Beam Loss Monitoring at the APS

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December 17, 2010
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Why care about beam loss?

- Beam loss reduces efficiency (e.g., injection and lifetime)
- Causes radiation that must be shielded
- Upsets and destroys electronics gear
  - In short, we care about beam loss because we want to keep people safe and beam loss costs $.

Beam loss

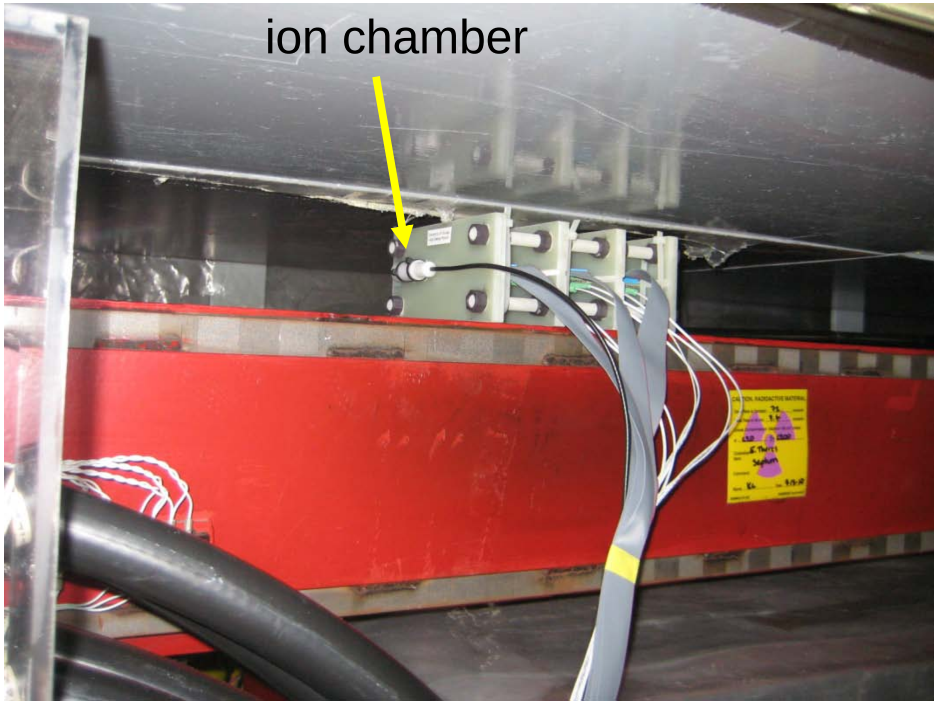
- At the APS, ionizing beam loss comes in two varieties:
  - photons (x-rays and γ's)
  - electrons
- Photons are a product of the electrons accelerated in magnetic fields. Electrons efficiently convert rf energy (λ~m) into x-rays (λ~Å).
- We will consider mainly electron– and γ–loss here

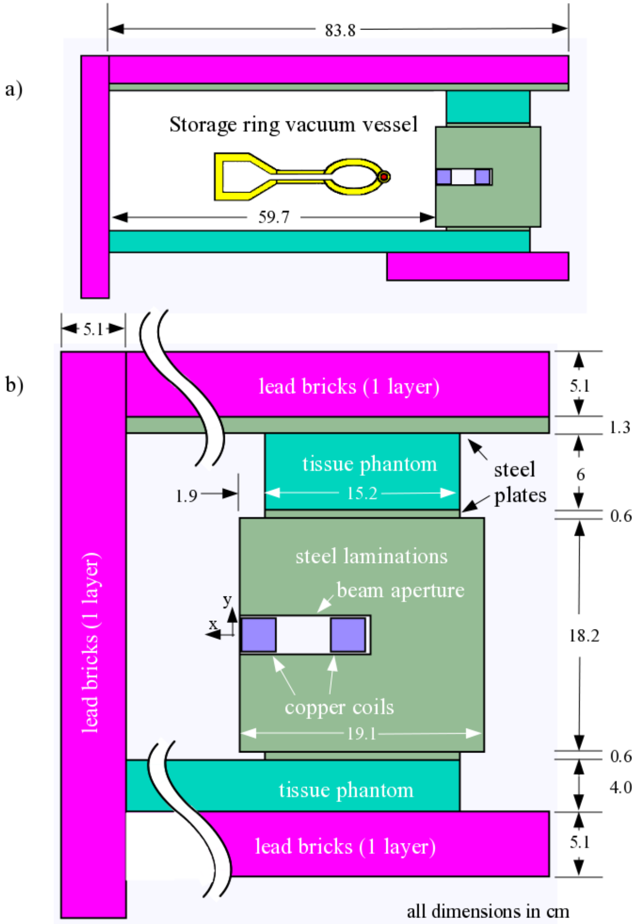
What is beam loss?

- At the APS, beam loss starts basically with electrons going places we don't want them
- Three categories:
  - *planned*: for example, intentional beam dumps or irradiation studies
  - *unavoidable*: beam injection (mismatch), Touscheck scattering, gas bremsstrahlung
  - *unplanned*: instabilities, loss of control, trips all leading to unintentional beam dumps or loss

Planned beam loss—SR thick septum

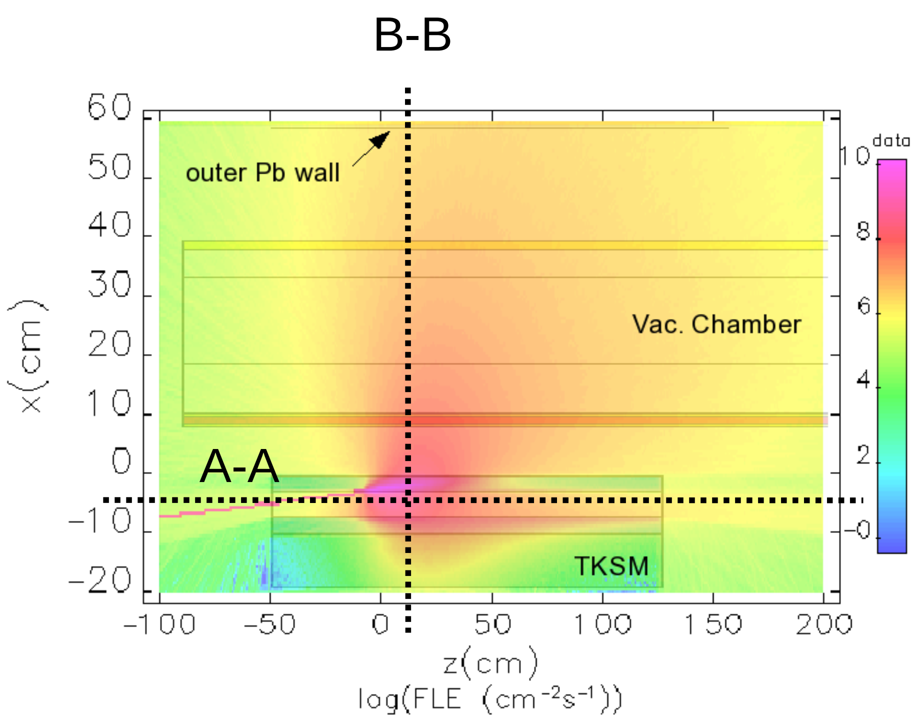
- Testing circuits for use at the LHC ATLAS detector
- 3 boards, looking for device failures and power supply current changes

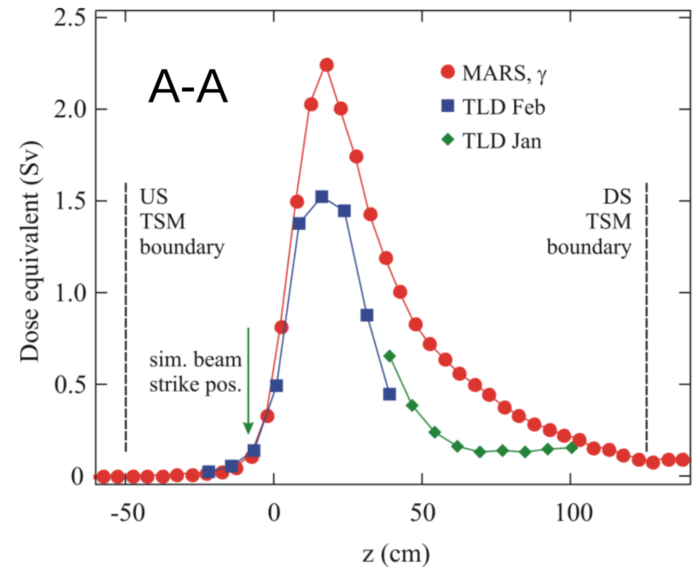


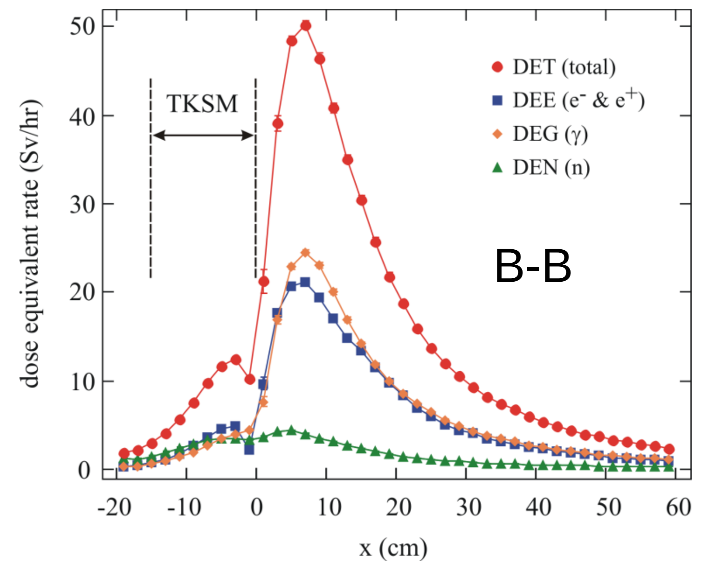


Planned beam loss—SR thick septum

- Modeled with MARS
- Want a known loss

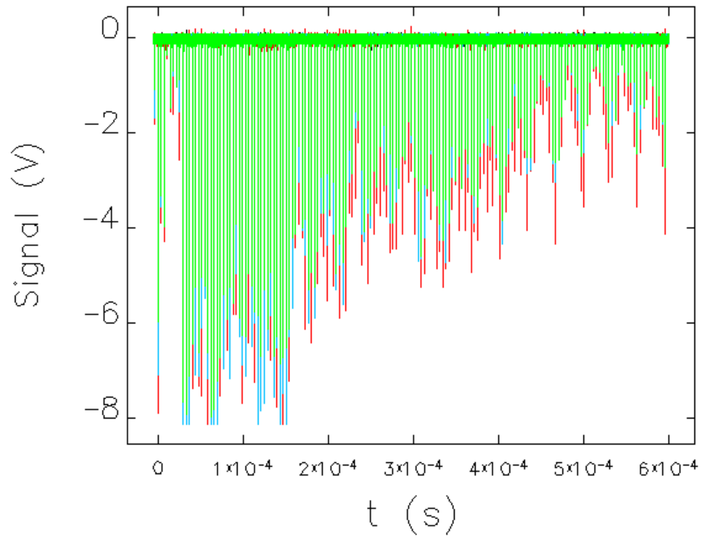




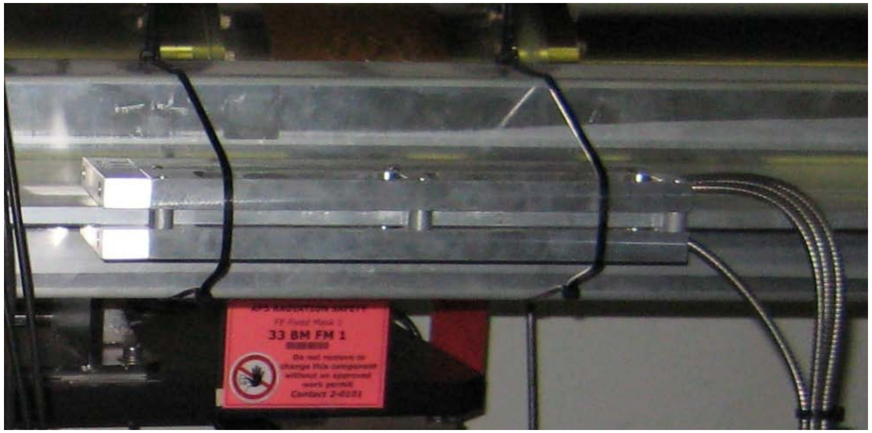


Unavoidable beam loss

FO BLPM prototype signals recorded during injection (4 ch.)



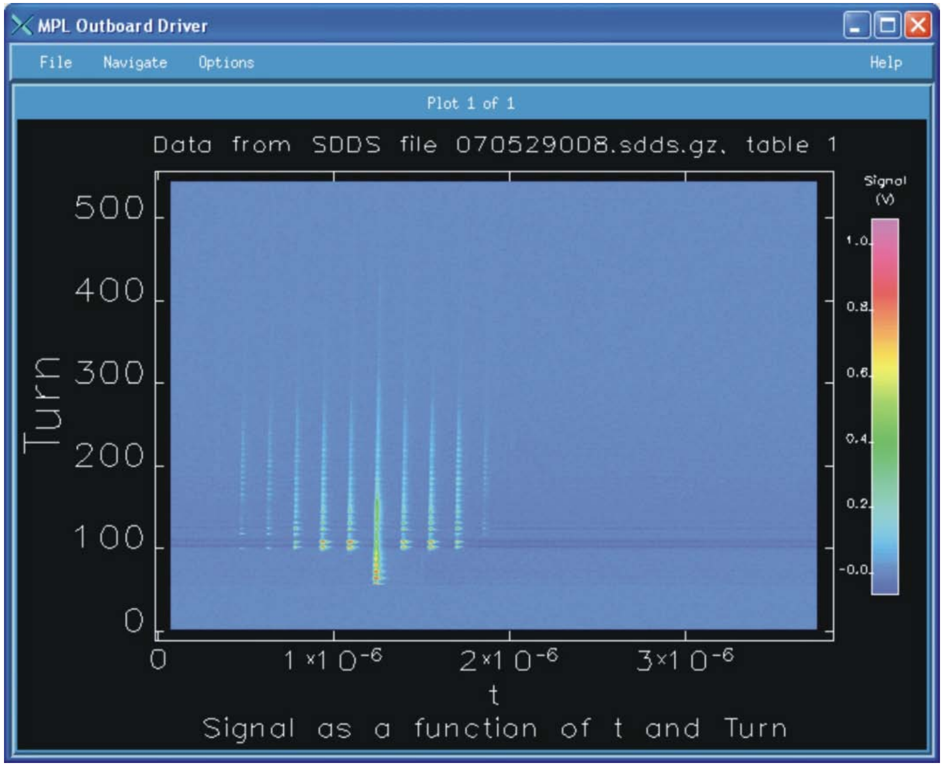
- injection (mismatch)
- Touschek scattering (e-e)
- gas bremsstrahlung (e-Z)



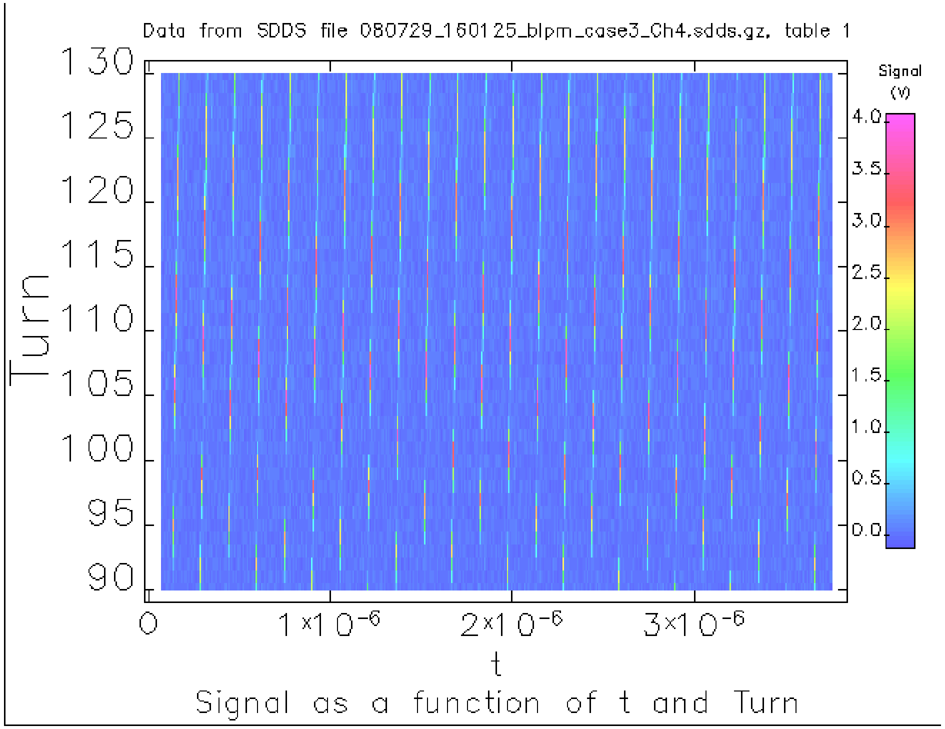
FO beam loss position monitor (BLPM) prototype (3 FO top, 1 FO bottom)

Unplanned beam loss

Beam dump (24 bunch)—single FO



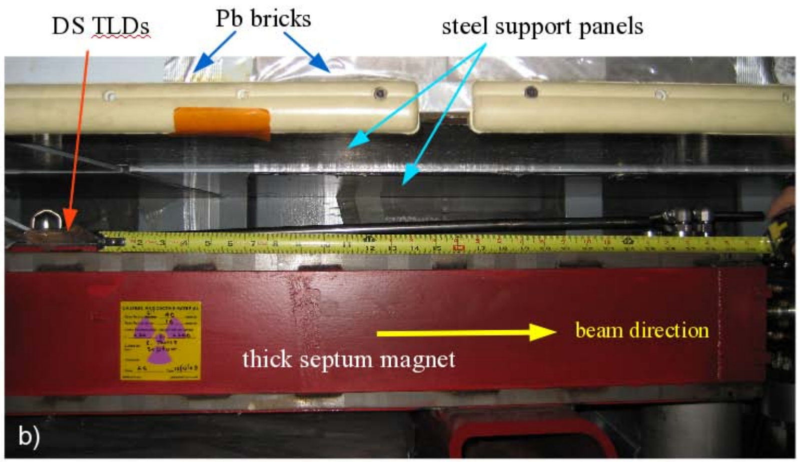
Instability—4 channel BLPM (bot ctr)
ΔI_{dipole}=0.4 A , 86 mA beam loss



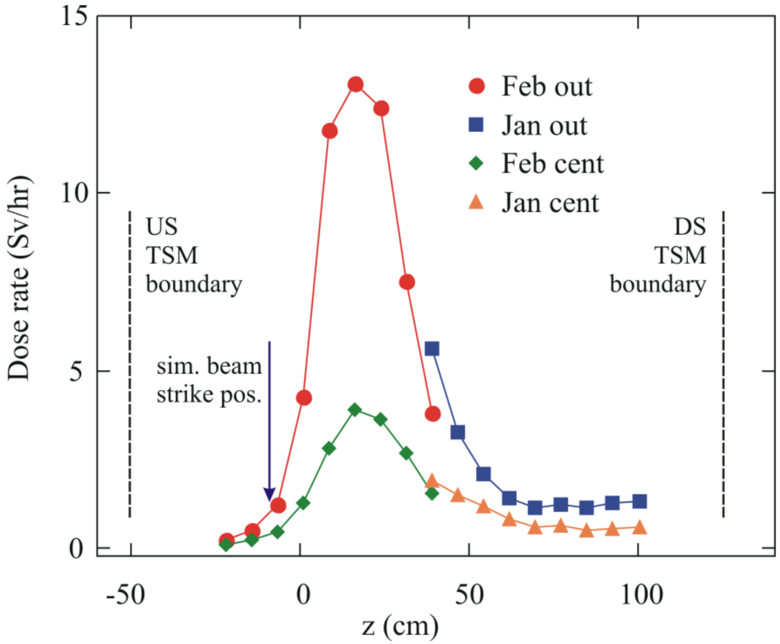
Radiation Diagnostics

- One of the main goals of our BLM work is calibration
- Calibration allows us to do dosimetry
- Important for de-magnetization assessment
- All energy is initially carried by electrons, so measure them
- However, need reference rad monitors for calibration

Radiation detectors—thermoluminescent dosimeters (TLDs) and alanine strips



- measurements Jan and Feb '09
- TLDs < 1 krad
- alanines > 1 kGray
- a big gap!

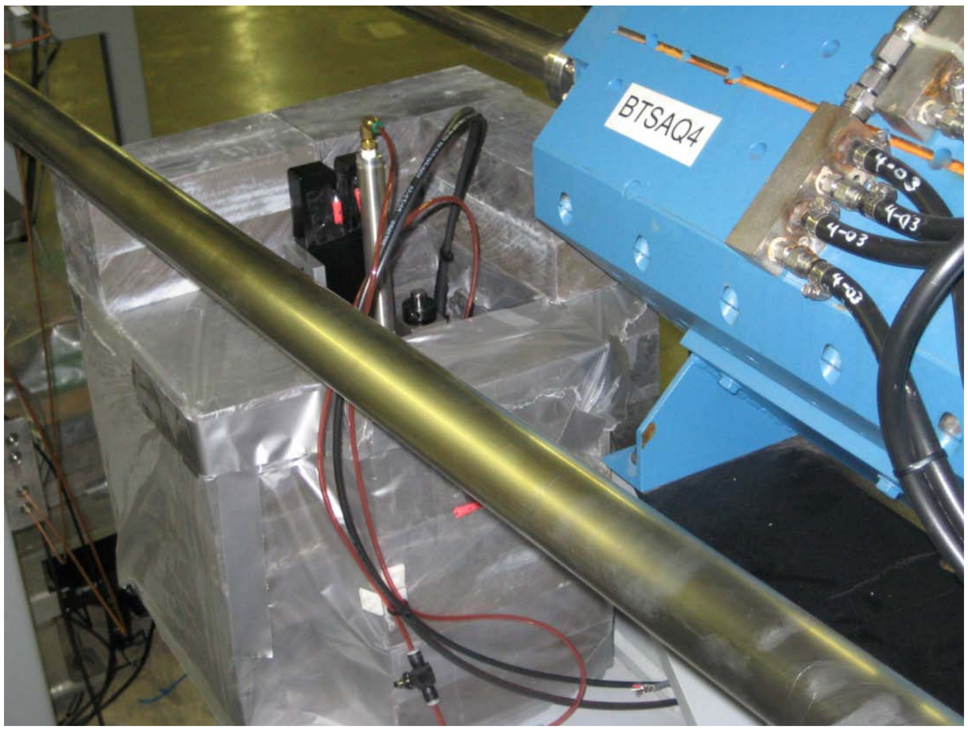


Measurements and simulations

- Must have good simulations to do accurate spatial dose distributions
- Complex geometry leads to complex simulations—even in the relatively simple BTS/BTX
- Would like a simpler geometry
  - former LEUTL (electrons)
  - S35 (photons).

Measurements and simulations

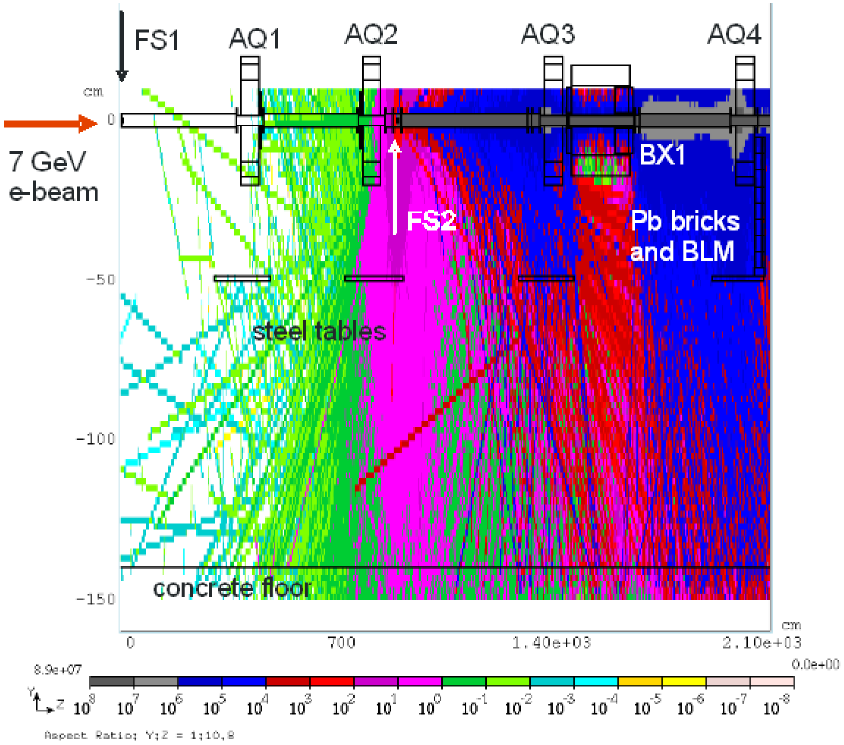
- BTS/BTX
- using LCLS BLM



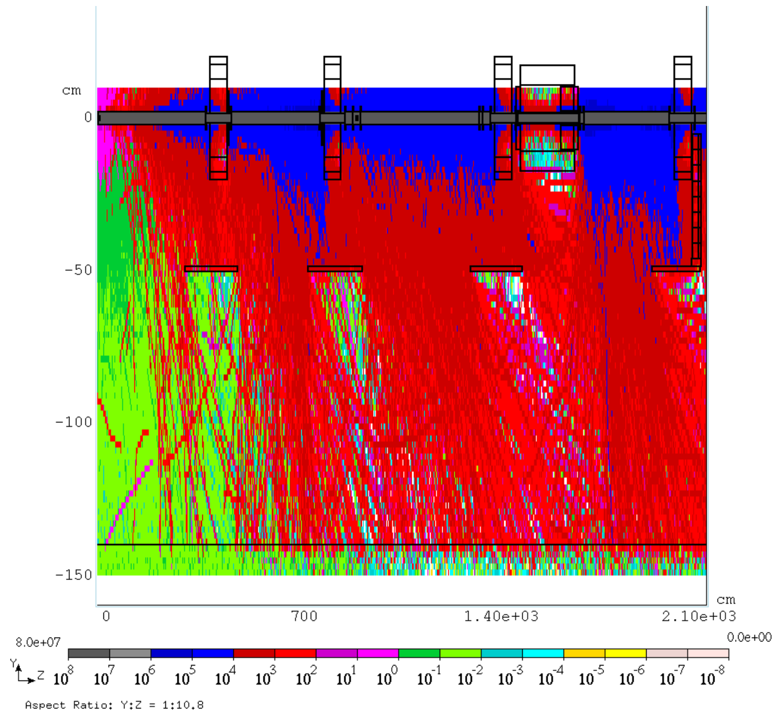
downstream view of BLM

upstream view of BTS/BTX

Measurements and simulations

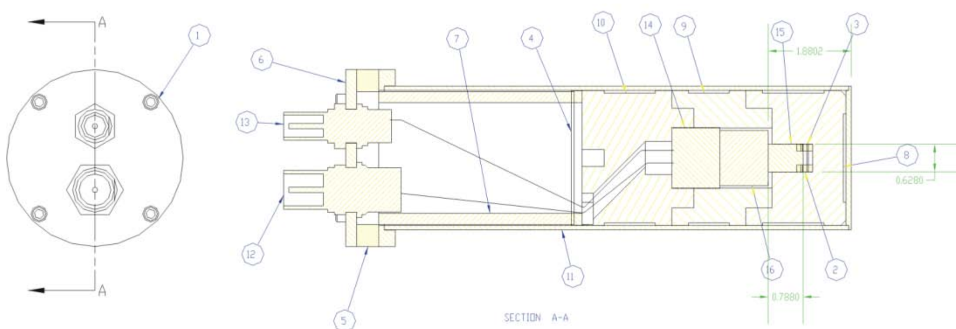


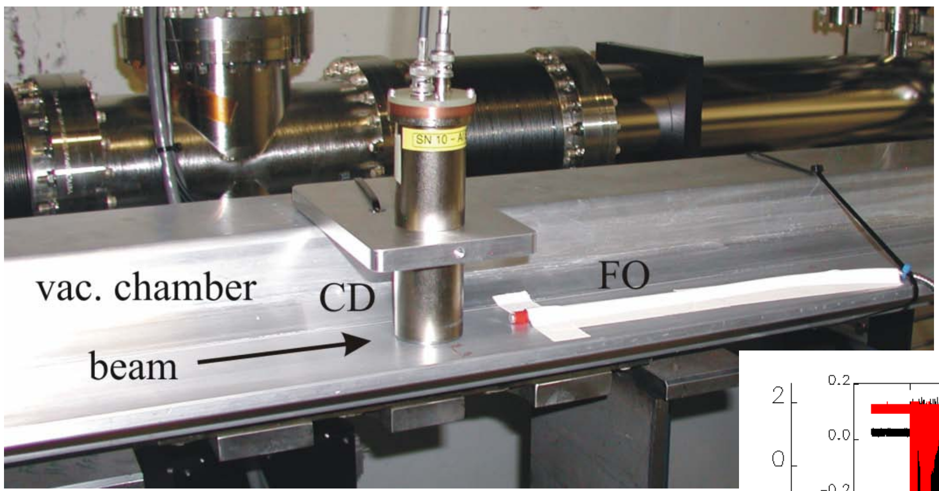
- upstream source of electrons necessary
- flags FS1 and FS2 are used



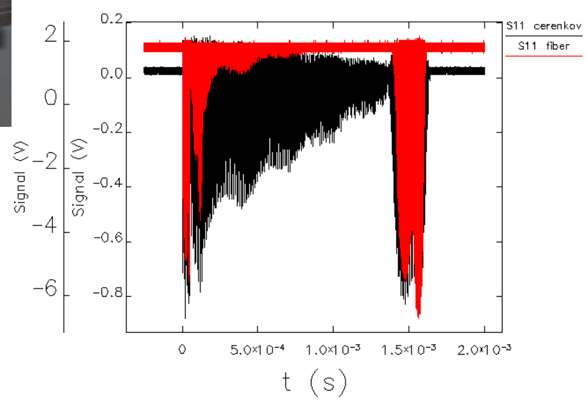
Optical Diagnostics—Cerenkov, OTR, scintillation

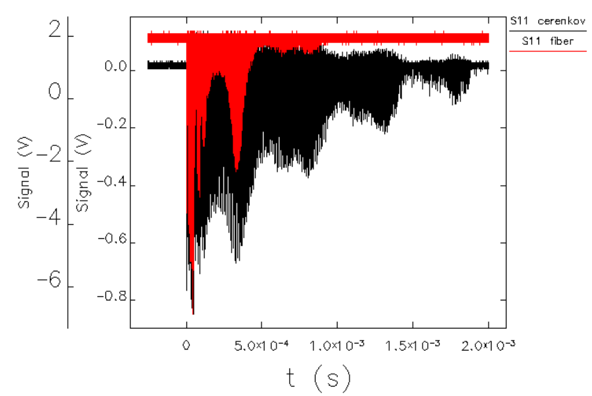
- Cerenkov Detector (CD)
- single FO bundle





S11, single bunch injected into an empty ring

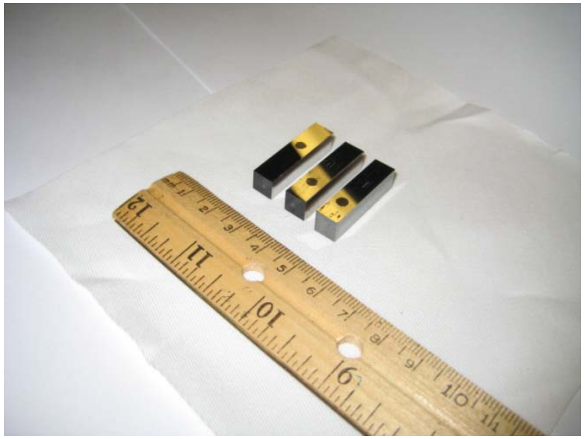




Optical Diagnostics—Cerenkov, OTR, scintillation

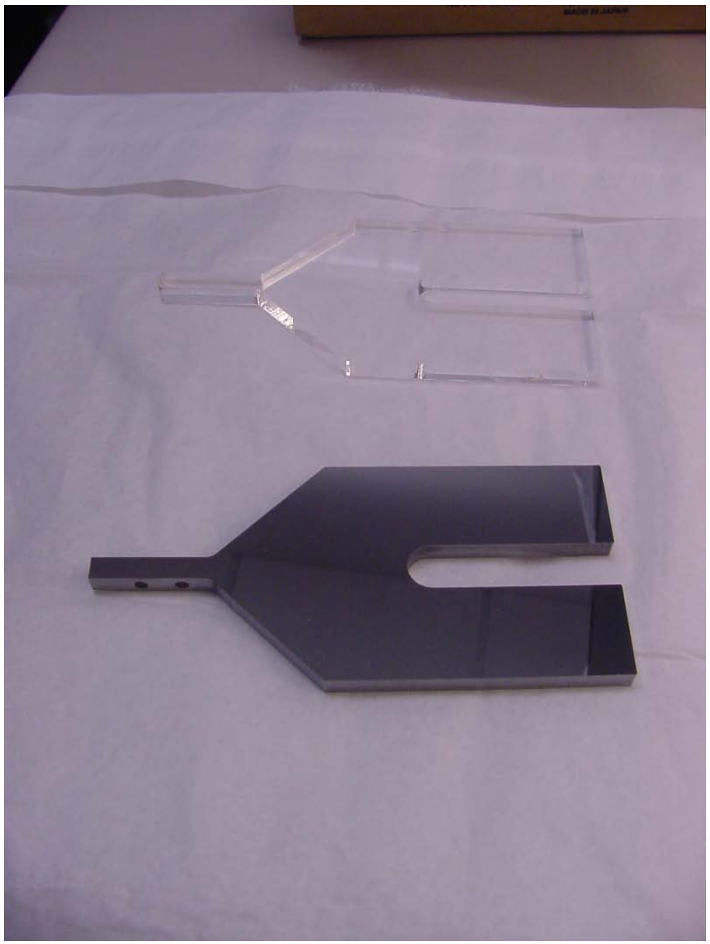
S33 ID SS upstream of the BLPM

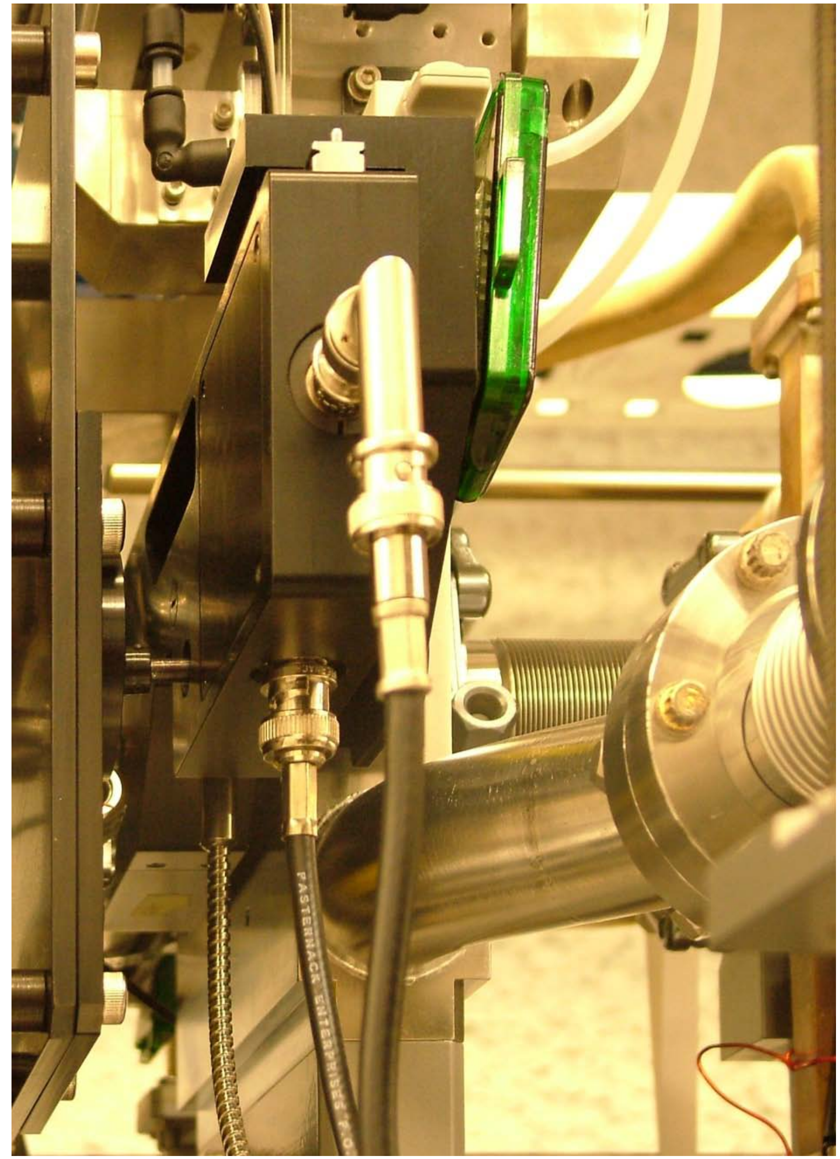
- LCLS-style and prototype BLMs
- fused-silica radiators



Optical Diagnostics—Cerenkov, OTR, scintillation

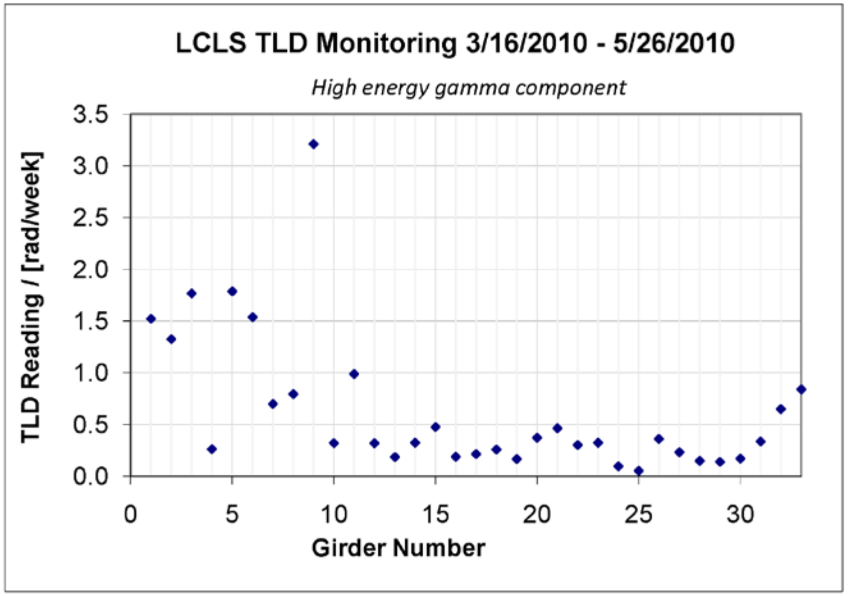
- LCLS BLMs (APS built)



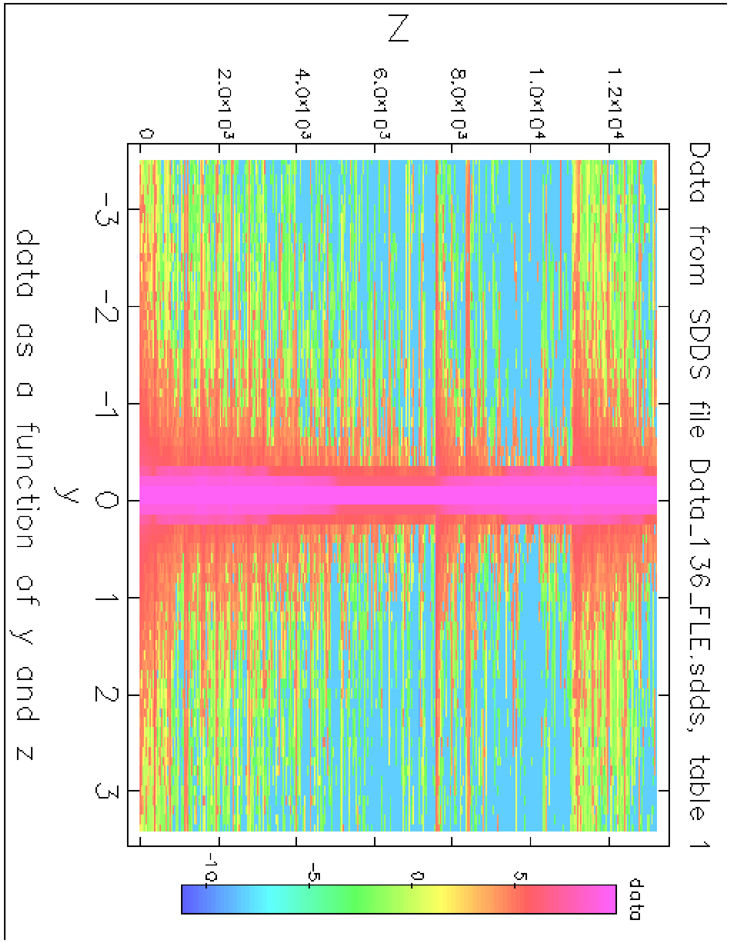


Measurements and simulations—LCLS undulators

- TLD data from March-May (courtesy of H.-D. Nuhn)
- Geometry complex



Electron fluence from MARS, OTR33 irradiation, 13.6 GeV



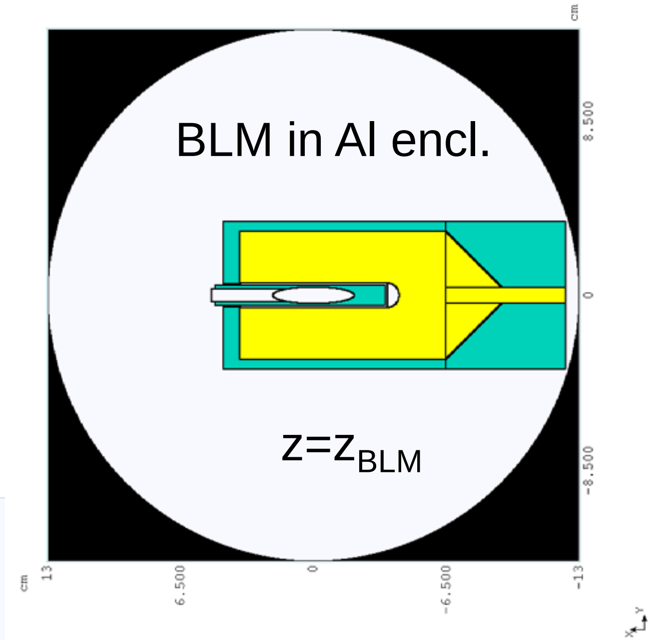
Simpler geometry

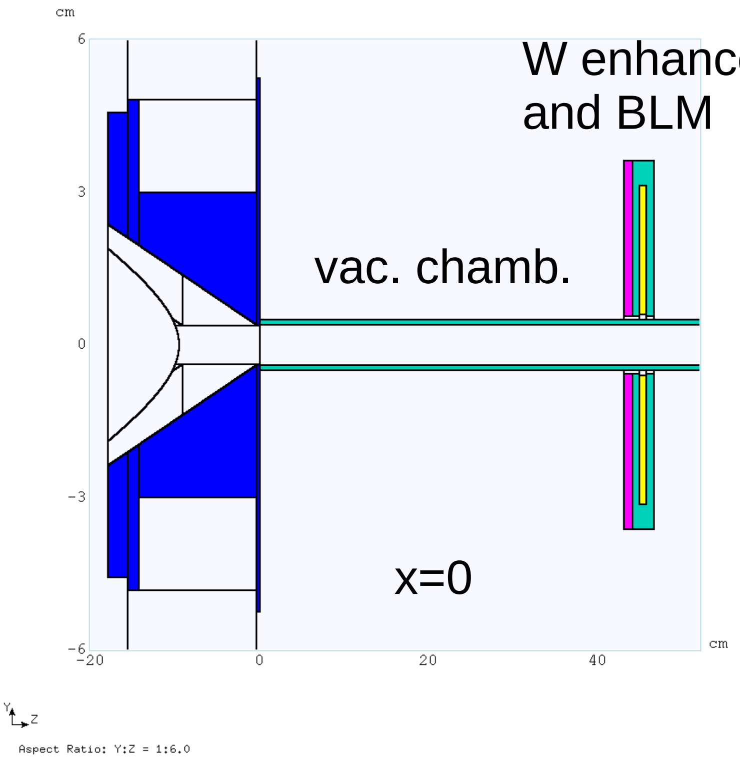
In the search for simpler geometry we considered

- LEUTL tunnel—debate about where to place the experiment and the need for low dose led us to look elsewhere
- SS beamline—did this
- Sector 35—and this

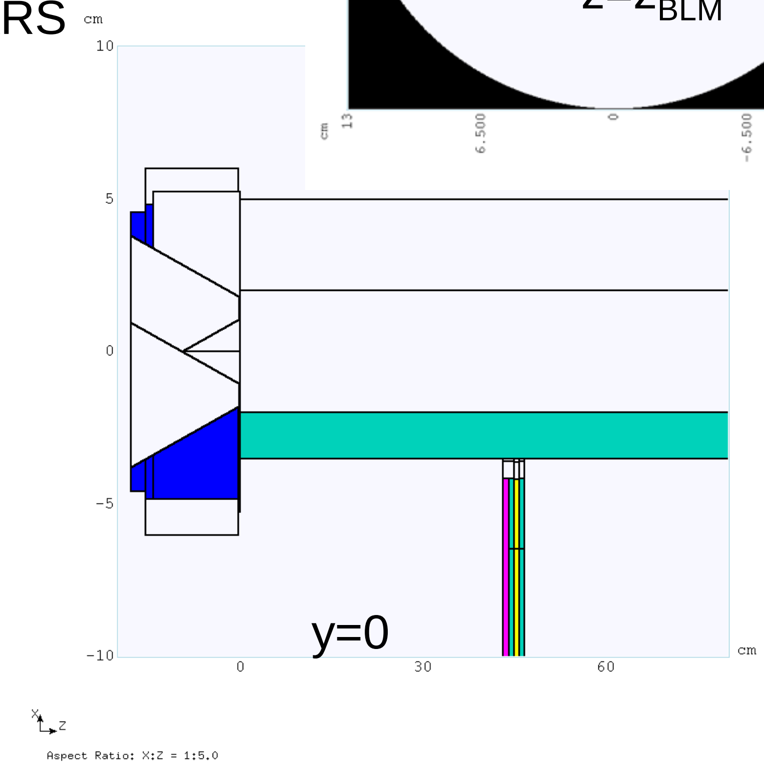
ID straight section

Transition piece into ID SS modeled in MARS





z_{BLM}=43 cm

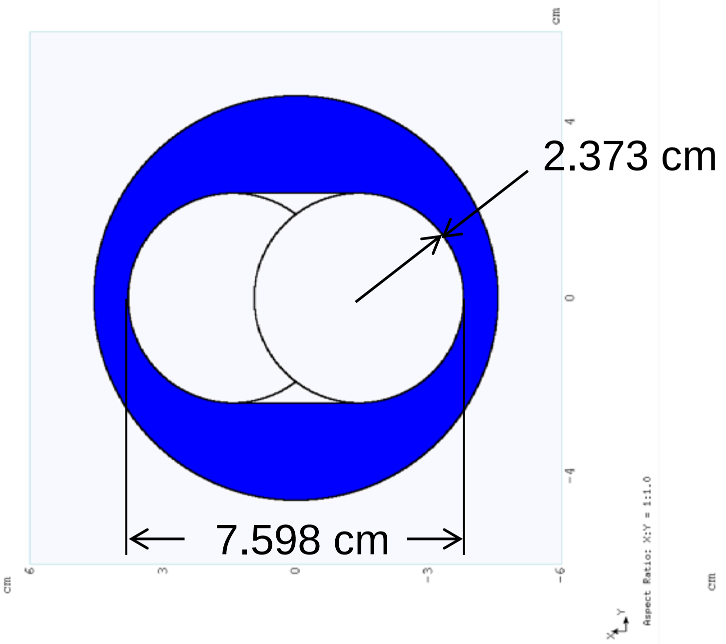


z_{BLM}=100 cm

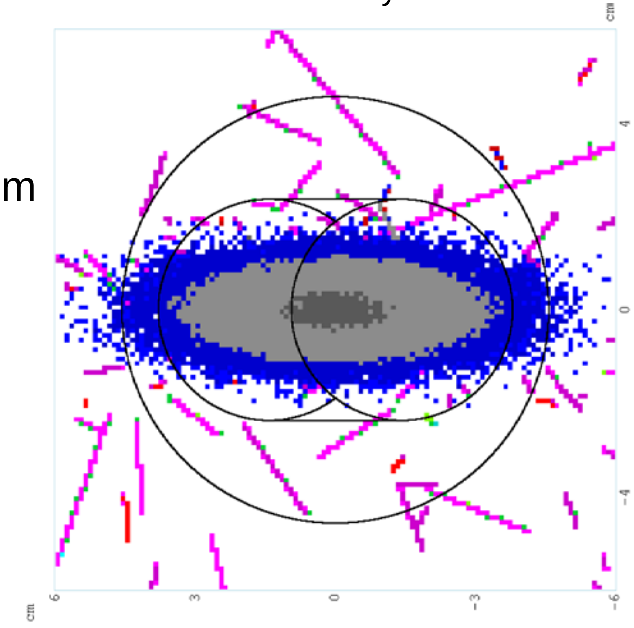
ID straight section

Looking for phenomenological differences in beam loss patterns with beam size

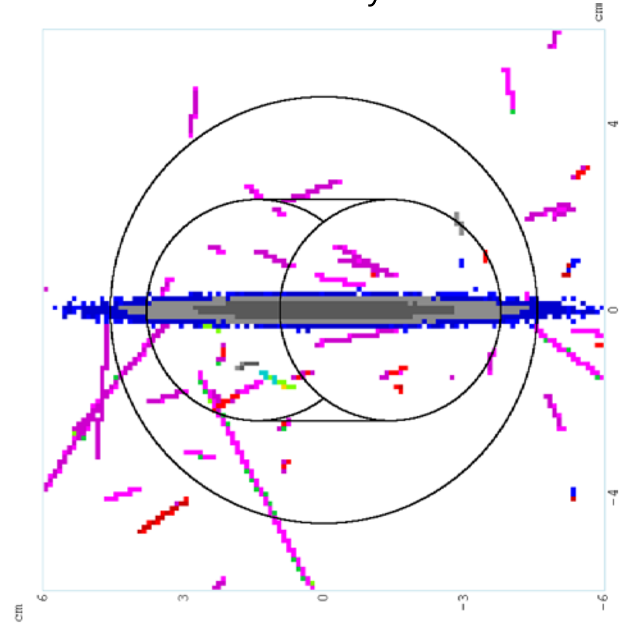
Upstream cross section
transition piece



Large beam
σ_x=1.5 cm, σ_y=0.5 cm

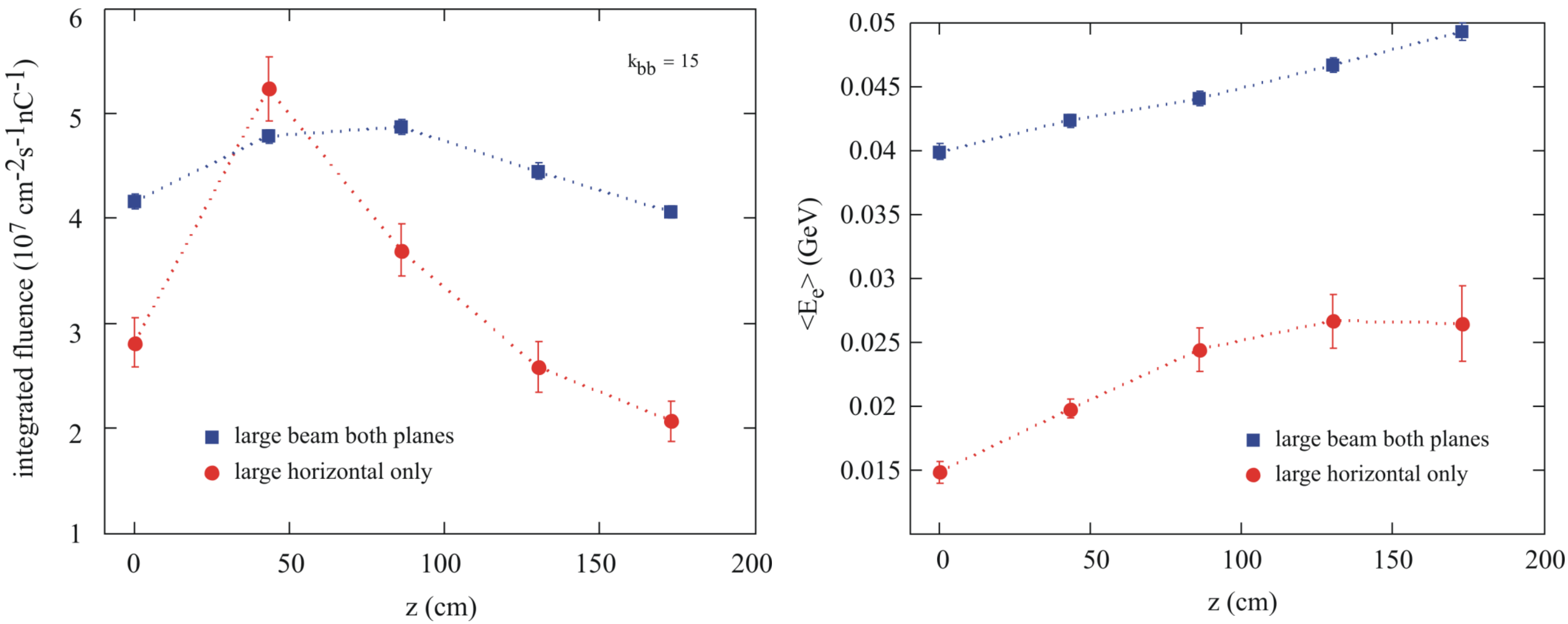


Large beam, horizontally
σ_x=1.5 cm, σ_y=0.1 cm



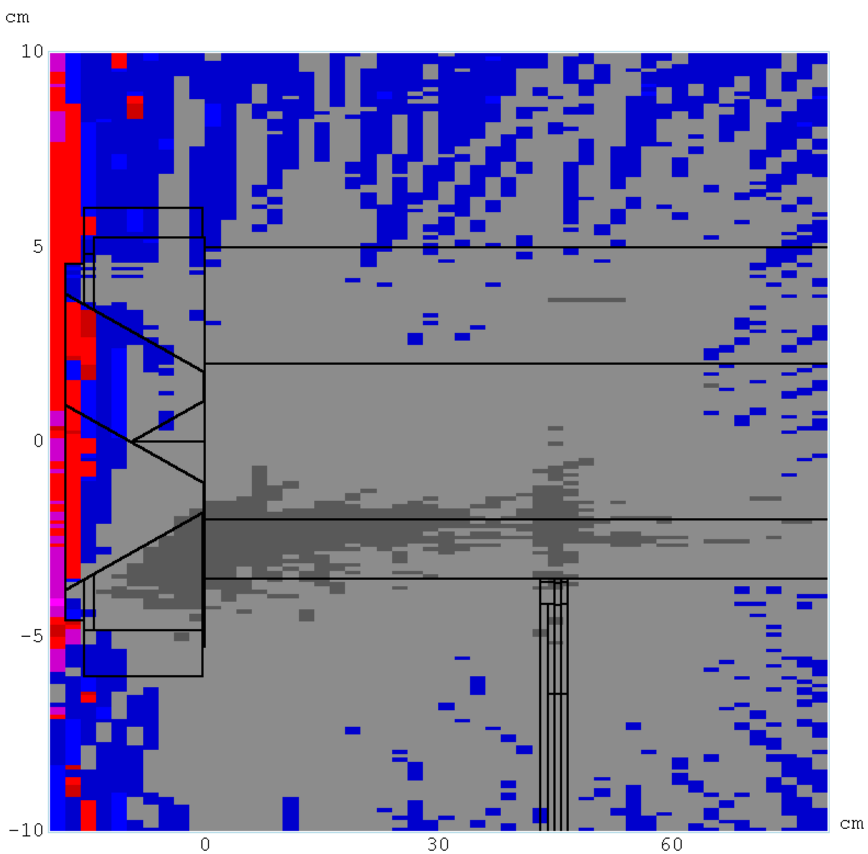
Simulation results

measurements agree with H-large only

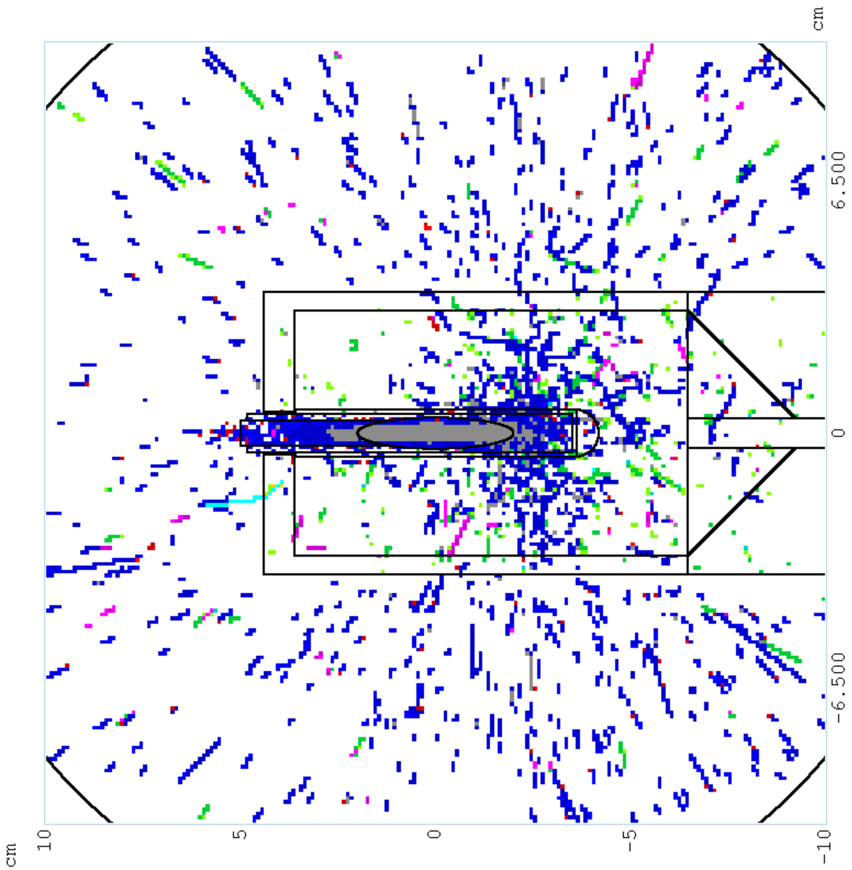


ID straight section

x-z electron fluence higher inside



x-y electron fluence not uniform

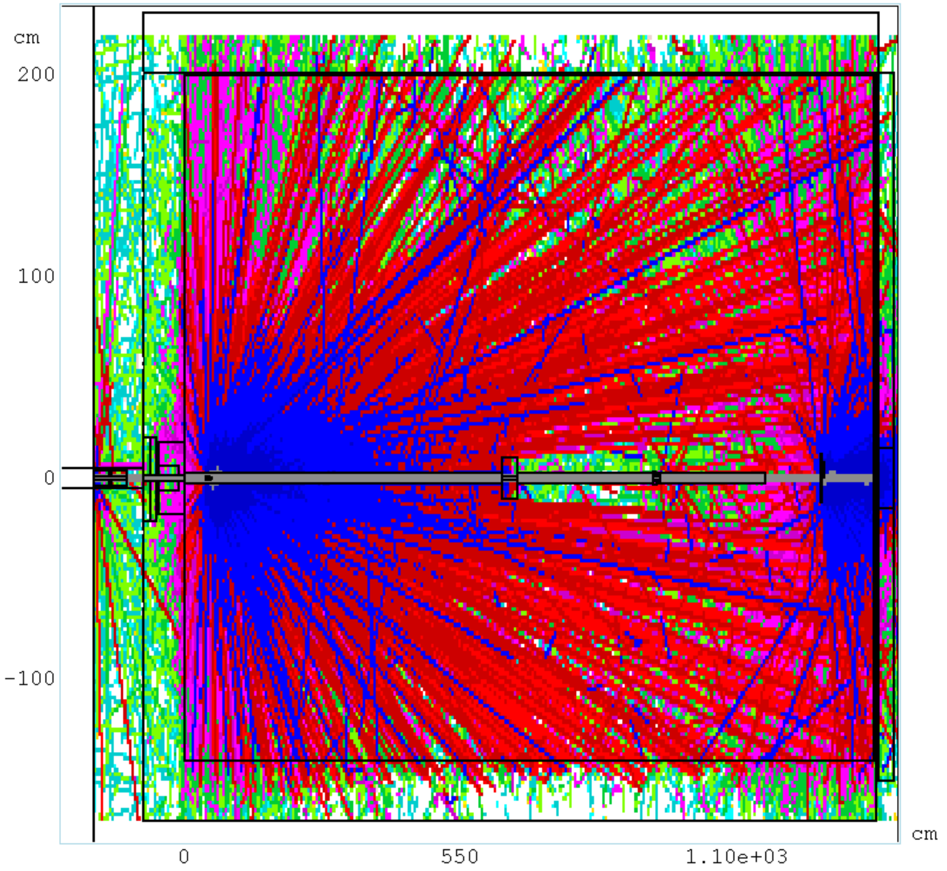


Conclusion: Not as useful for calibration as hoped. 1) non uniform irradiation and 2) not clear how to make a calibrated loss source.

On to S35

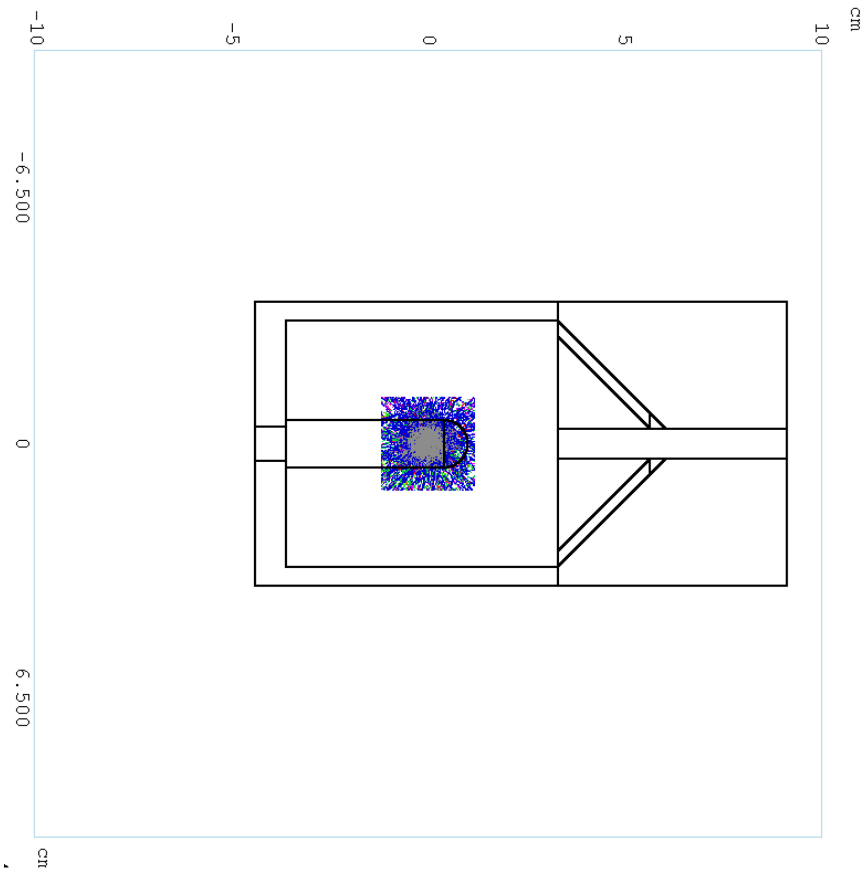
Sector 35 beamline (a beamline in general) has the following advantages

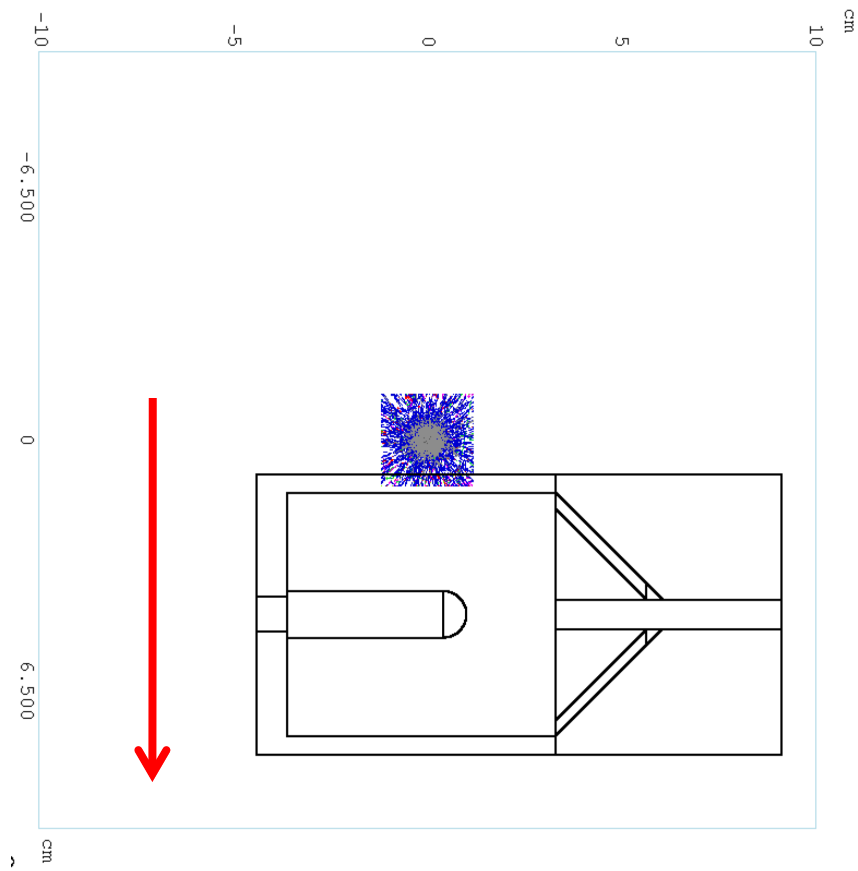
- steady source (gas bremsstrahlung)
- low fluence
- small, well-defined beam (of photons)
- electrons generated through pair-production
- relatively simple geometry



S35—BLM scans

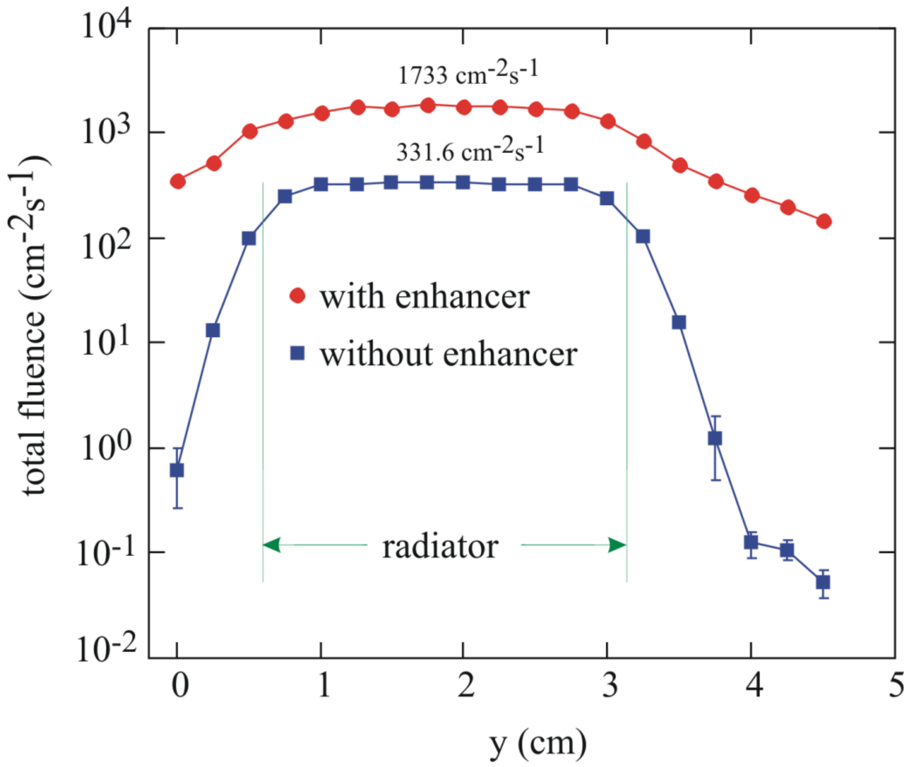
Simulations of BLM scans through GB radiation (with and without W enhancer)



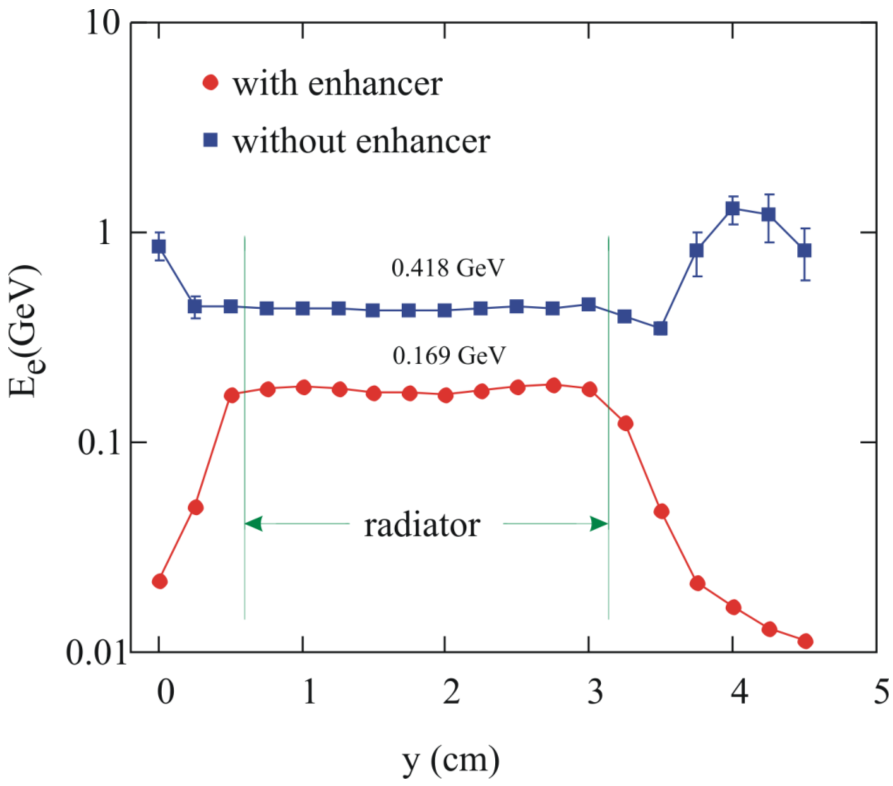


S35 simulated scan

Electron fluence rate

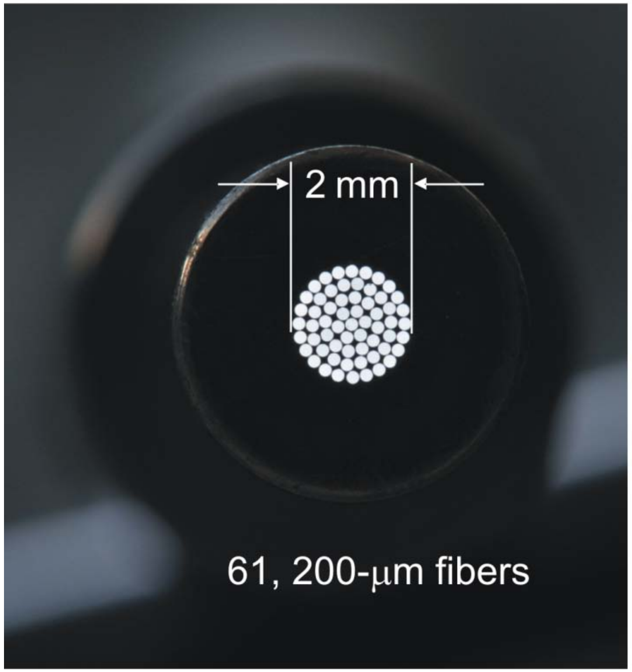


Average electron energy

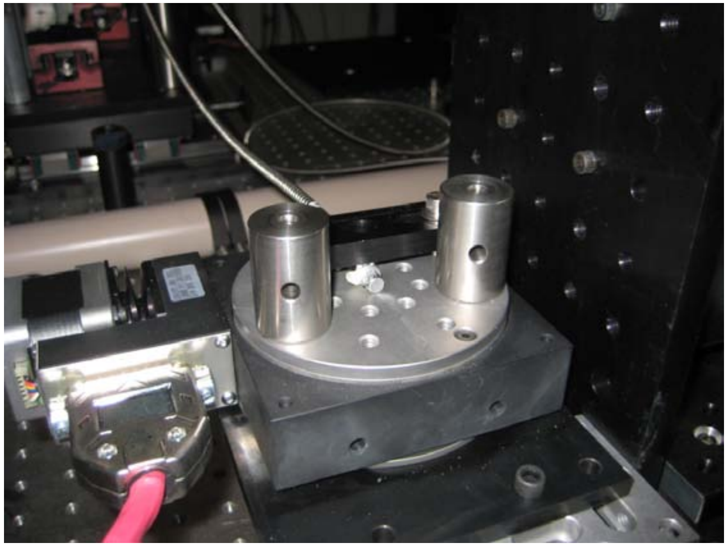


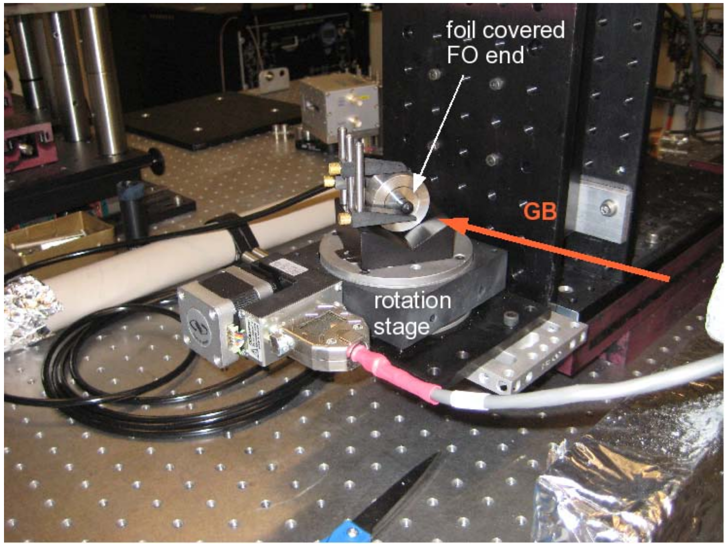
S35 calibration of FO bundle

3-m length, fused silica bundle



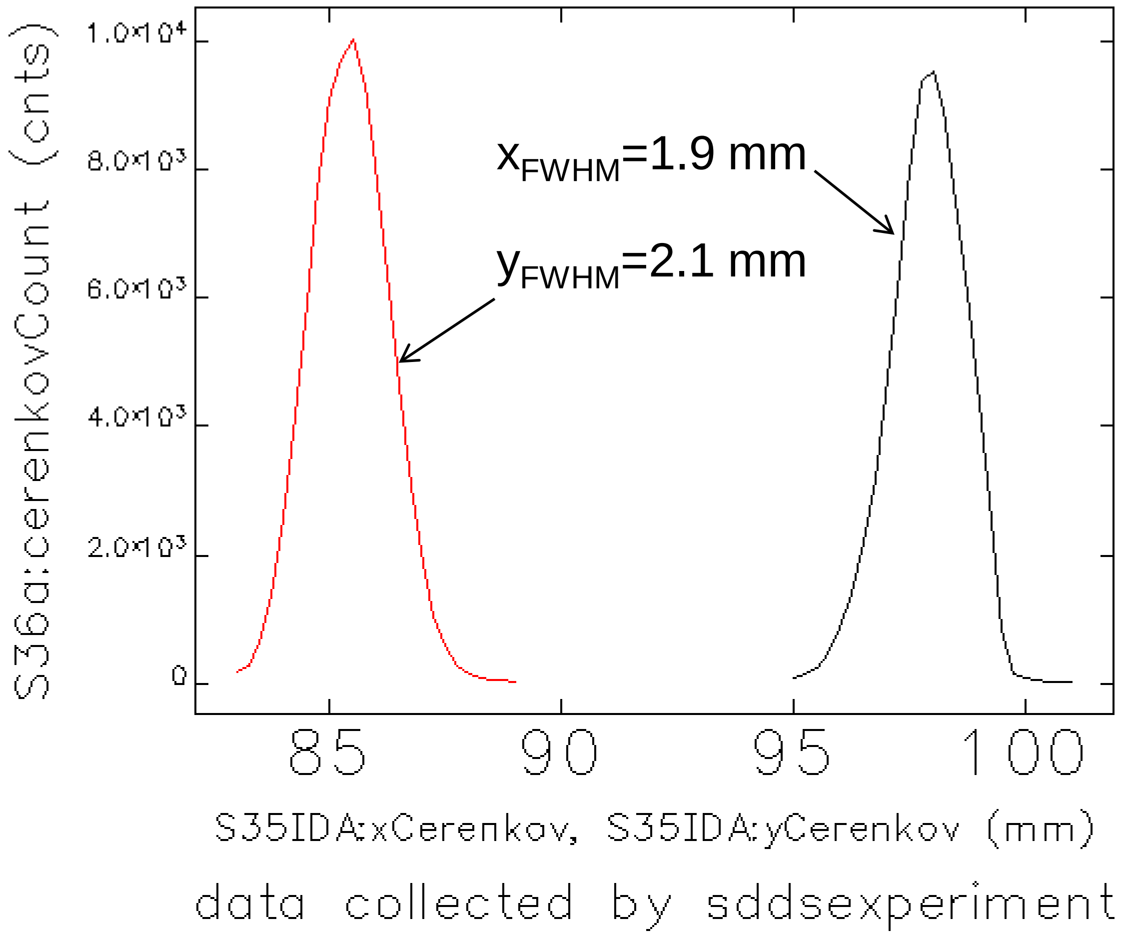
—photo courtesy of M. White





S35 calibration of FO bundle

Initial linear x- and y-scans



These widths are significantly less than $2\theta_{gb}L$ where $\theta_{gb}=1/\gamma=73$mrad and L=38 m

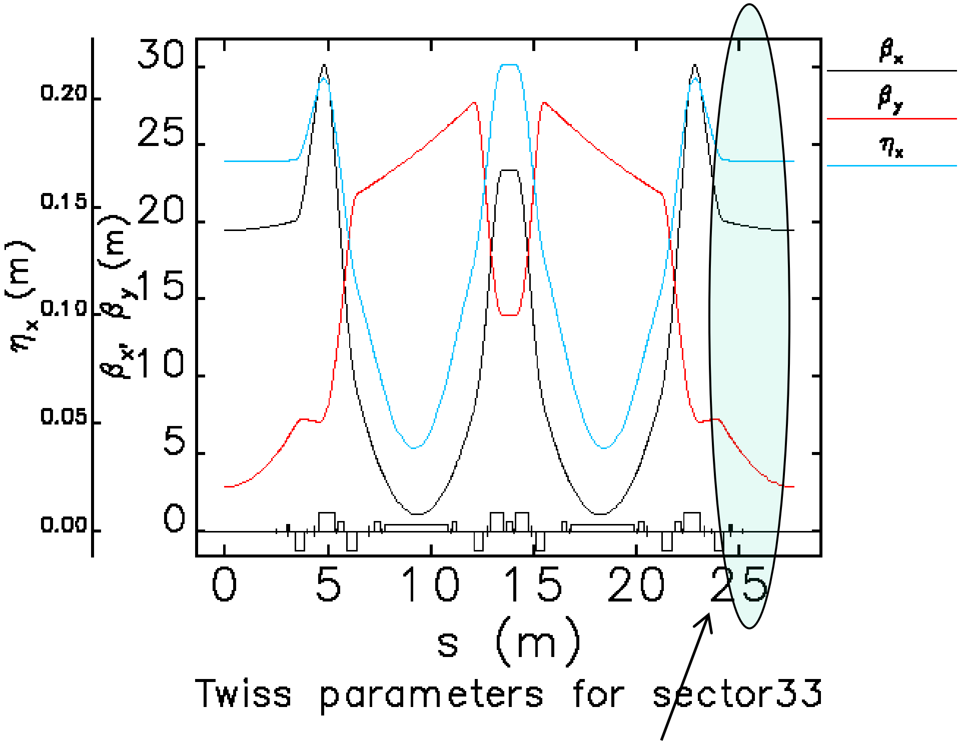
$2\theta_{gb}L$ =5.5 mm

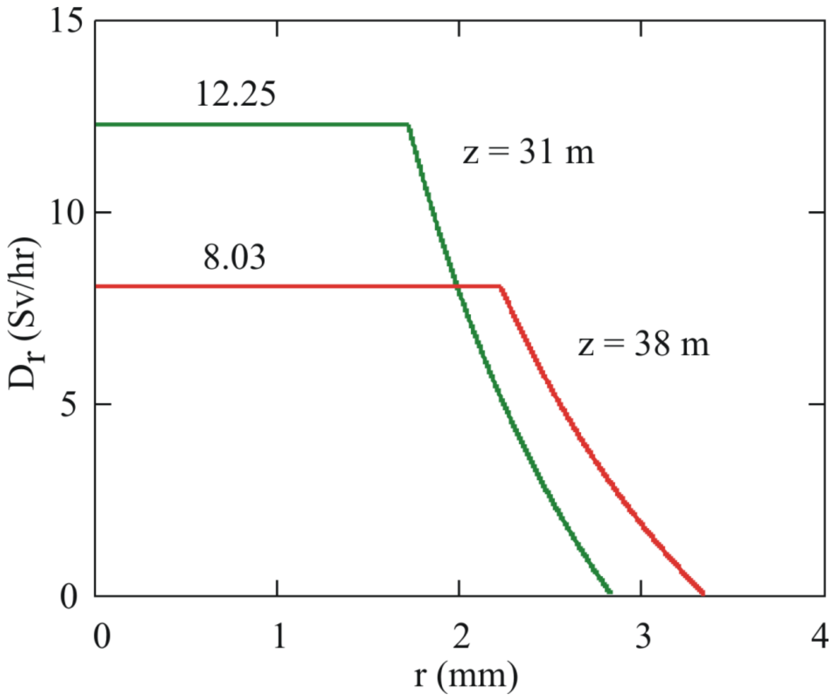
In addition, the width will be a convolution ofthe FO aperture and the true beam size.

Why?

S35 calibration of FO bundle

- The GB transverse size is partially determined by the electron beam size.
- The e-beam creates the GB.

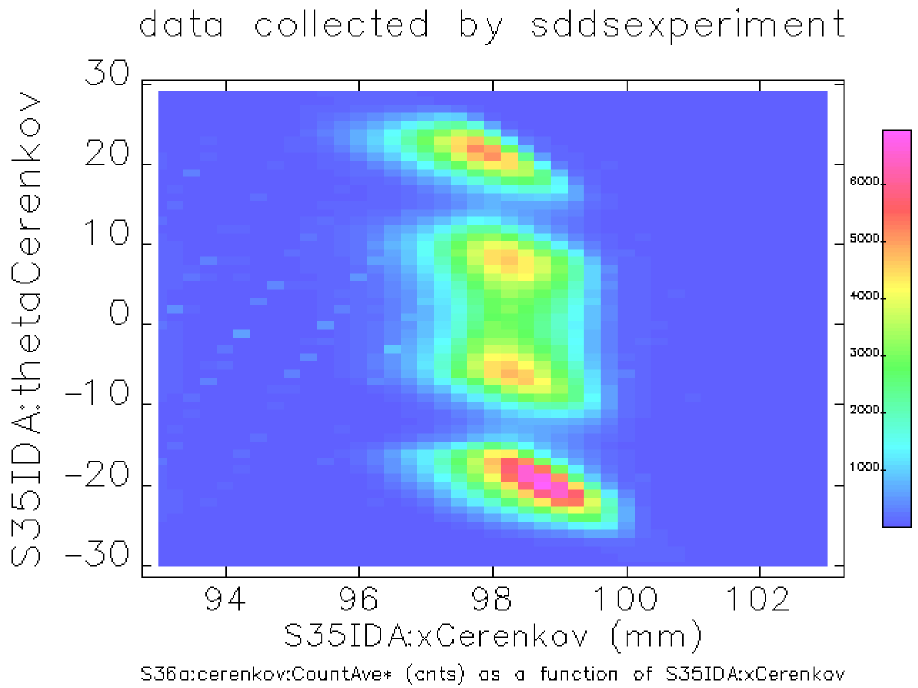




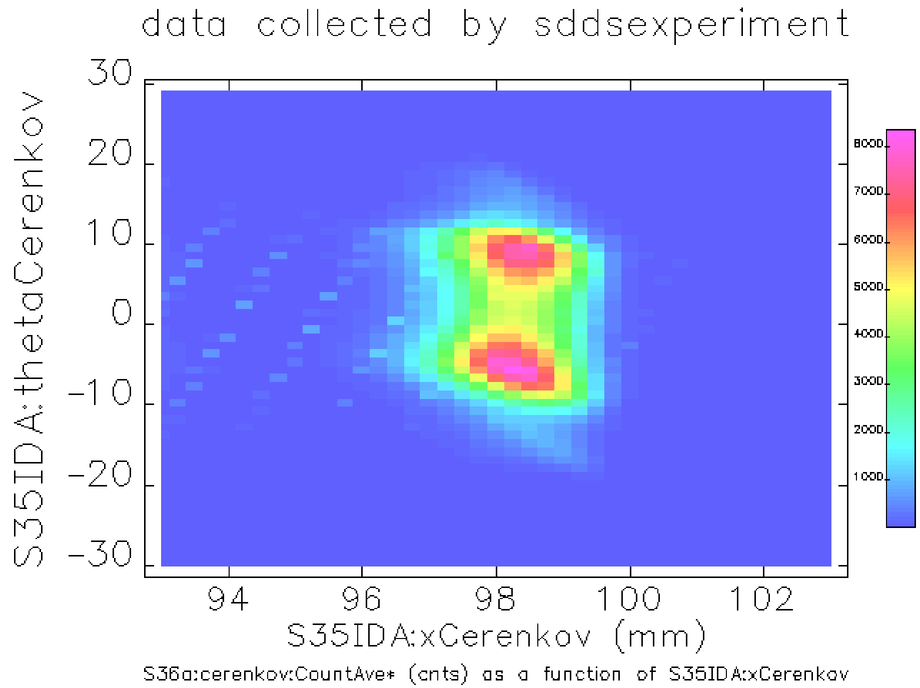
- Gentle focusing of the electron beam at the upstream end of the ID SS.
- This is where we expect the GB to originate.

S35 calibration of FO bundle

Rotational scans of the FO bundle led to some interesting and puzzling results



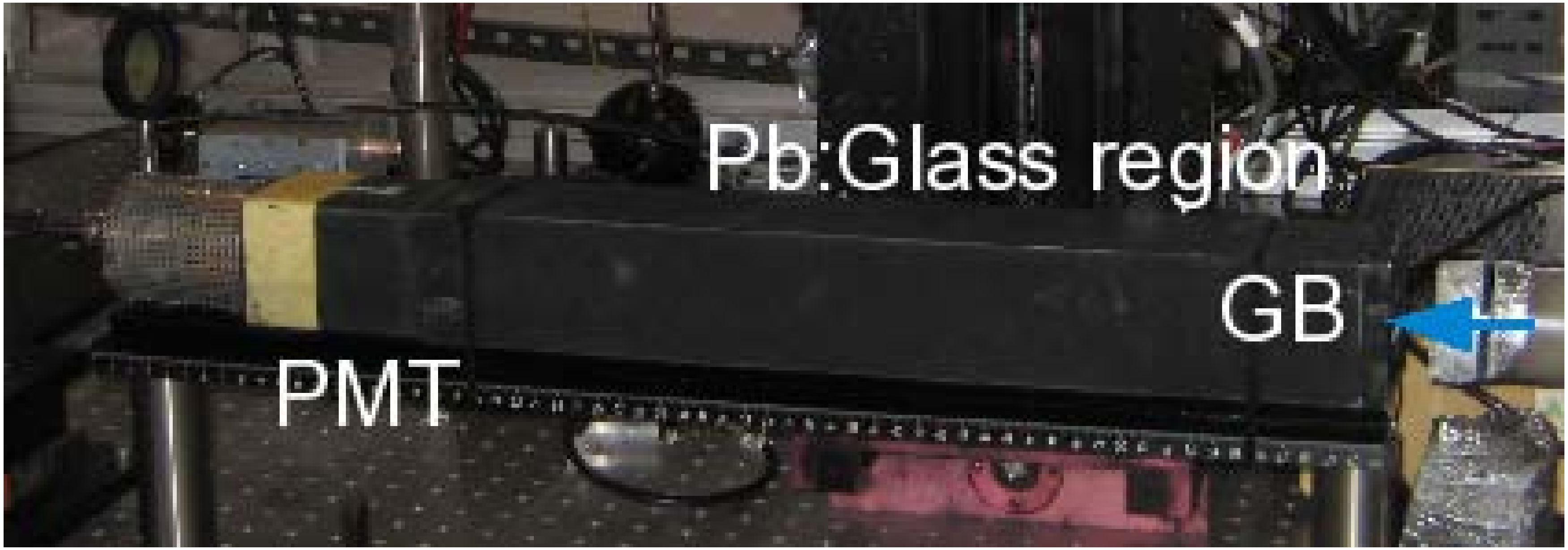
w/o Al foil



w/ Al foil

S35—characterizing the GB

Pb:Glass calorimeter—capable of capturing virtually all of the GB



Characterizing GB

- For fully-screened nuclei of atomic number Z, the number of photons per second in photon energy increment dk may be expressed as (Rossi),

$$F(k)dk = 4\alpha r_e^2 \frac{N_A}{A} Z(Z+1) \frac{dk}{k} f(\nu, Z)$$

- where the form factor is expressed as,

$$f(\nu, Z) = \left\{ \left[\nu^2 - \frac{4}{3}\nu + \frac{4}{3} \right] \ln\left(\frac{183}{Z^{1/3}} \right) + \frac{1}{9}(1-\nu) \right\}$$

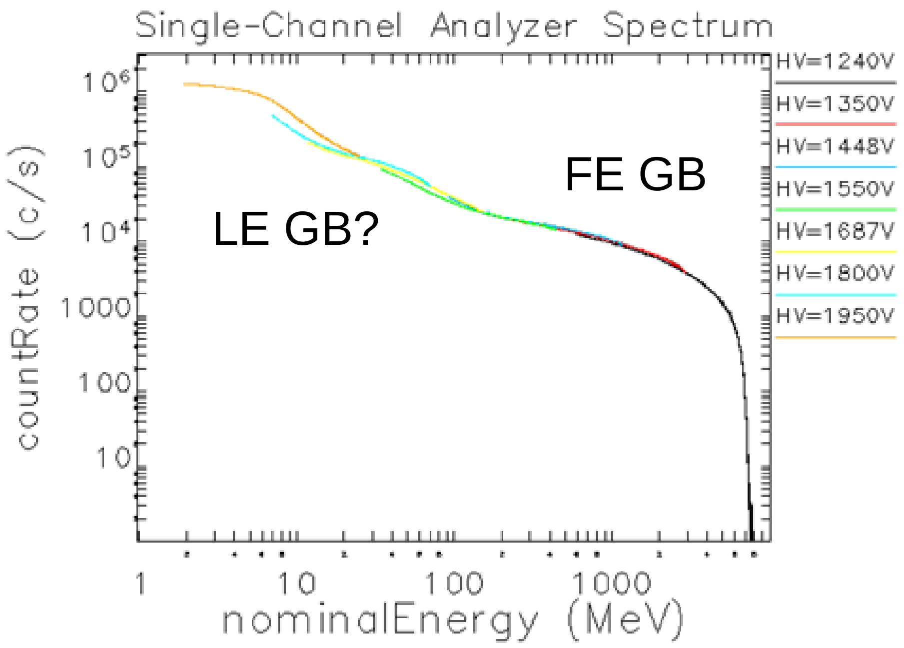
and ν=k/E where k is the photon energy and E the maximum electron energy

Characterizing GB

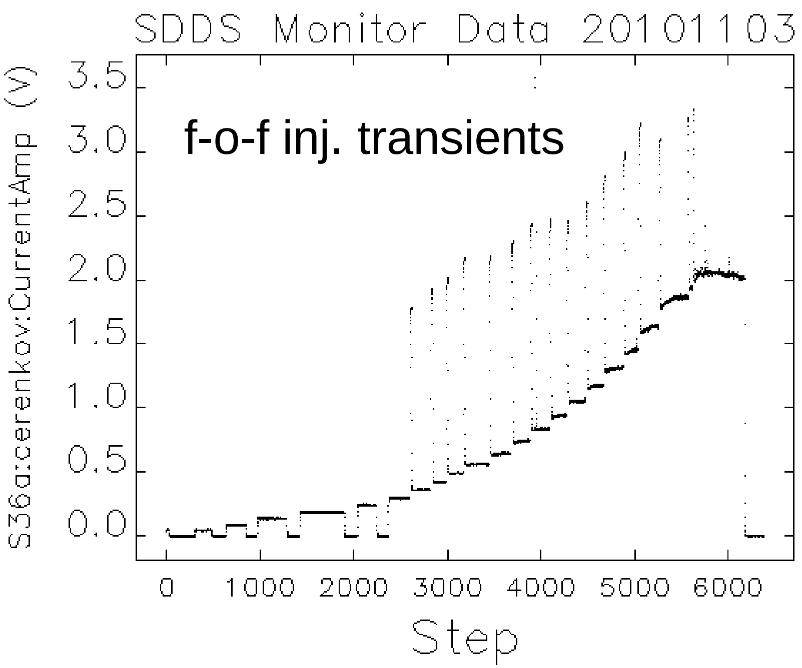
- we can now capture virtually all the GB power
- we know that all the GB power will initially be in the form of photons
- however we still have work to do to determine the target parameters; specifically,
  - target density, ρL_{ss}
  - target chemical constituency (Z or Z_{eff})
- nevertheless, GB should provide a good calibration source

Recent measurements in S35

assembled spectrum



GB power vs beam current



Characterizing GB

- Because we know how to calculate the GB power, we can work backwards to determine pressure in the ID SS
- Conduct high-current studies to see how pressure varies with beam current
- Obtain or build new GB detectors to allow faster counting (using lead tungstate, $PbWO_4$)
- Install RGAs to evaluate background gas constituencies
- Leak known amounts of gas, such as Ar, to verify

Conclusions

- GB is a good source for calibration
- We can use it to look at local conditions in ID ss
- Beginning work to characterize GB (e.g., high-current study planned for Dec. 21st)

Acknowledgments

Many thanks to our beam loss monitor team:

- Bill Berg
- Adam Brill
- Lester Erwin
- Bingxin Yang

also,

John Vacca