GEM Module Design for a TPC at ILC

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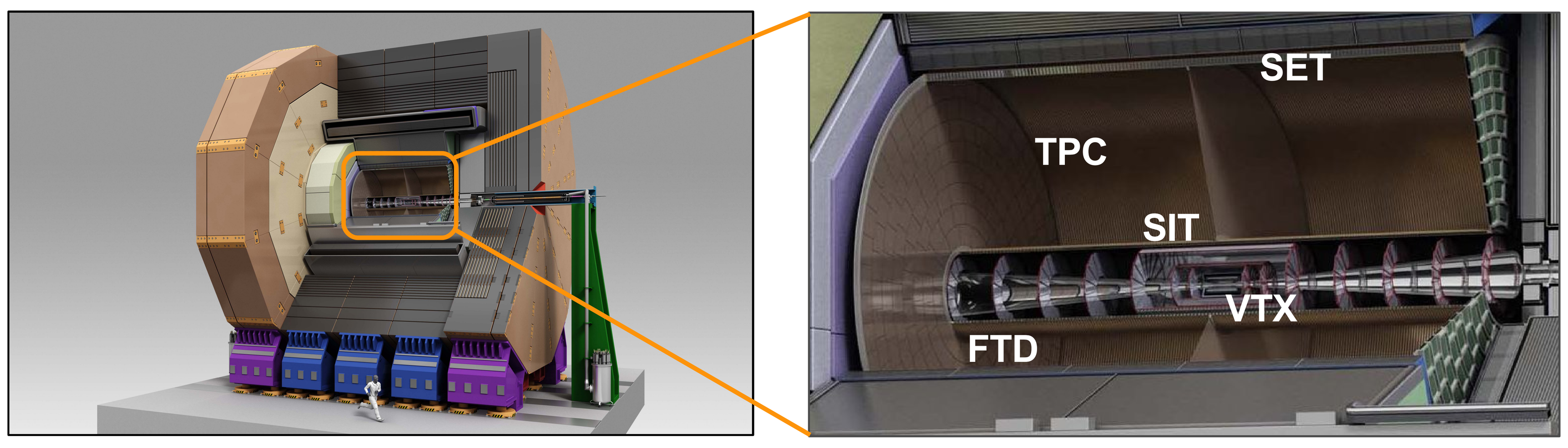
A TPC for the ILC

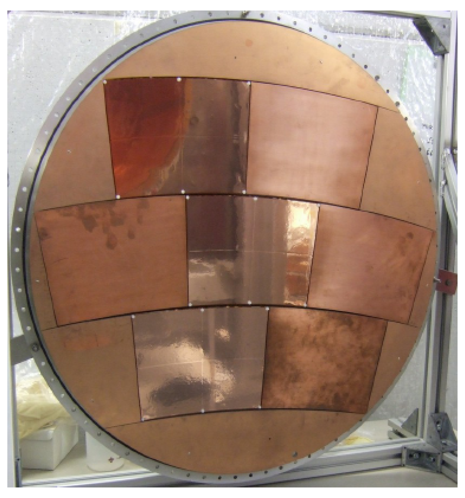
Requirements:
- Momentum resolution: $\sigma(1/p_t) = 2 \times 10^{-5}$ /GeV for Higgs mass measurement (TPC alone 10^{-4} /GeV)
- Tracking efficiency: Close to 100% down to low momentum to fulfill Particle Flow Algorithm (PFA) requirements.
- Minimum material: In front of the highly segmented calorimeter

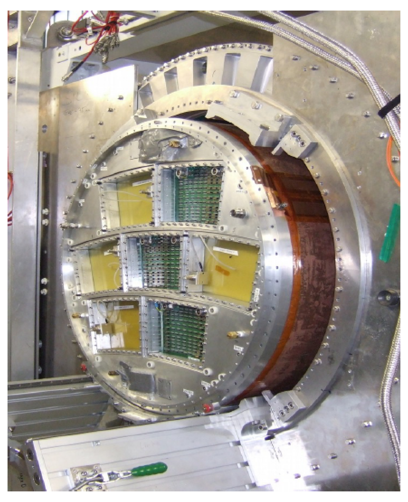
Solution: TPC with MPGDs
- ~200 position measurements along each track
- Single point resolution of $\sigma_{r\varphi}$<100 μm
- Lever arm of around 1.2 m in the magnetic field of 3.5-4 T

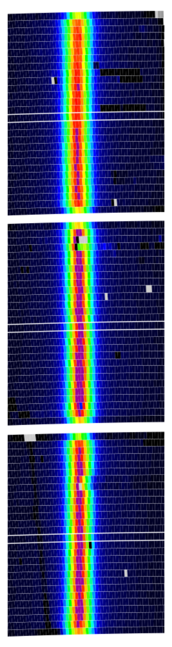


Testbeam Setup

- Magnetic field up to 1T
- $e^{+/-}$ beam up to 6 GeV
- Movable stage in 3D
- 3 modules,
  → 7200 channels with ALTRO electronics (120 ns shaping time)
- Lever arm of ~50cm along the beam

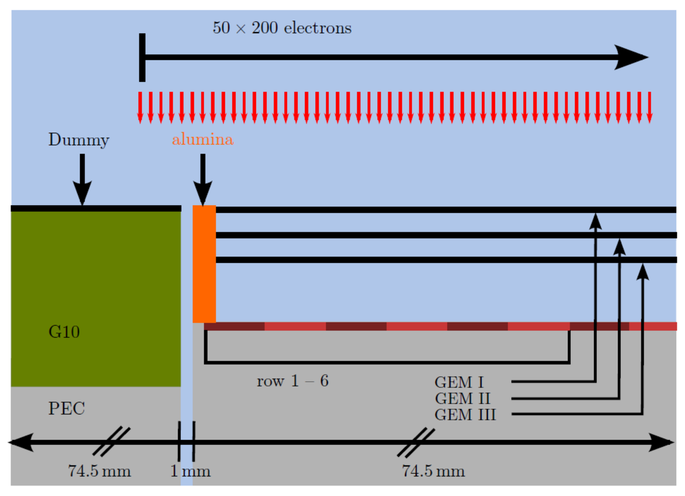


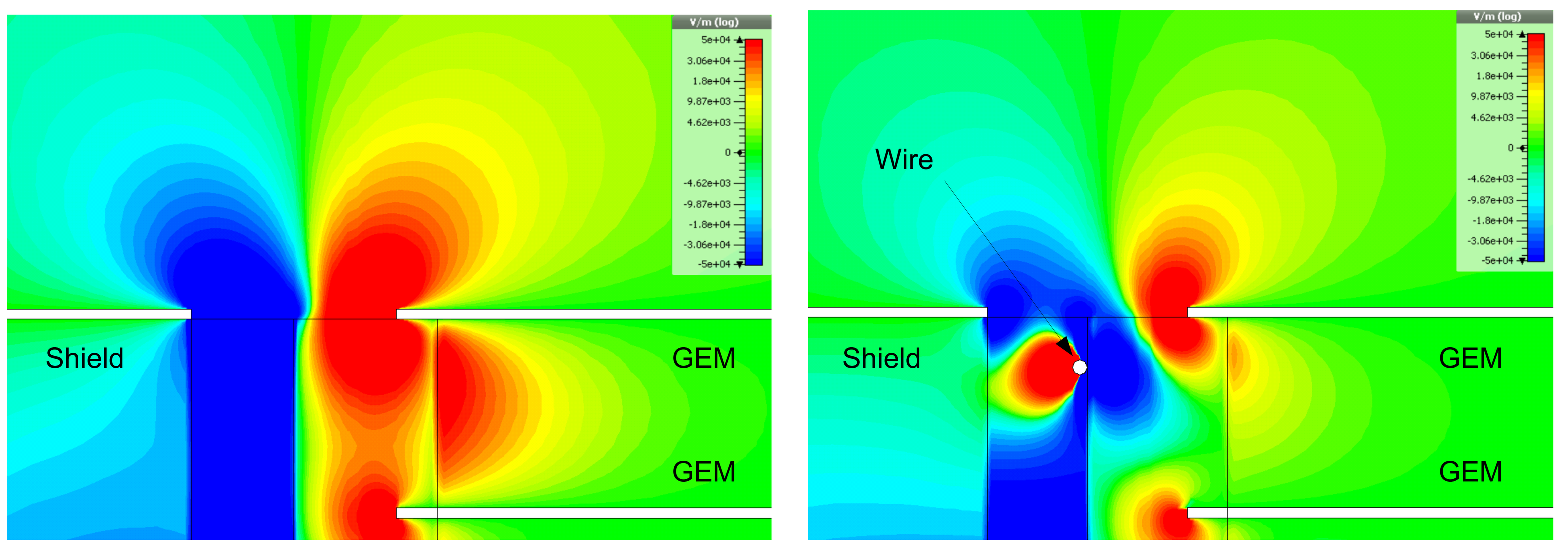




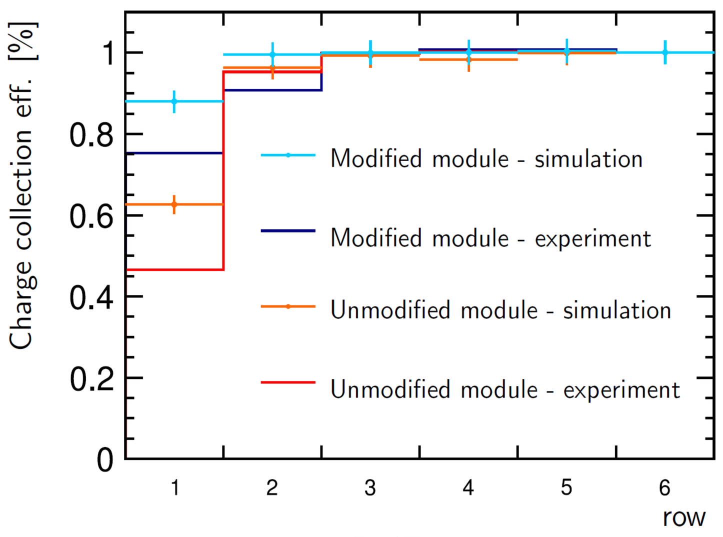
Field Simulations

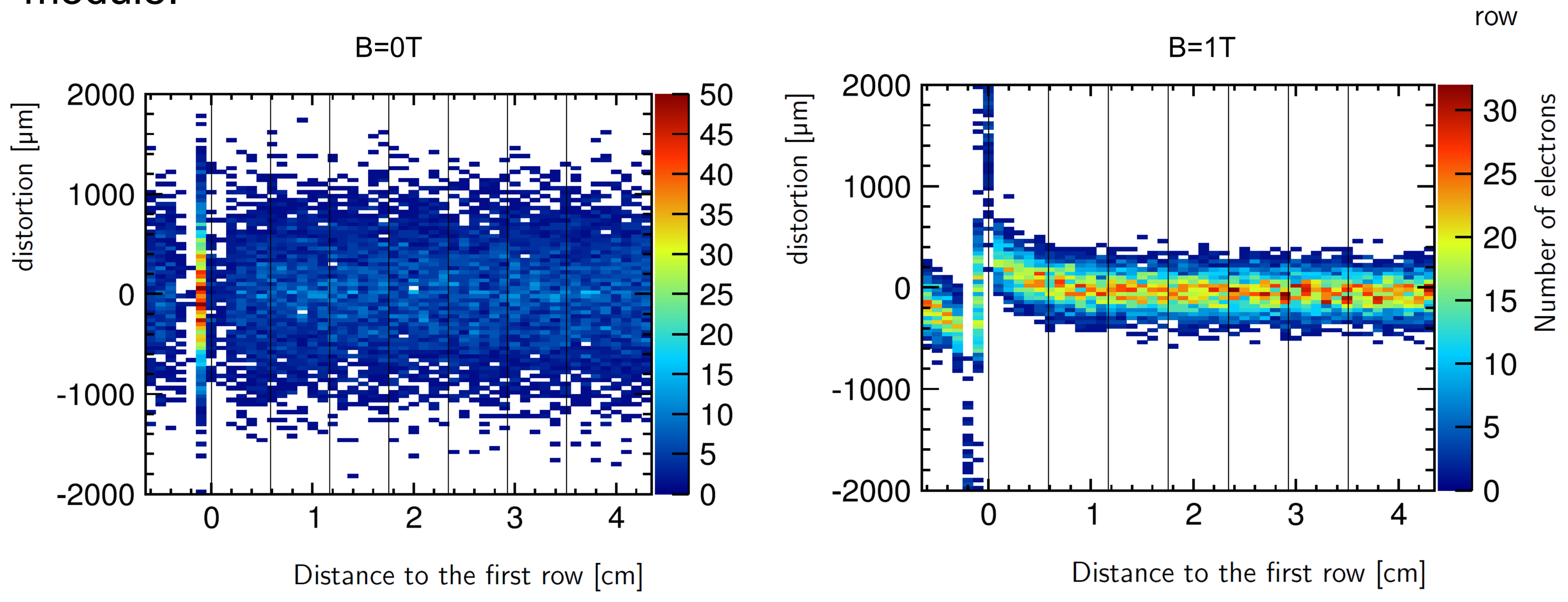
An electrostatic field simulation was carried out with CST™ to study the field behavior at the border of the GEM module. Garfield++ is used to drift electrons along these field lines.





The addition of a field shaping wire reduces the field distortions. The charge collection efficiency could be improved by 30% both in simulation as well as in the measurement.
To study the distortion of the electron path, 200 electrons are started at 50 different positions along the pad rows but at the same distance above the module.





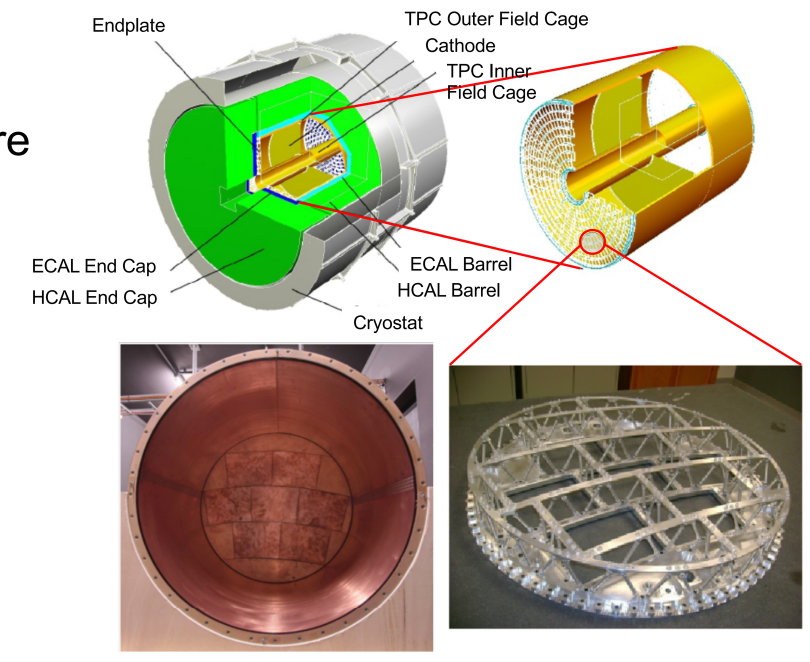
Without magnetic field the electrons follow the electric field lines and end up in the gap between modules. With the introduction of a magnetic field ExB effects change the electron drift path resulting in a distortion of the electron arrival positions near the module border.

The Large Prototype

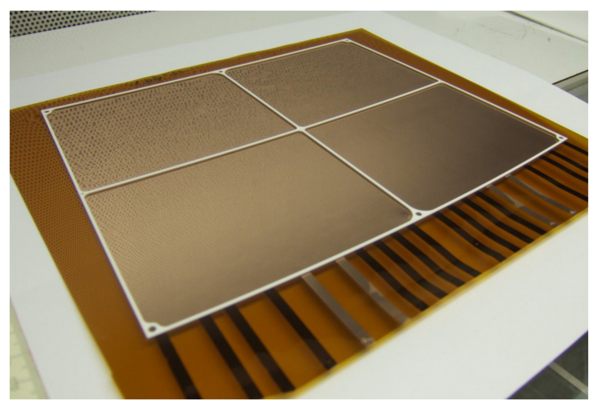
The Large Prototype has been built to compare different readout modules under identical conditions and to address integration issues.

LP field cage parameters:
- L = 61 cm
- D= 72 cm
- Up to 25 kV → E_{Drift} ~350 V/cm
- Made of composite materials → 1.24 % X_0

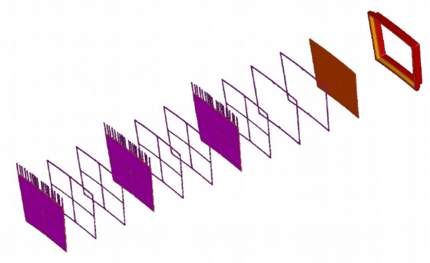
Modular endplate for 7 modules ~ 22x17 cm^2



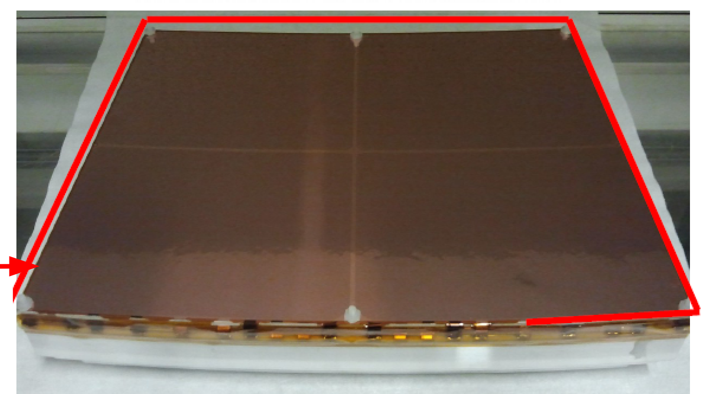
GEM Module Design



Goals:
- Minimal dead space
- Minimal material budget
- Flat GEM surface without stretching
- Stable HV operation



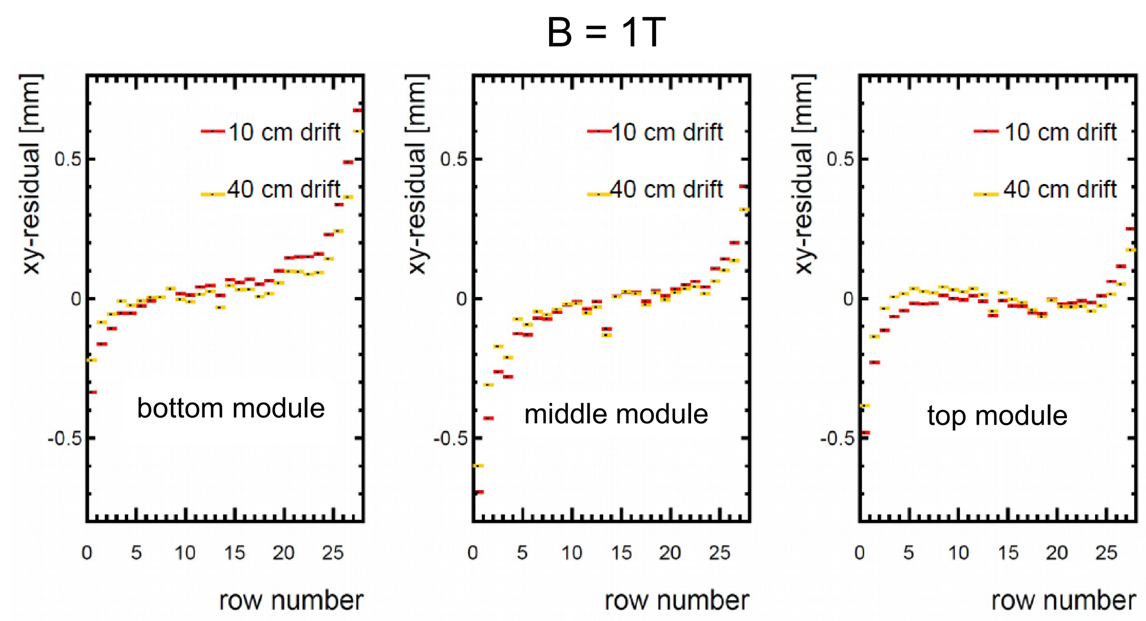
Solution:
- Divide anode side of GEM into 4 sectors
  → HV stability
- No division on cathode side
  → better field homogeneity
- Thin ceramic mounting structure
  → ~5% dead space
  → good GEM flatness
- Triple GEM stack
  → stable and versatile operation at high gain
- Field shaping wire
- Fully sensitive readout board
  → 4892 pads (1.26x5.85 mm^2)



Measurements: Module Boundaries

Field distortion are observed at the boundaries of the modules. This leads to charge loss on the outer rows and bending of the drift path of the electrons due to ExB effects.

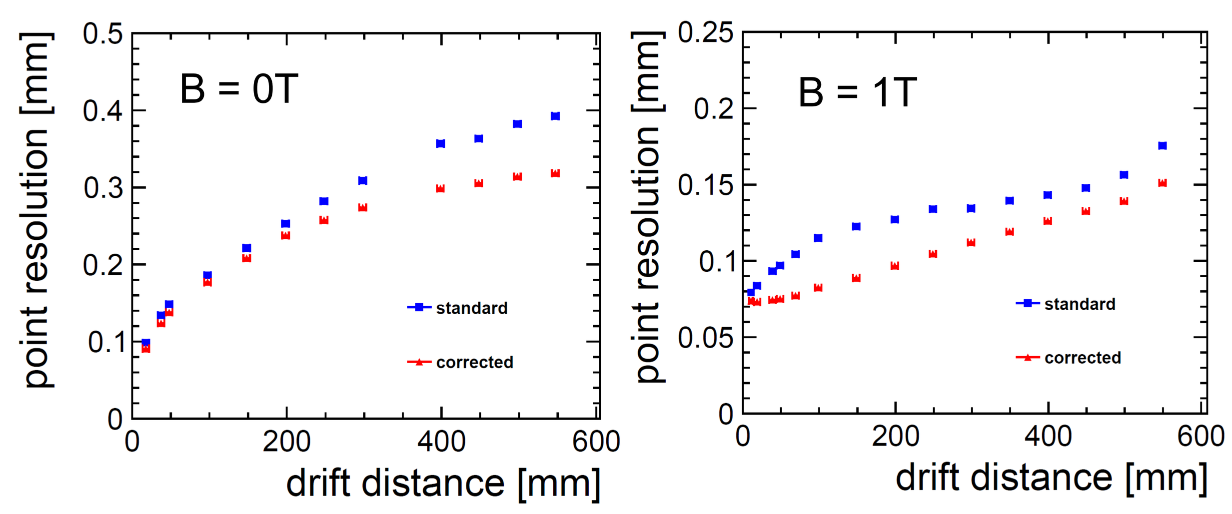
The hit efficiency was improved to above 95% due to the guard ring. The charge efficiency is still lower at the module borders.
It is important to understand these distortions and their systematics, also in regard to reconstruction and tracking algorithms.



Measurements: Single Point Resolution

The single point resolution is influenced by the track quality and therefore by the field distortions. Remaining distortions can be corrected offline improving the resolution.

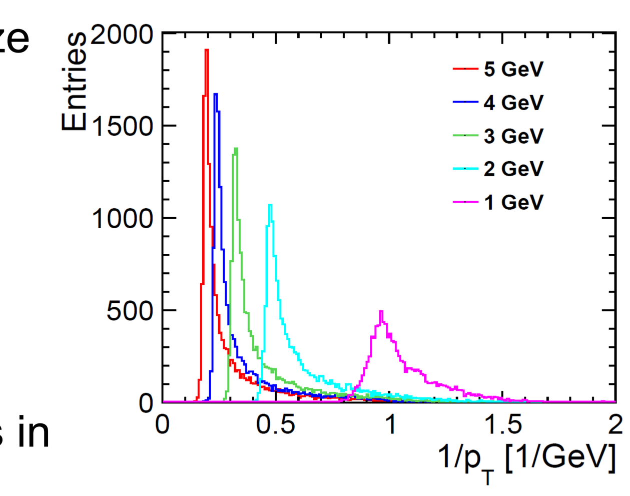
The results are very preliminary with simple track fits and minimal cuts applied. All points are used. The goal of 100 μm is almost reached even at this stage of the reconstruction.



Next Steps

- Successful test beam campaign → lots of data to analyze
- Constantly improving the reconstruction
- Gain better understanding of distortions
- Work ongoing on calibration and correction procedures

Important Goal:
- Measure the momentum resolution
- This requires an external tracker
- The momentum distribution is dominated by energy loss in the magnet and beam spread.



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