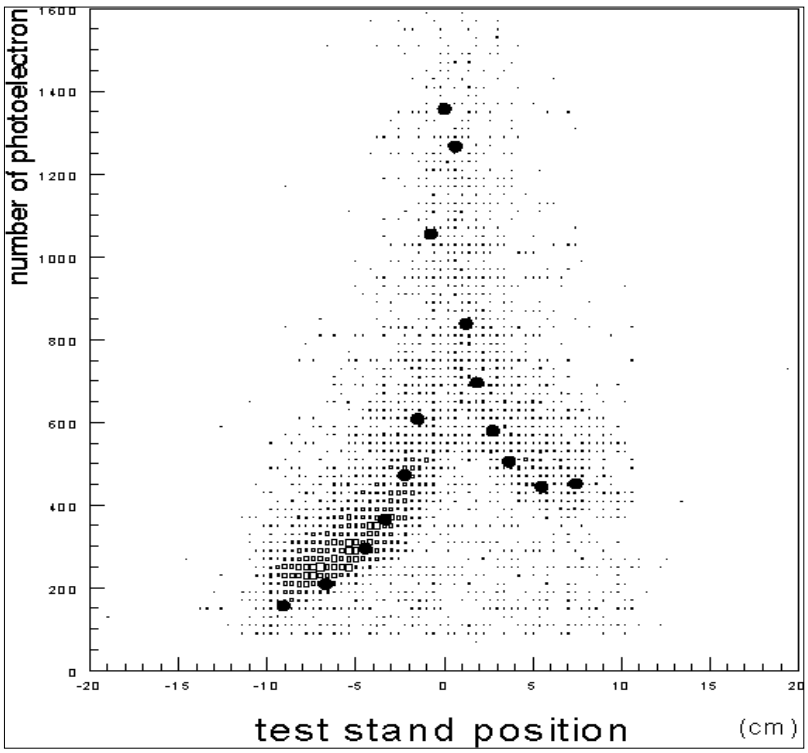
- **Prototype counters test in a cosmic ray test stand**



- **Test stand resolutions**
  - σ_T ~ 56 ps (predicted time)
  - σ_X < 1cm (from timing)

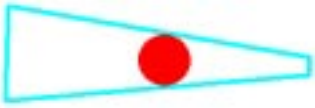
of Photoelectrons
(measured vs. predicted)

- **Average charge as a function of the position of the charged particle hit measured in the test stand**
- ***N_{MC}*** (energy loss, scintillator efficiency, photon collection efficiency, quantum efficiency)



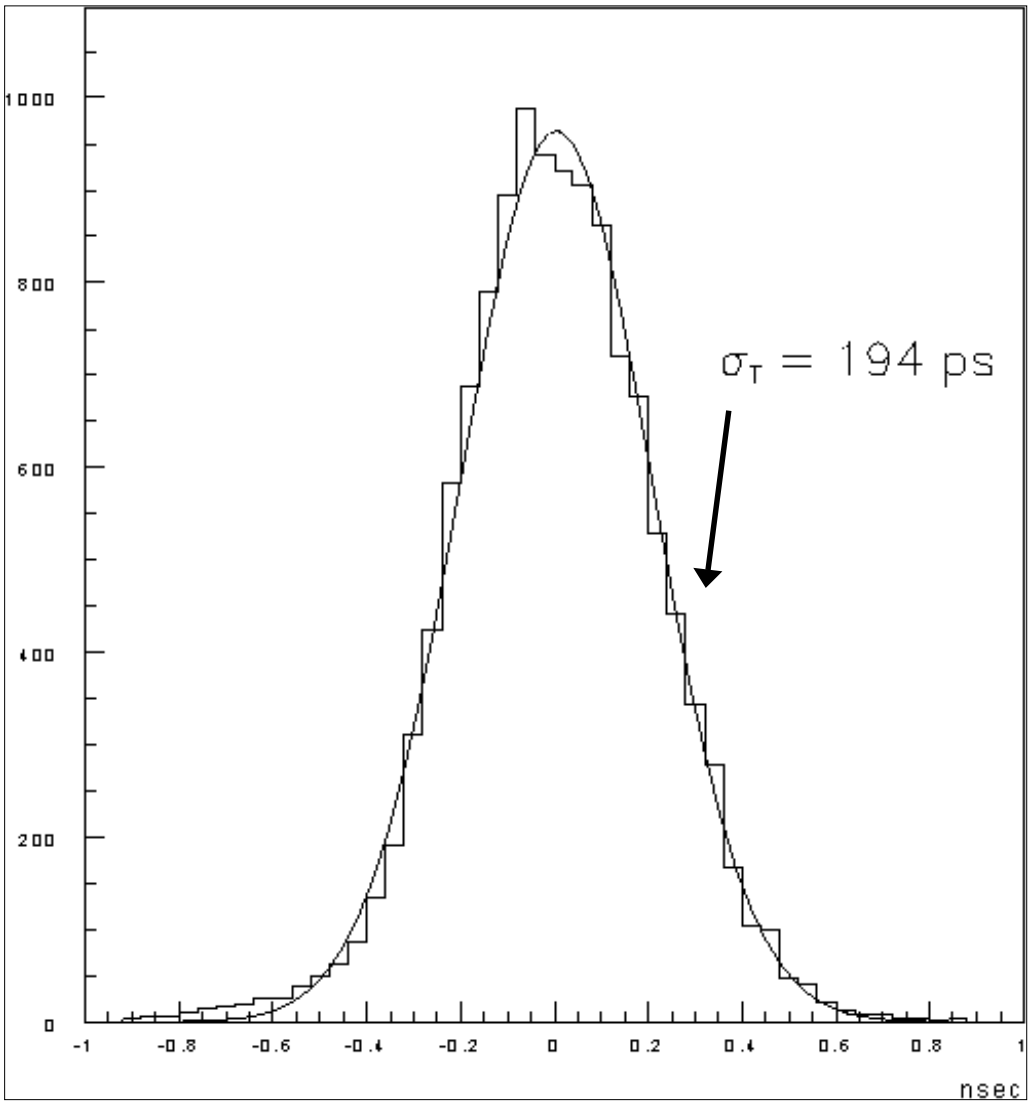
scatter plot : data

• : simulation



Prototype Counter Time Resolution

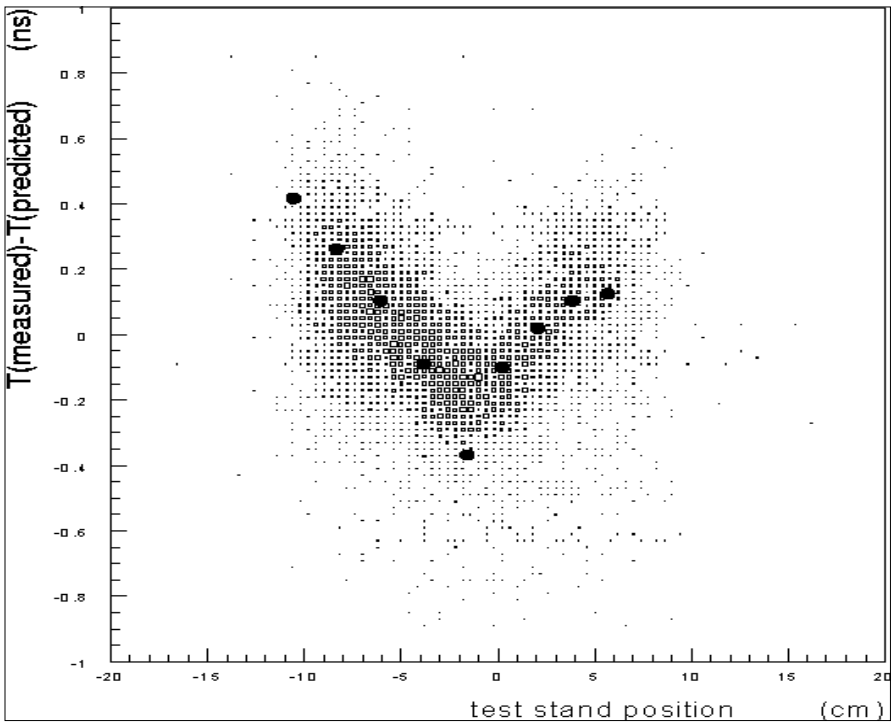
- **Prototype has time resolution of 194 ps.**



Difference between the measured and predicted times

Source of the Timing Uncertainty

- **Dominant contribution:** variation in photon propagation times as a function of the position of the charged particle hit
  - **Prototype test:** differences between the measured and the predicted times
  - **Monte Carlo:** average photon propagation time vs. position (normalized to data)



scatter plot : data

• : simulation

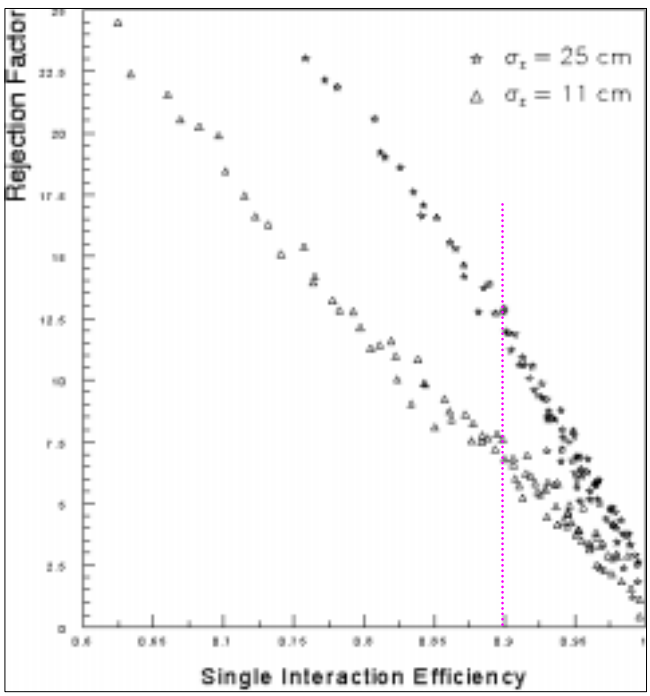
Multiple Interaction Trigger Flags

- **Identify single or multiple interaction in each beam crossing**

- **Algorithm: time difference between the earliest and the third latest hits**
  - **prevent single interactions with few out-of-time hits from being misidentified as multiples**
  - **on average 11 counters being hit in each array for single interaction events and 16 for multiple interaction events**
  - **FPGA-based design**

Multiple Interaction Trigger Flags

- **Simulation Studies**
  - **σ_z = 25 cm for 396 ns bunch spacing (36p x 36$\bar{p}$)**
  - **σ_z = 11 cm for 132 ns bunch spacing (140p x 121$\bar{p}$)**



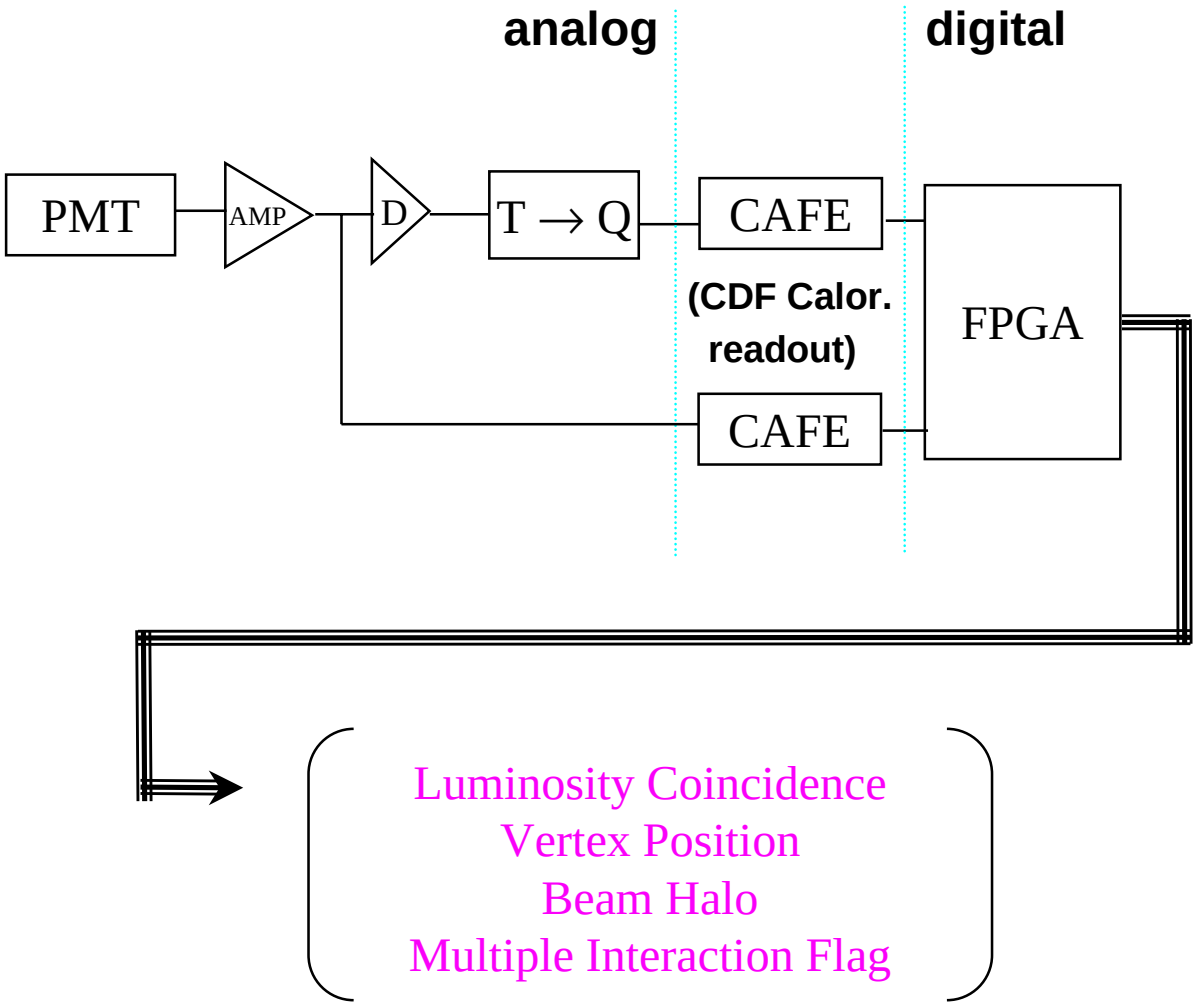
R ~ 12 @ 90% for σ_z = 25 cm

R ~ 7 @ 90% for σ_z = 11 cm

- **Rejection Factor (R) : ratio between the fraction of correctly identified single interaction events to the fraction of double interaction events passing the algorithm**

Readout Electronics

- **New readout electronics**
  - **Bunch spacing decreased from 3.5 μs to 396 and 132 ns during Run II**



Summary

- Design meets all our goals and considerations
- Counters are built; testing underway at Brown University
- Will finish the readout electronics design in the coming year
- Associated software projects (MC, online, offline, and database) are underway
- Run II begins in Apr. 2000