Radiation Monitoring at the Tevatron:

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What is Radiation Monitoring?

If you know the enemy and you know yourself, you need not fear the result of a hundred battles -- Sun-Tzu (ca.400 BC)

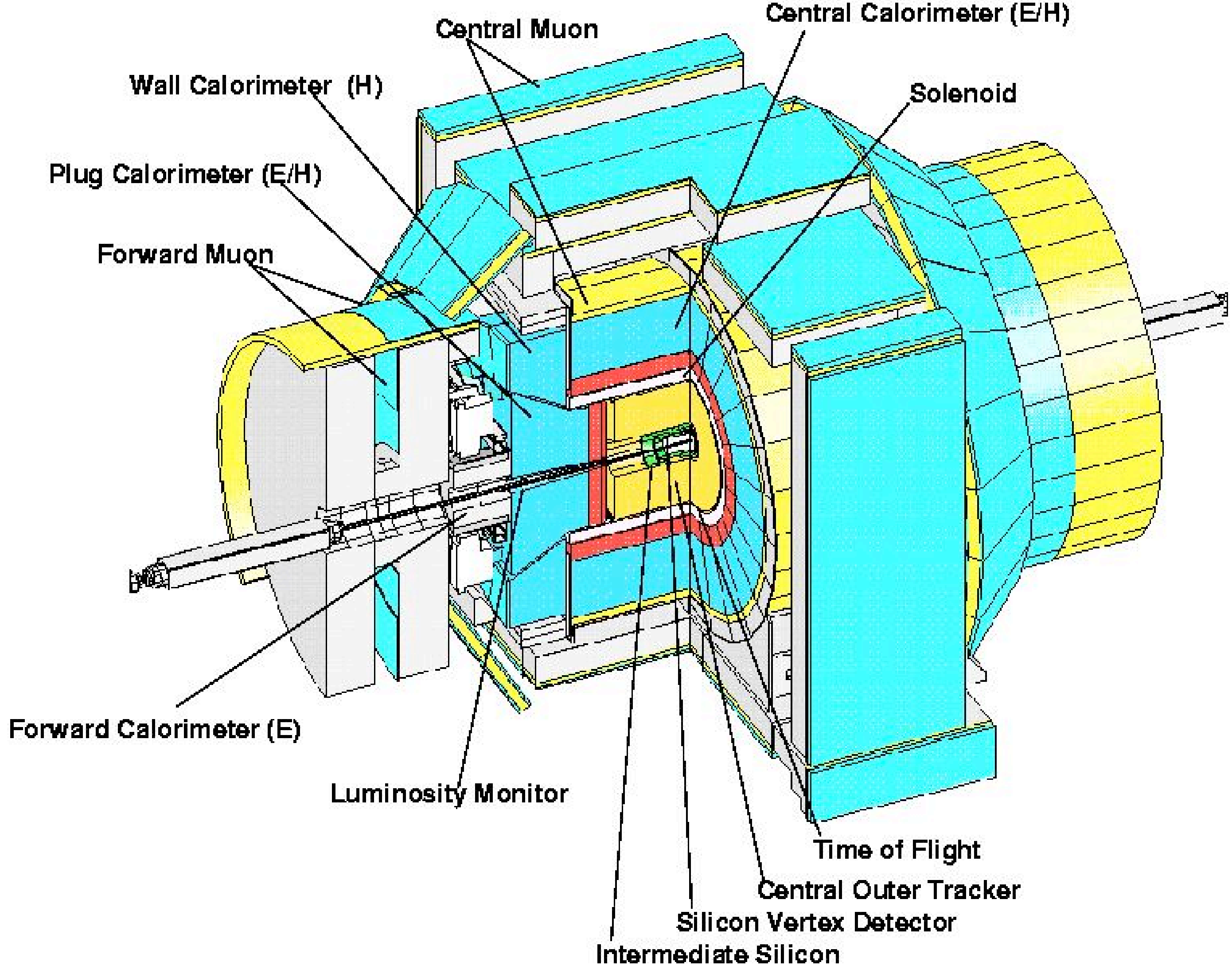
Operational Definition:

Monitor any beam induced conditions which affect the performance, reliability, lifetime of detectors or infrastructure.

Methods adopted at CDF (D0):

- Record/Monitor beam conditions and radiation.
  - real time and samples
- Evaluate the radiation field.
  - measurements and simulation
- Modify conditions to reduce risk.
  - modify/abort the beam (beam position, tune, collimator positions)
  - modify the conditions in the monitored region (shielding)

CDF-II Detector (G-rated)



Radiation Monitoring at CDF

Initial Goals:

- Measure distribution and rates of radiation
- Provide early estimate of Si tracker lifetime

Secondary Goals:

- Identify/evaluate radiation sources in/near CDF
- Additional instrumentation for the accelerator

Monitoring Technologies:

- Thermal Luminescent Dosimeters (TLDs)
- Silicon PIN diodes
- Ionization chambers
- Silicon detectors
- Scintillation counters
- Other beam monitors

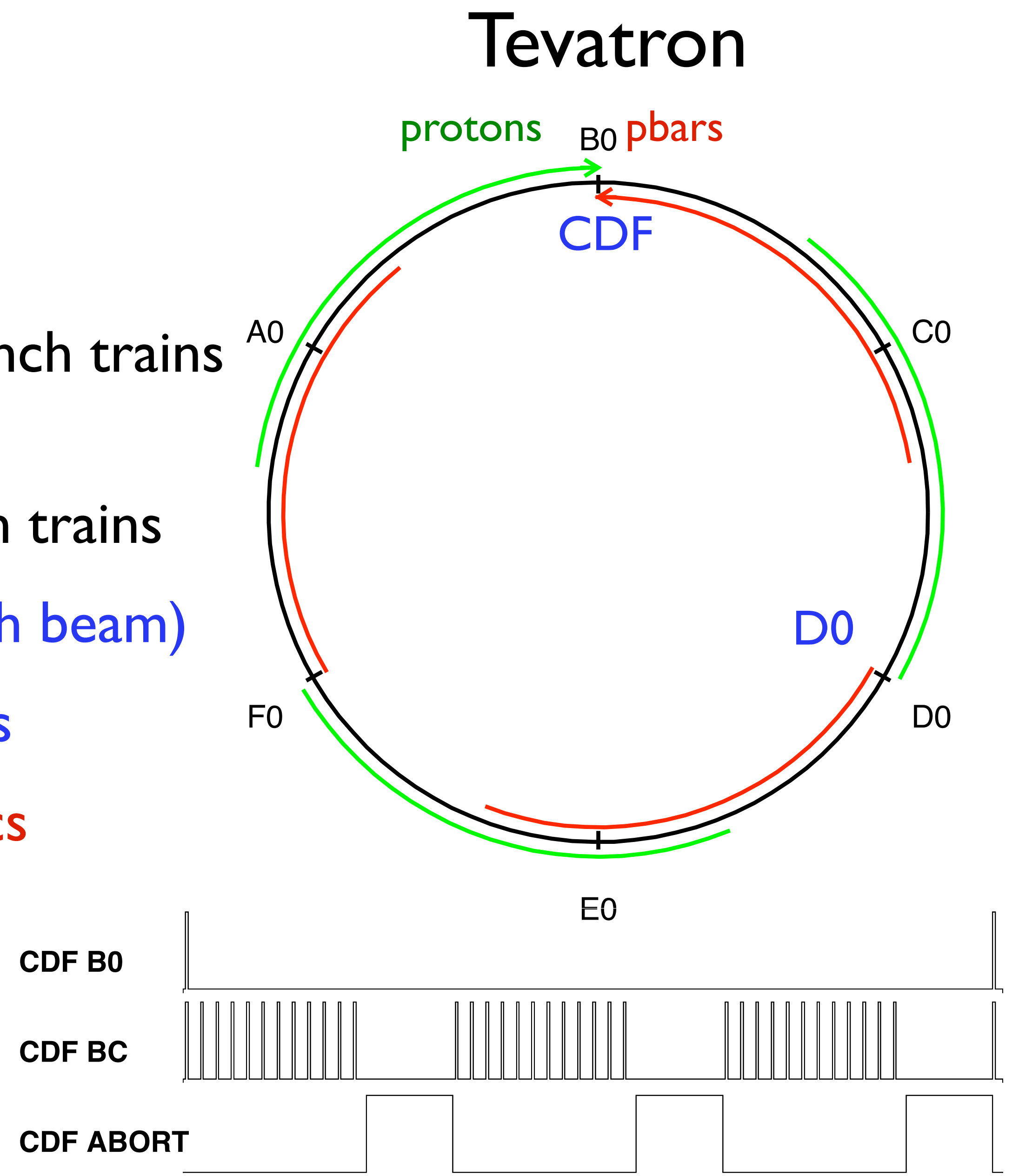
Beam Structure

- 36 1ns bunches in 3x12 bunch trains (396ns bunch spacing)
- 2.2μs space between bunch trains

* Monitor losses (in time with beam)

* Monitor beam in abort gaps

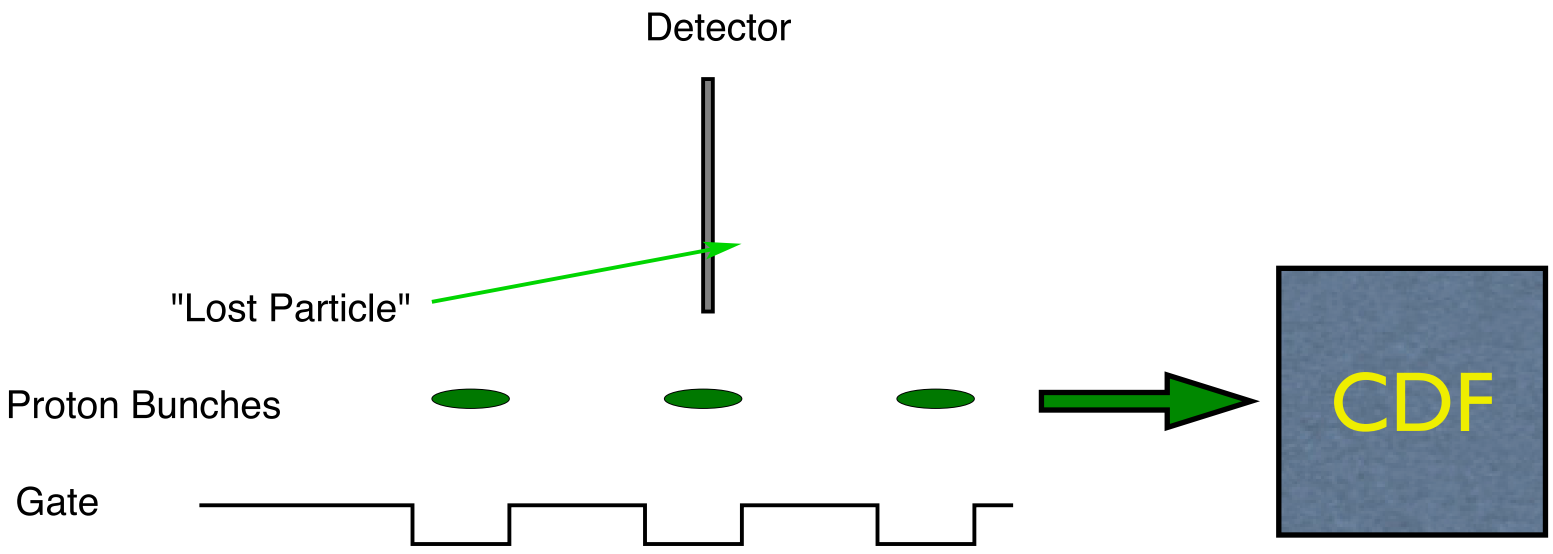
> Fast detectors & electronics



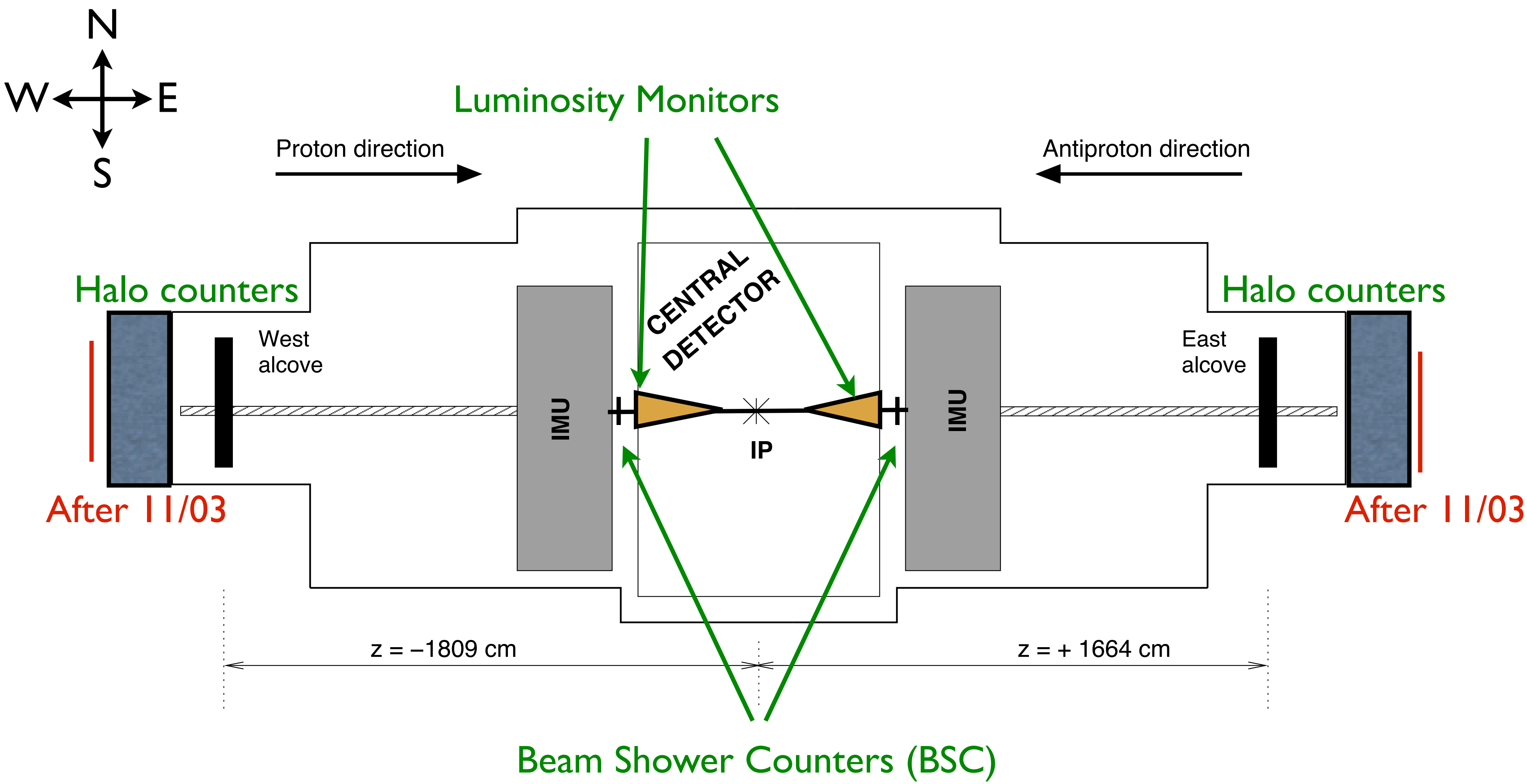
Calculating Losses

Beam Losses all calculated in the same fashion

- Detector signal in coincidence with beam passing the detector plane.
- Accelerator Network (ACNET) variables differ by detector/gating method.



Beam Monitors



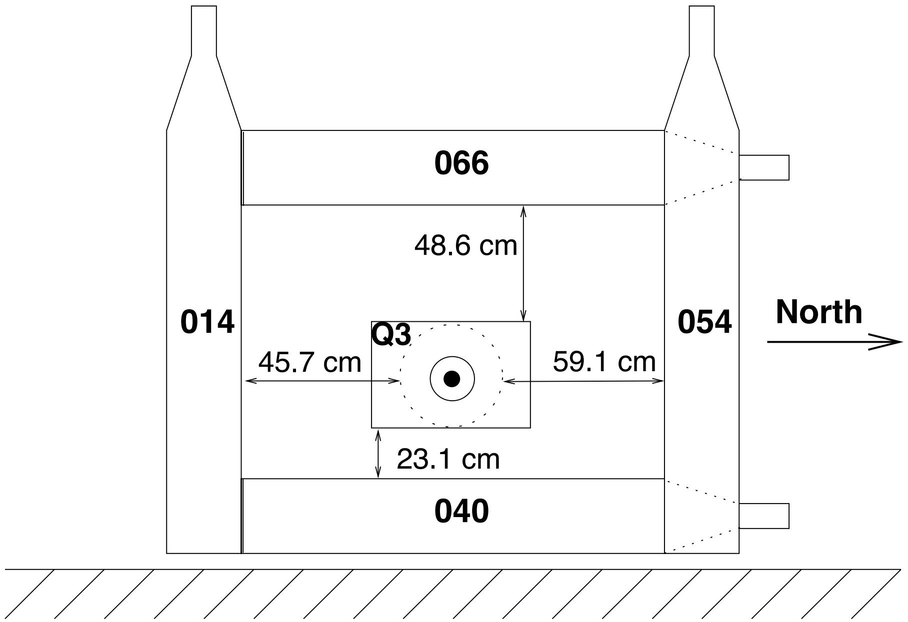
Luminosity monitors: monitor proton-antiproton collisions

BSC counters: monitor beam losses and abort gap

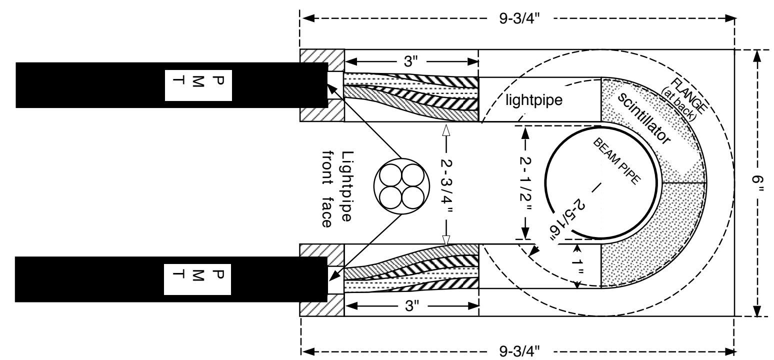
Halo counters: monitor beam halo and abort gap

Detectors

Halo Counters



Beam Shower Counters

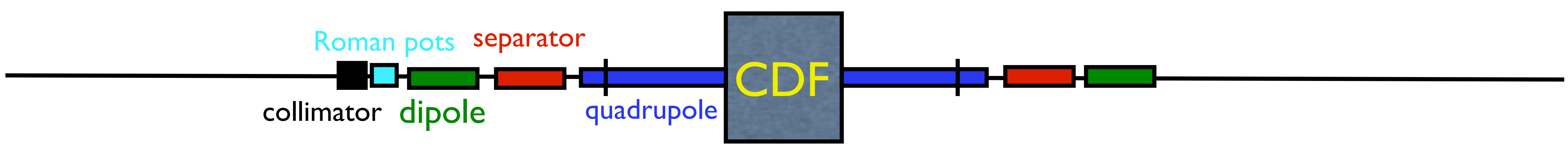


ACNET Devices:

B0PHSM: beam halo
B0PBSM: abort gap losses
B0PAGC: 2/4 coincidence abort gap losses

B0PLOS: proton losses (digital)
LOSTP: proton losses (analog)
B0MSC3: abort gap losses (E*W coincidence)

Beam Halo Counters



Typical Store

Beam Parameters:

Protons:	5000 - 9000	10^9 particles
Antiprotons:	100-1500	10^9 particles
Luminosity:	10 - 70	10^{30} cm^{-2}s^{-1}

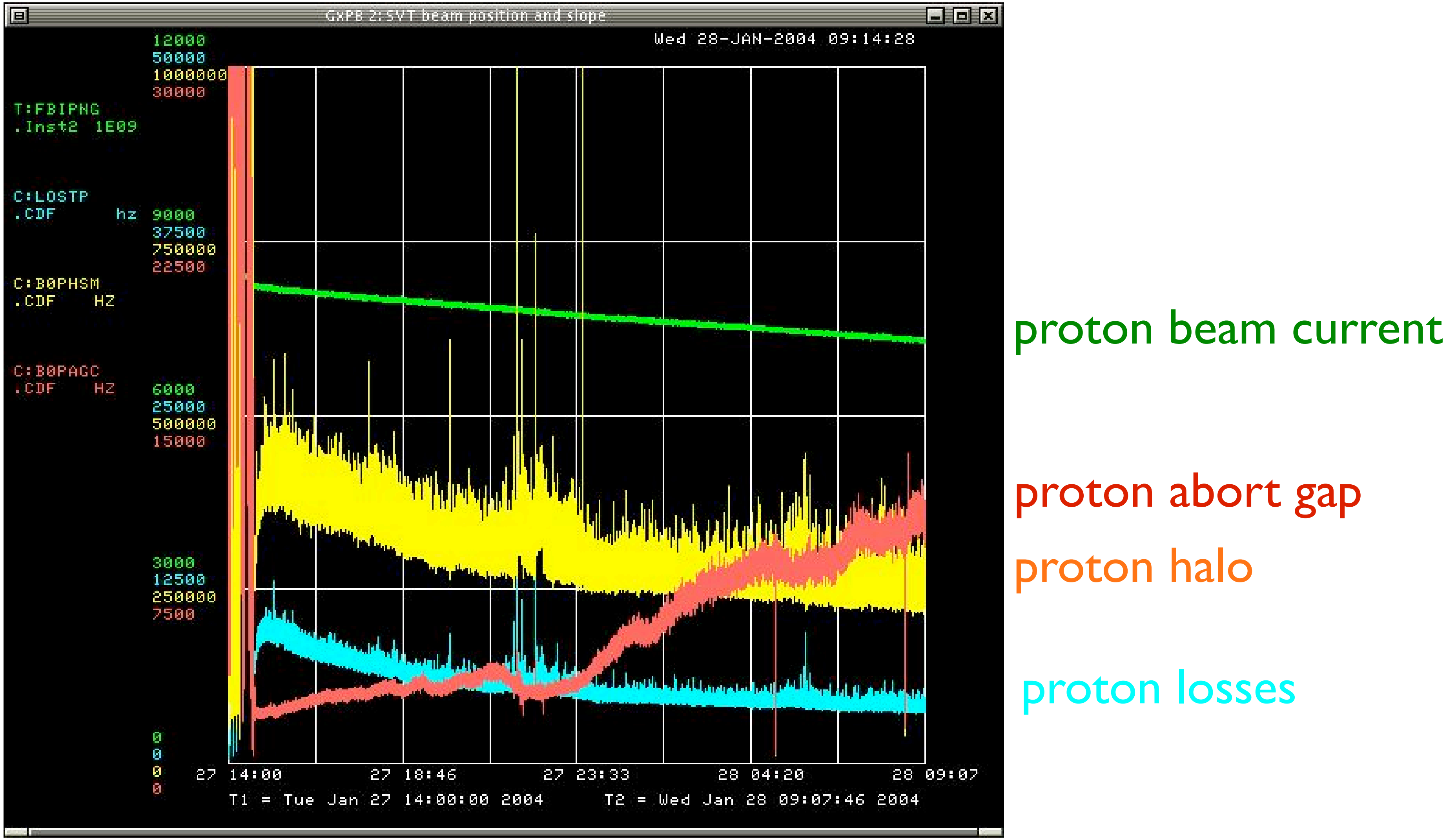
Losses and Halo:

Quantity	Rate (kHz)	Limit (kHz)	comment
P Losses	2 - 15	25	chambers trip on over current
Pbar Losses	0.1 - 2.0	25	chambers trip on over current
P Halo	200 - 1000	-	
Pbar Halo	2 - 50	-	
Abort Gap Losses	2 - 12	15	avoid dirty abort (silicon damage)
L1 Trigger	0.1-0.5		two track trigger (~1 mbarn)

Note: All number are taken after scraping and HEP is declared.

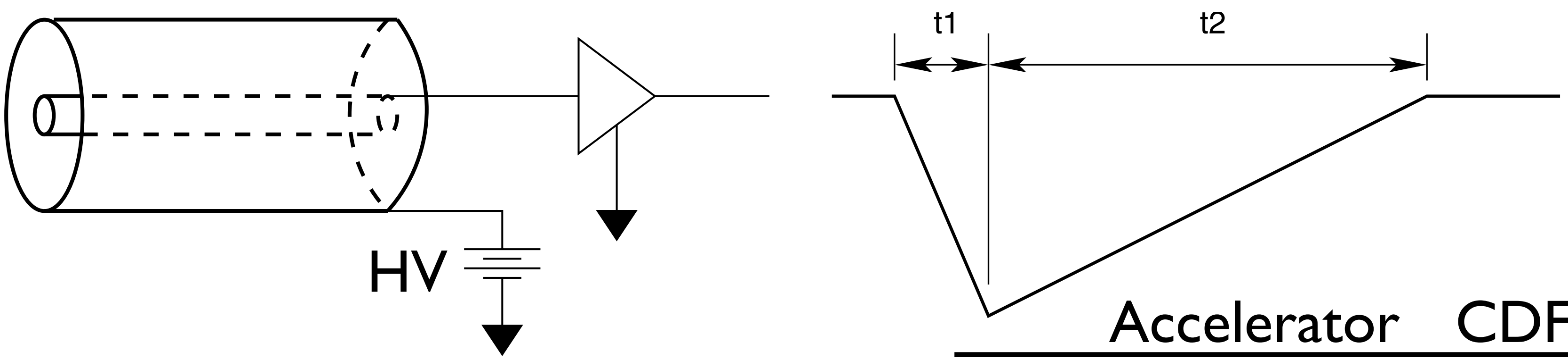
Monitor Experience

"Typical good store"



Tevatron Radiation Protection Beam Loss Monitors(BLM)

- Cylindrical Ionization Chamber
  - 110 cc Ar @ atmospheric pressure

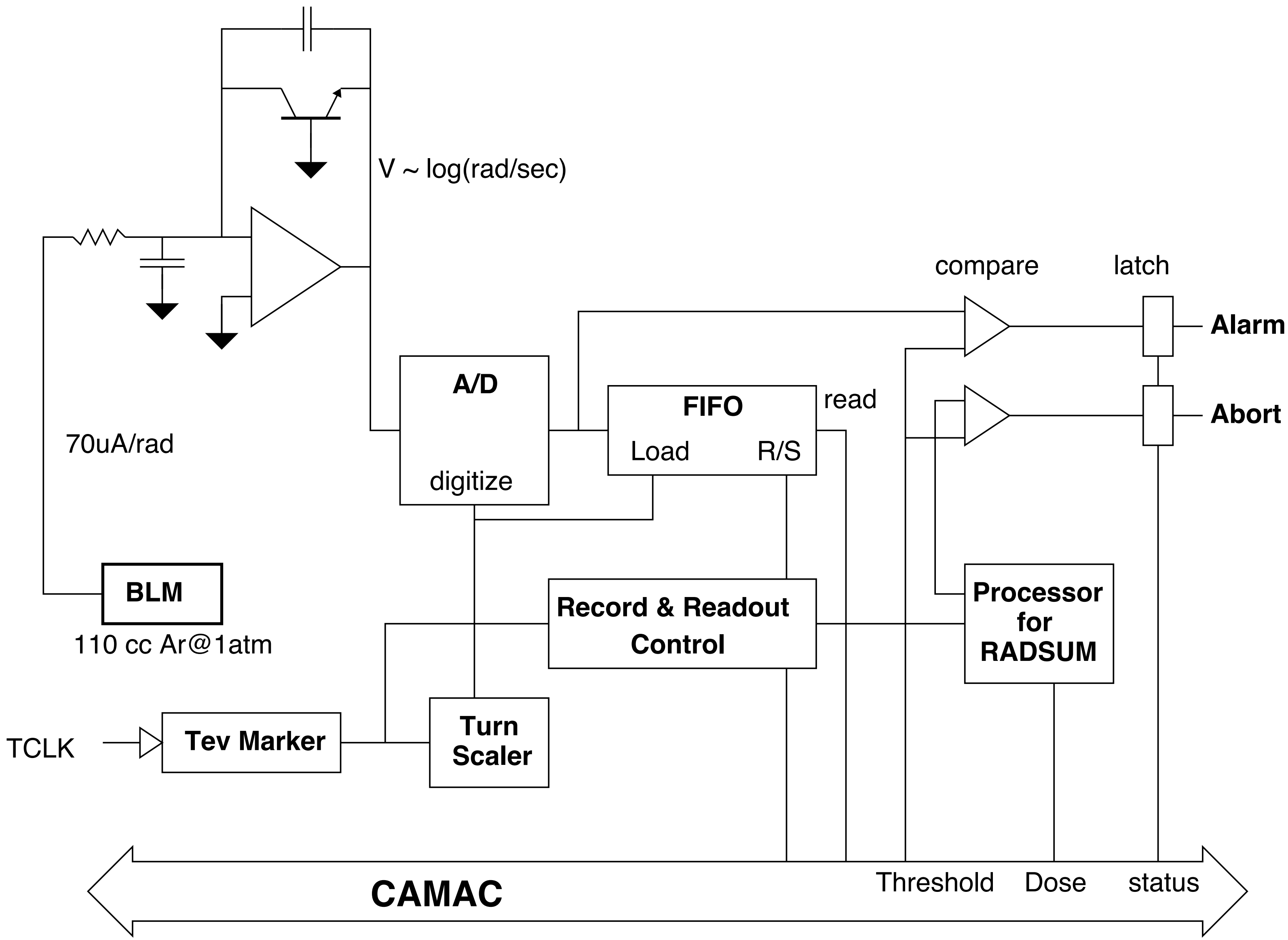


	Accelerator	CDF/D0
t1	24μs	24μs
t2	67ms	940ms

- Part of Tevatron abort system
  - Samples every 10 turns, abort on any sample above threshold
  - Conversion 70nA/(rad/s)

Note: Tevatron revolution time = 21μs

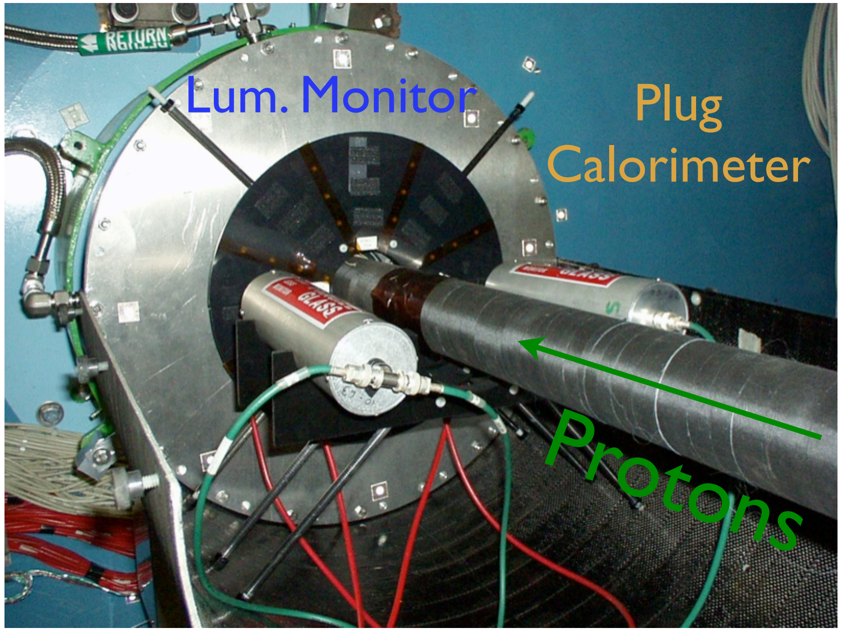
BLM Electronics

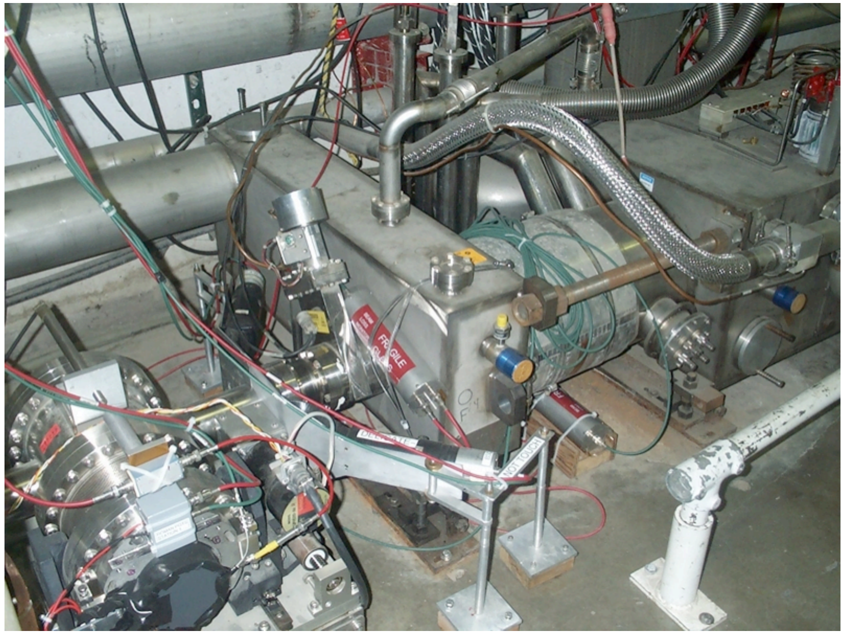


BLM Locations

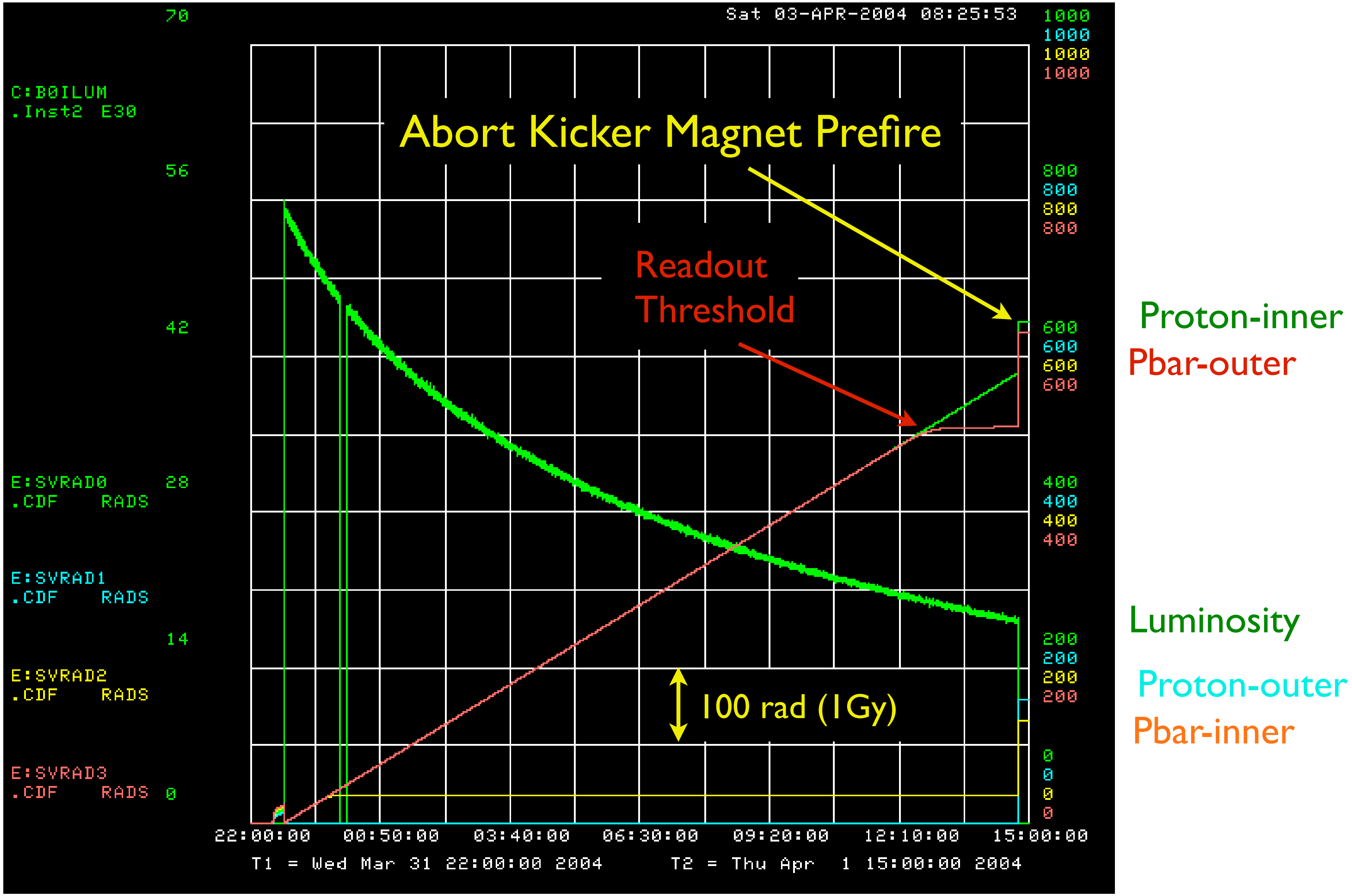
Accelerator Tunnel

CDF

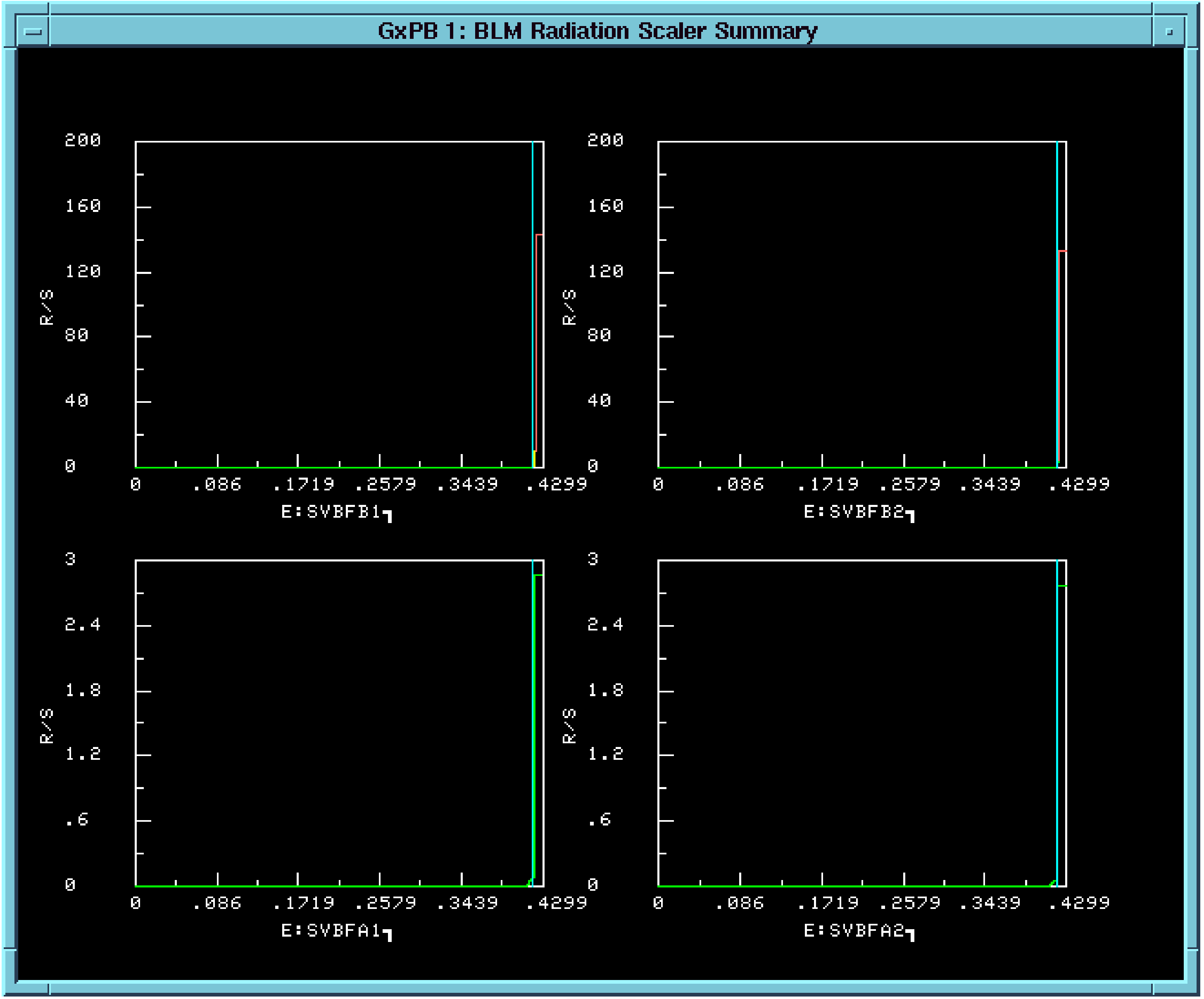




BLM Data


Sat 03-APR-2004 08:25:53
C:B0ILUM
.Inst2 E30
E:SVRAD0
.CDF RADS
E:SVRAD1
.CDF RADS
E:SVRAD2
.CDF RADS
E:SVRAD3
.CDF RADS
70
56
42
28
14
0
1000
800
600
400
200
0
Abort Kicker Magnet Prefire
Readout Threshold
100 rad (1Gy)
22:00:00
00:50:00
03:40:00
06:30:00
09:20:00
12:10:00
15:00:00
T1 = Wed Mar 31 22:00:00 2004
T2 = Thu Apr 1 15:00:00 2004
Proton-inner
Pbar-outer
Luminosity
Proton-outer
Pbar-inner

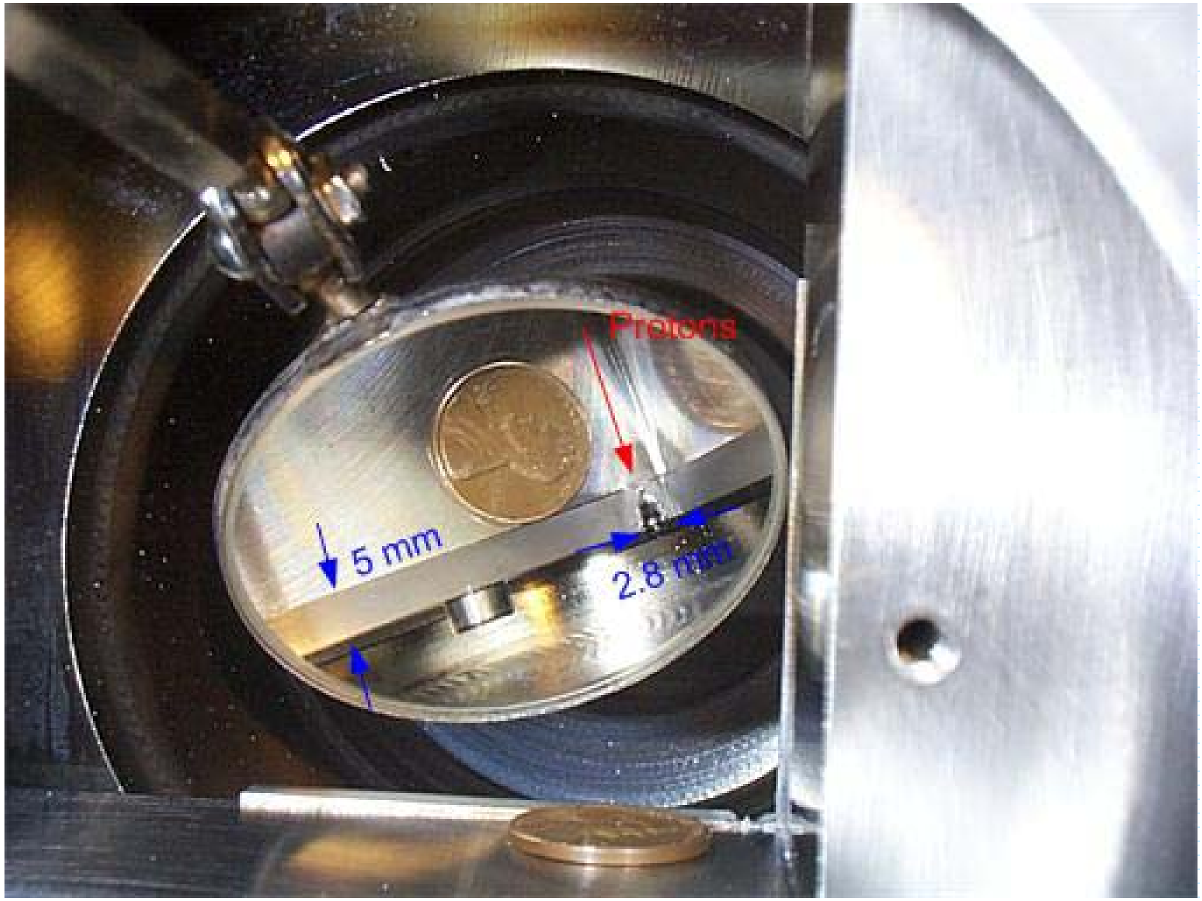
BLM FIFO on Abort



BLM Protection Disabled

- Magnet quench
- Beam deflected into D49 target
- Estimate 20-30 turns to make hole (400 -600μs)

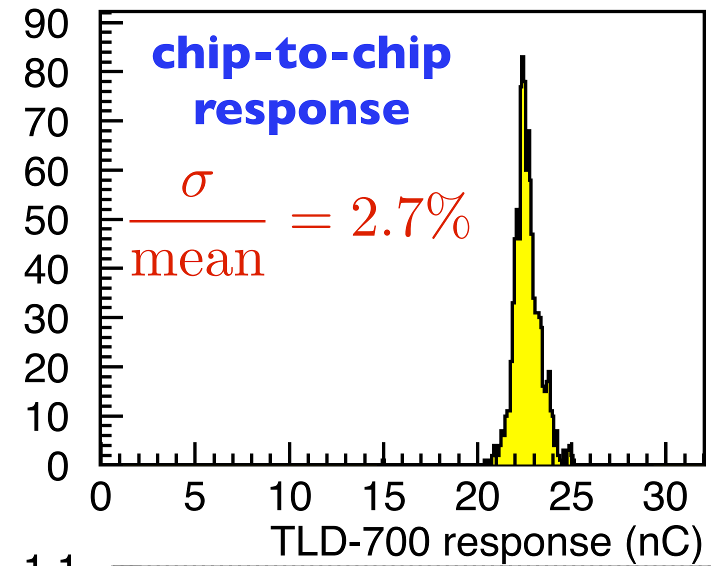
> Existing system does not react fast enough to prevent damage to target in this incident.

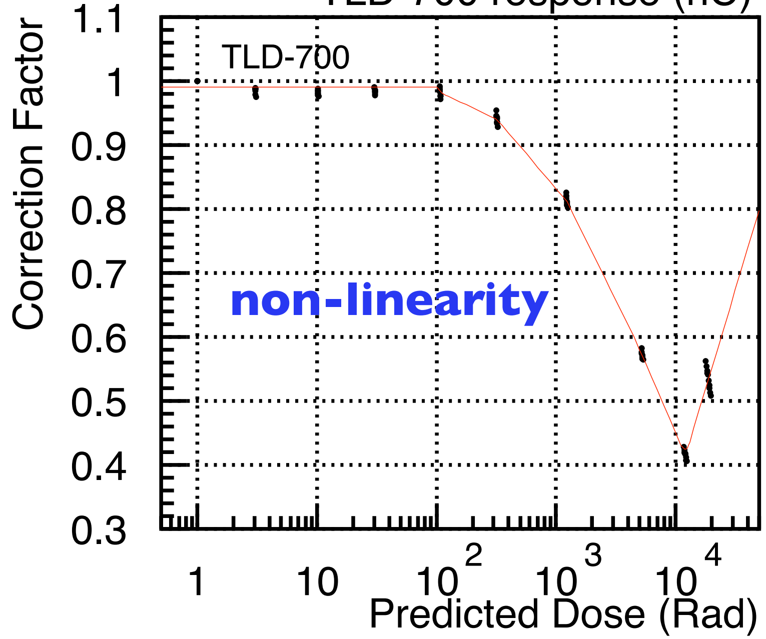


Upgrade in BLM system being considered.

Measuring the Radiation Field

- Thermal Luminescent Dosimeters (TLDs)
- Calibrate other devices
- Advantages:
  - \+ passive
  - \+ large dynamic range(10^{-3}-10^{2} Gy)
  - \+ good precision (<1%)
  - \+ absolute calibration
  - \+ γ,n measurements
- Disadvantages:
  - \- harvest to read
  - \- large amount of handling
  - \- non linearity at high doses
  - \- only measure "thermal" neutrons

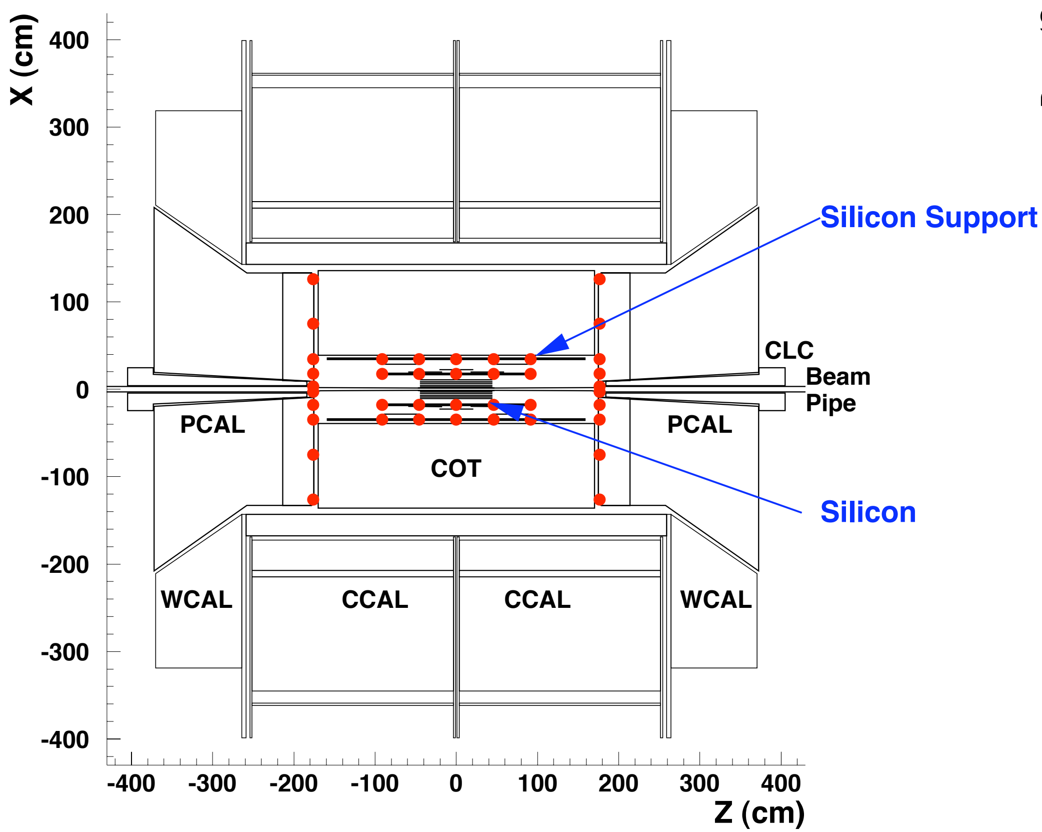


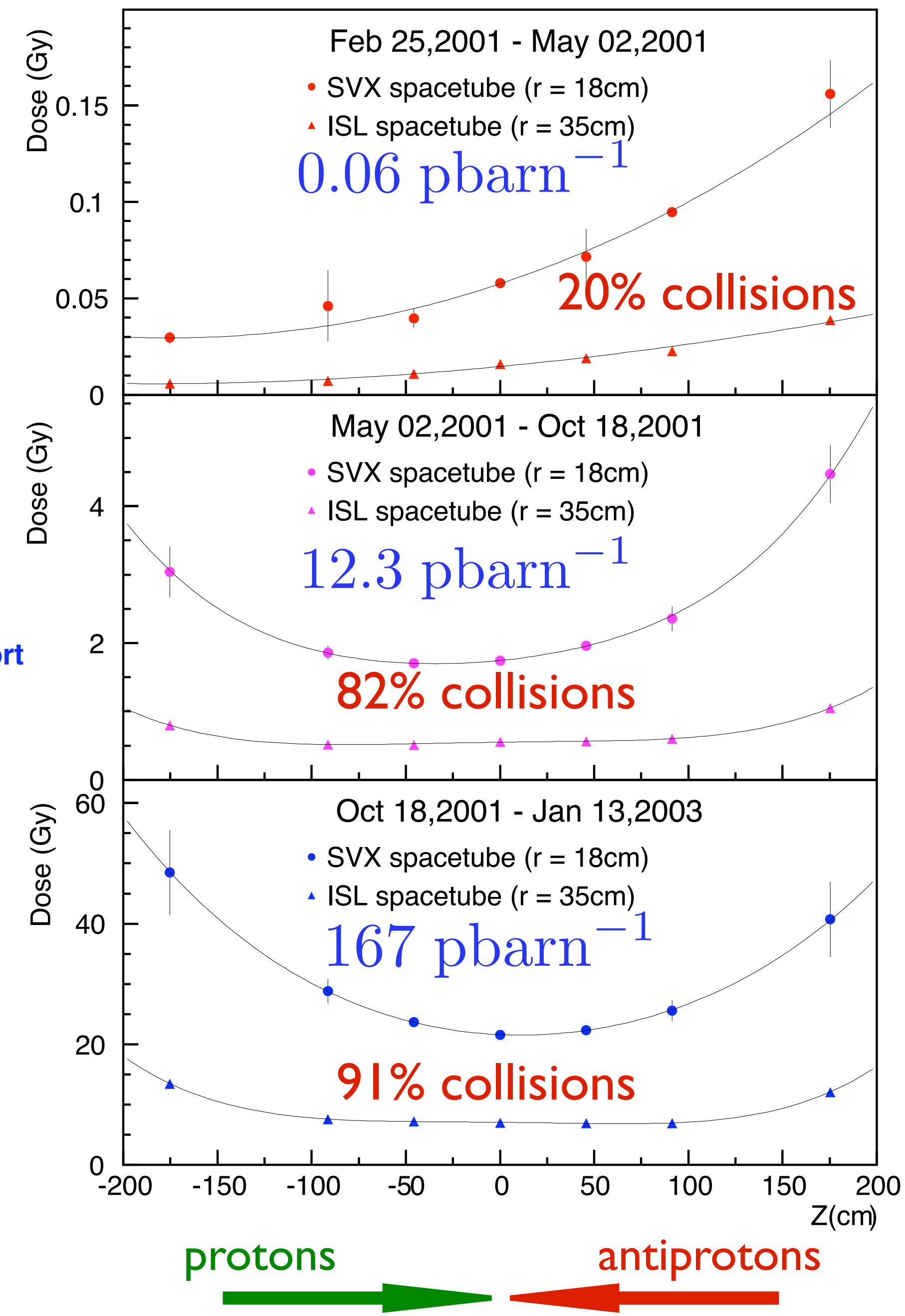


Good for accurate, low-medium dose evaluation

Radiation Field Measurements

- TLDs installed in tracking volume
- 3 exposure periods
  - 0.06 $pbarn^{-1}$ (p-loss dominated)
  - 12.3 $pbarn^{-1}$
  - 167 $pbarn^{-1}$





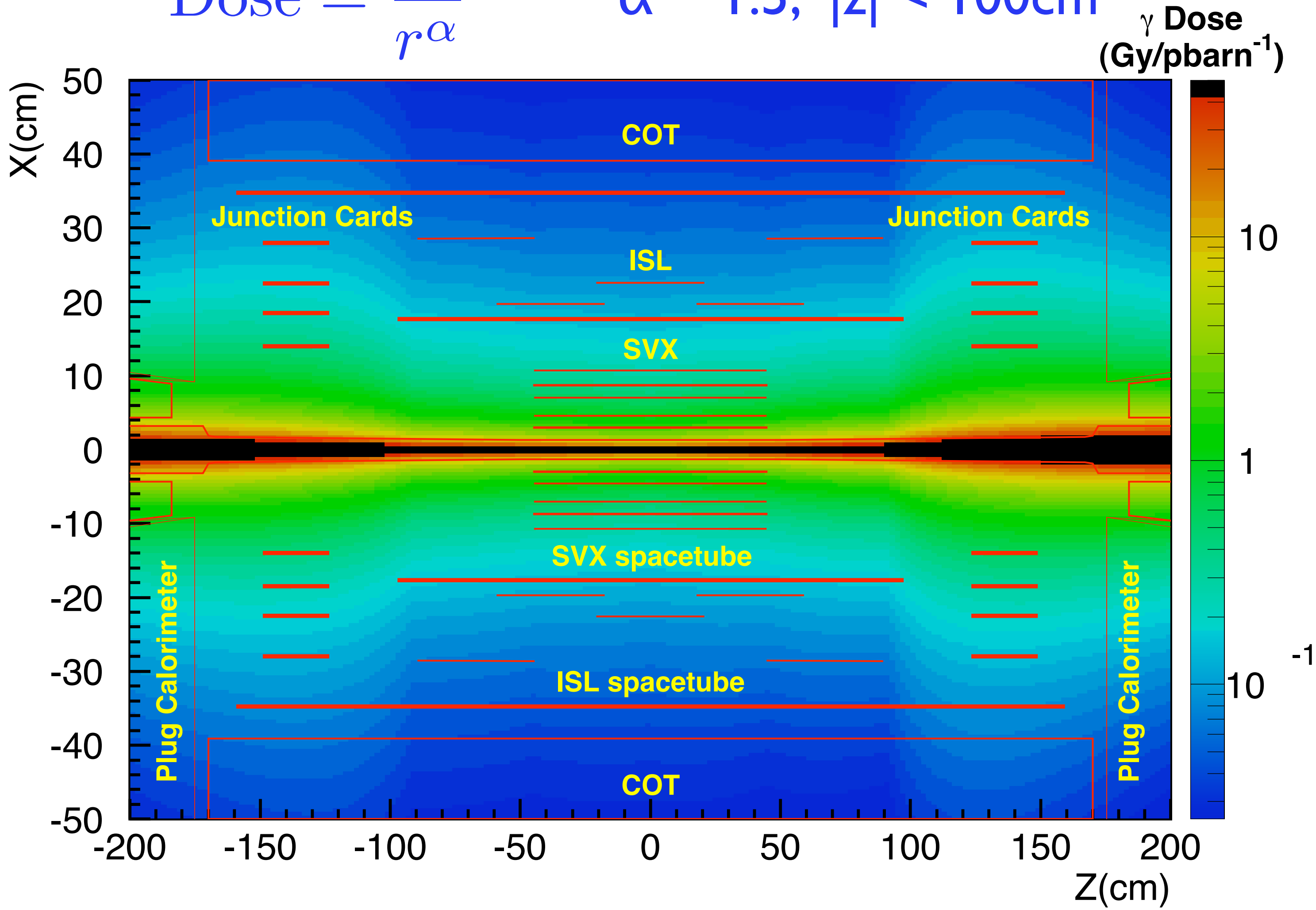
Radiation from Collisions

TLD measurements + model

r measured transverse to the beam

$$\text{Dose} = \frac{A}{r^{\alpha}}$$

$\alpha \sim 1.5$; $|z| < 100$cm



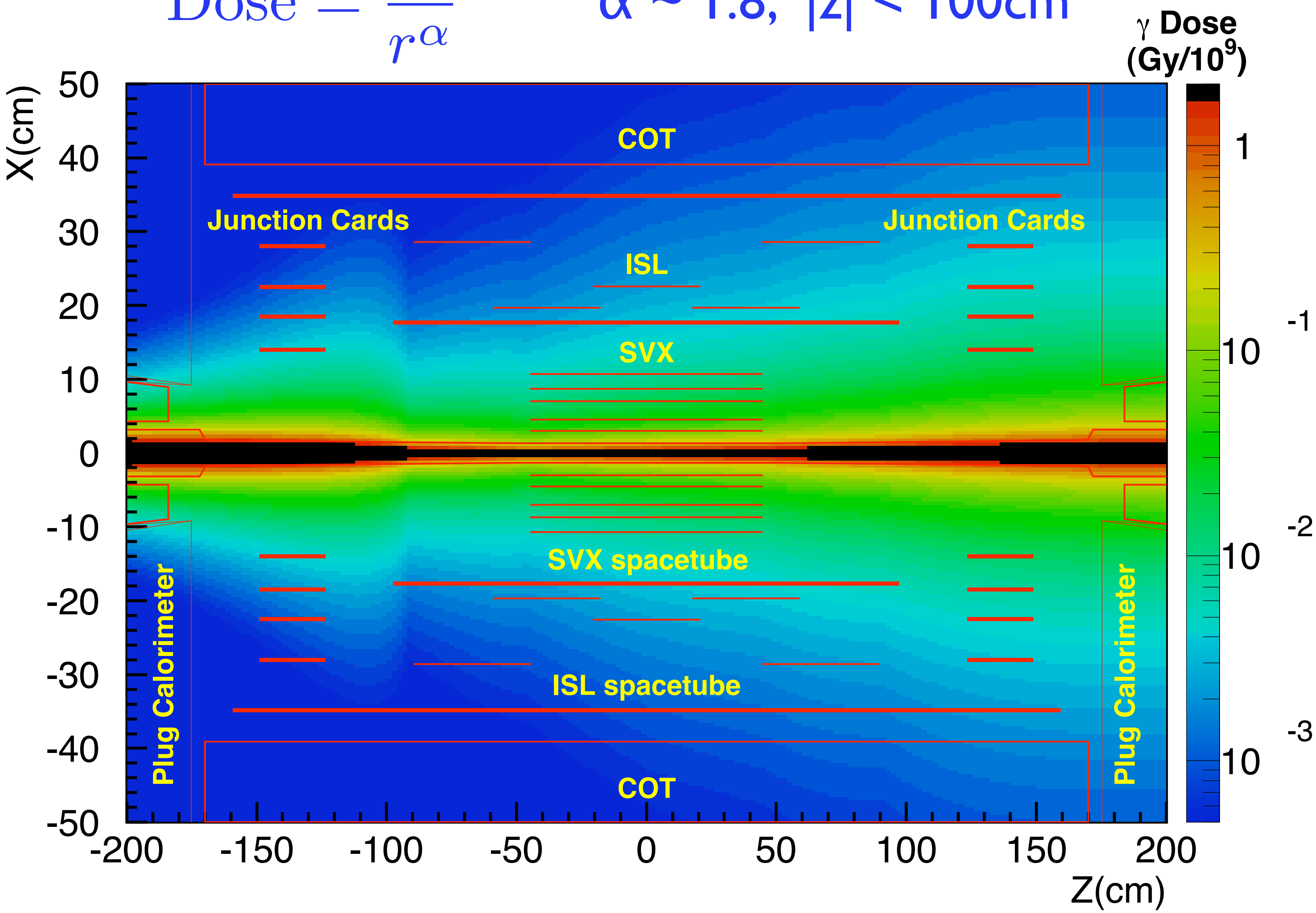
Radiation from Beam Losses

TLD measurements + model

r measured transverse to the beam

$$\text{Dose} = \frac{A}{r^{\alpha}}$$

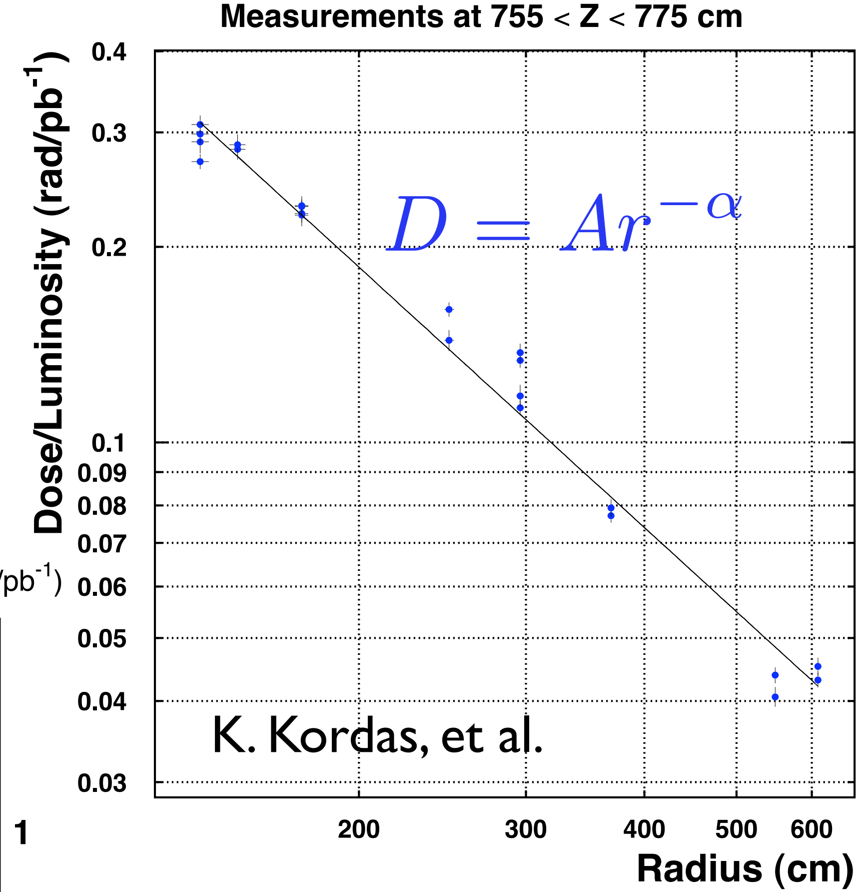
$\alpha \sim 1.8$; $|z| < 100$cm



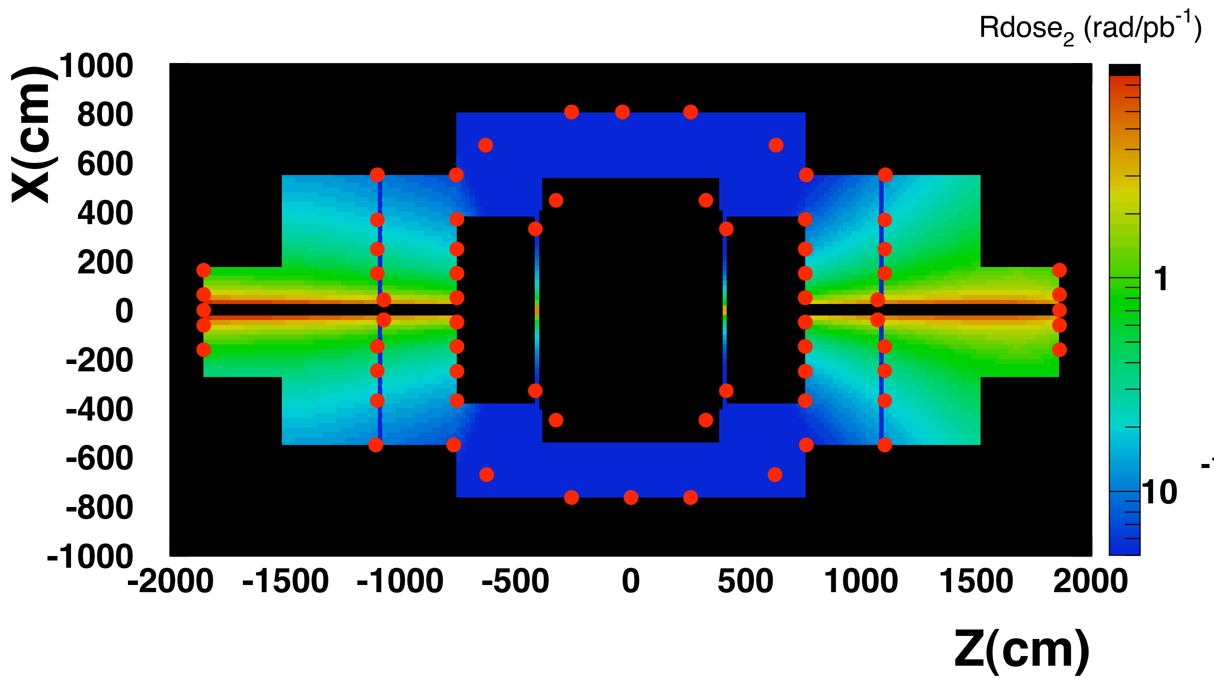
Collision Hall Radiation

Measure radiation in the collision hall using thermal luminescent dosimeters (TLDs).

- Ionizing radiation
- Low energy neutrons (thermal)



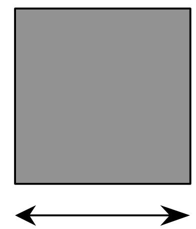
r measured transverse to beam



Measure Larger Accumulated Doses

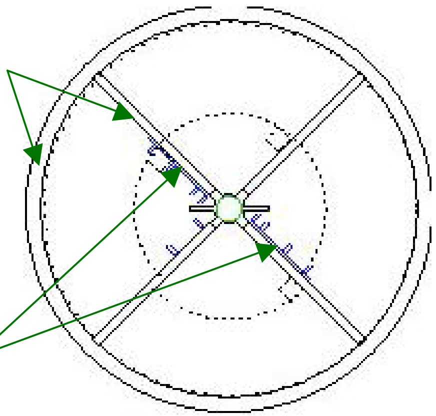
PIN Diodes

- Advantages:
  - \+ passive/active
  - \+ in-situ readout
  - \+ large dynamic range (10^2 - 10^5Gy)
- Disadvantages:
  - \- Temperature/history dependent
  - \- Calibrate in-situ
  - \- active operation needs periodic calibration



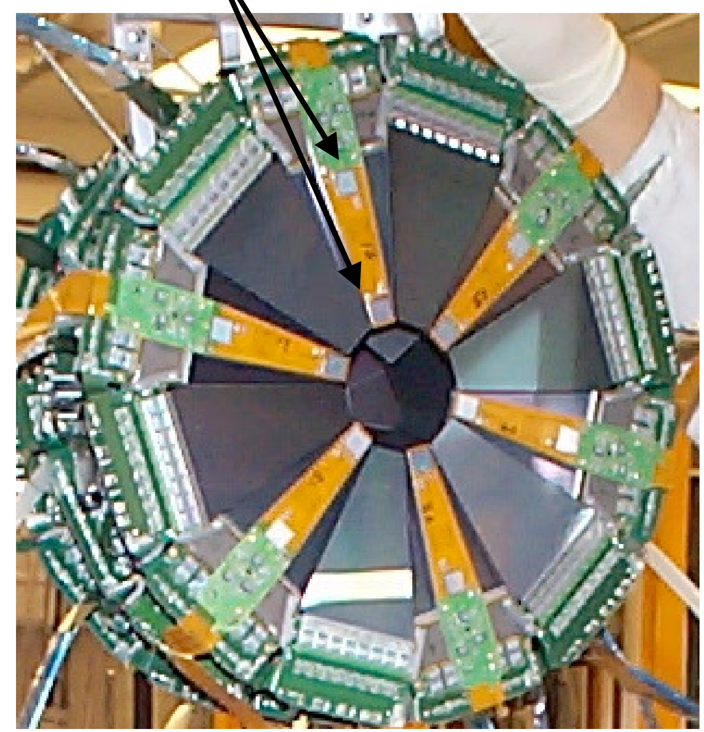
CDF

Cross calibrated with TLDs



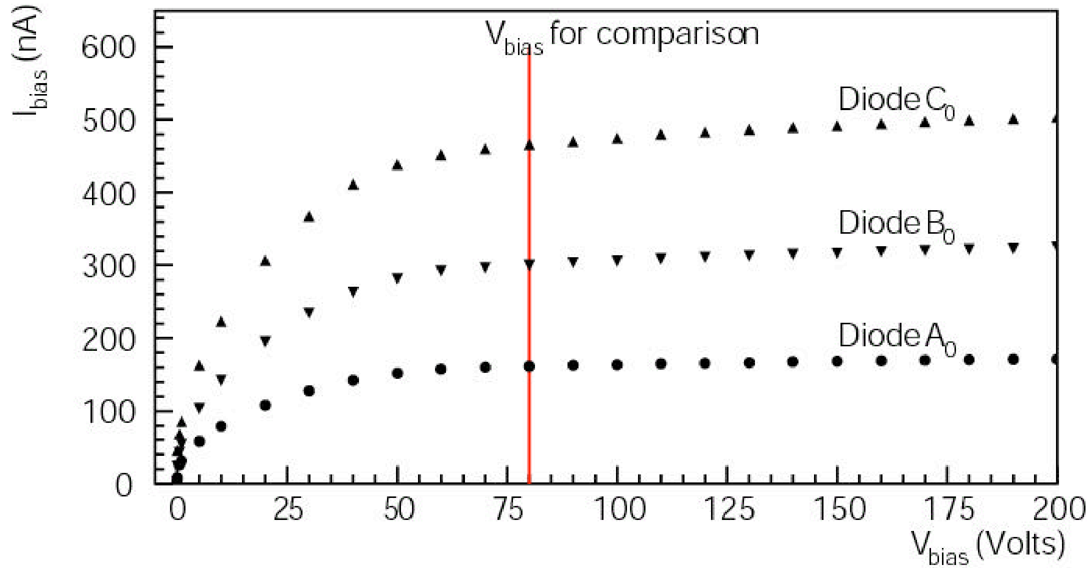
DØ

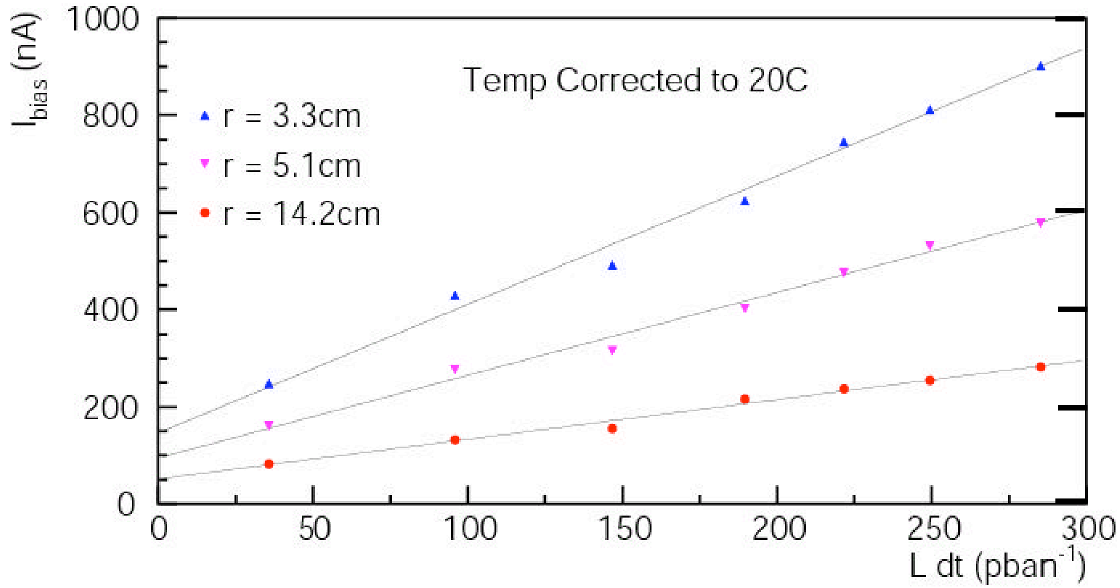
(Active)



Passive Diode Measurements

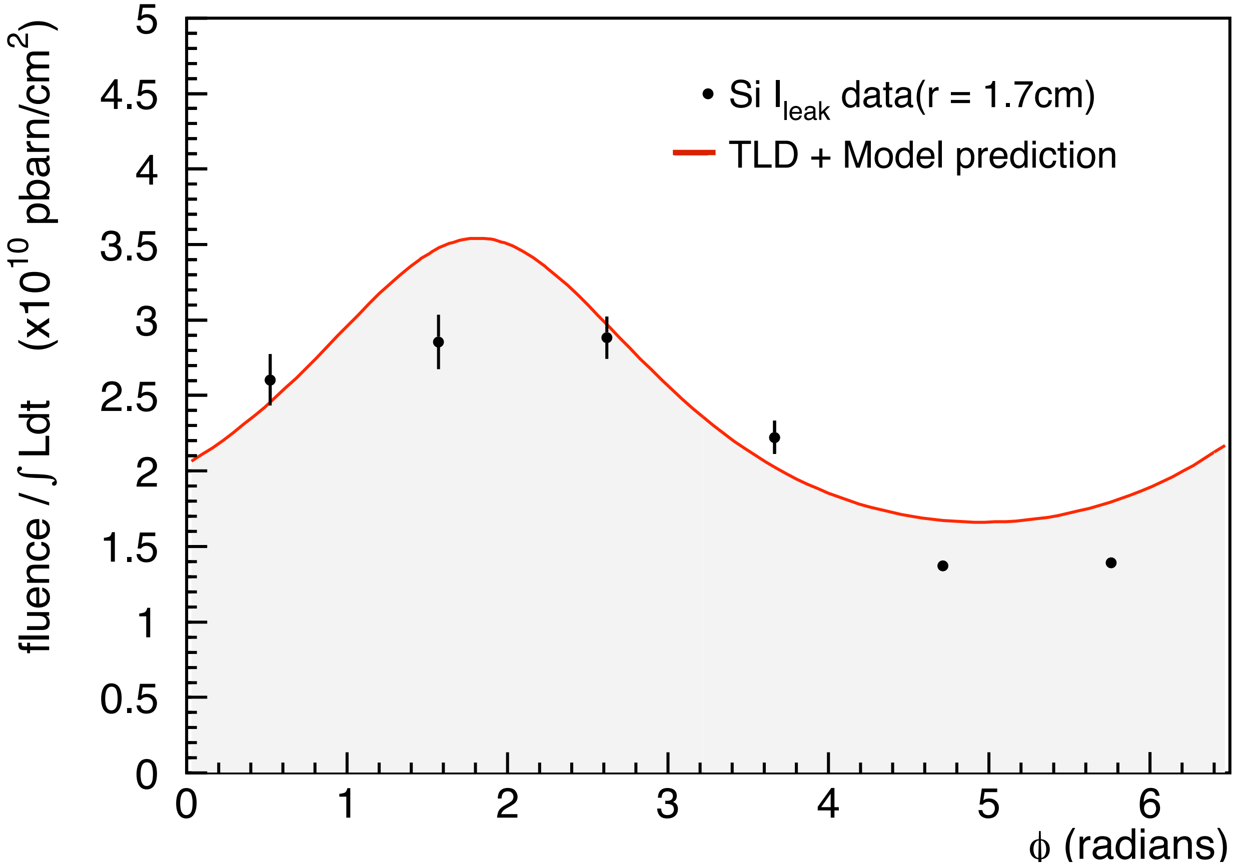
- I/V measurements
  - Bias currents larger for diodes closer to the beam.
- I_{bias} vs beam
  - Correct for T changes
  - No annealing corrections
  - Radiation from collisions dominate (TLD measurements)





Silicon Detector Dose (Damage)

- Measure I_{bias}
  - correct Temp. to 20C
  - α_{damage}=3.0x10^{17}A/cm
- Compare with TLD Data
  - Assume $r^{-\alpha}$ scaling
  - 1Gy=3.8x10^5 MIPS/cm^2



Note: Beam offset 5mm from detector axis

Plans for Future (CDF)

- Simulations of the radiation
  - collisions
  - beam-gas (losses)
- Measure neutron energy spectrum near CDF
  - Improve neutron dosimetry
  - Bonner spheres + TLDs Additional diodes near silicon
- Active monitors (diamond?)

Summary

- Multi-faceted approach to monitor radiation
  - Redundant measurements
  - Multiple technologies
  - Relate measurements to beam quantities
  - Monitors work well
- Improvements anticipated in the future
  - Telescope for halo and abort gap monitors
  - Synchrotron light to monitor beam in abort gap

References:

CDF/D0 Radiation Monitoring:

- http://ncdf67.fnal.gov/~tesarek/radiation
- http://www-d0.fnal.gov/nikhef/radmon/

Radiation Monitoring:

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- S.D'Auria, *et al.,* Nucl. Instr. and Meth. **A513** (2004) 89.
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- R.J. Tesarek, *et al., Proceedings: IEEE-NSS/MIC Conference,* Portland, OR, November 19 -25 (2003).

Beam Loss Monitors:

- R.E. Shafer, et al., "Proc. of the 12th Conf. on High Energy Accelerators", Fermilab (1993)609.

Beam Monitoring:

- M.Karagoz-Unel, R.J. Tesarek, Nucl. Instr. and Meth. **A506** (2004) 7.
- M. Gallinaro, *et al.*, **FERMILAB-CONF-02-121-E** (2002).
- D. Acosta, *et al.*, Nucl. Instr. and Meth. **A461** (2001) 540.

Activation Backgrounds:

- J.D Cossairt, "Radiation Physics for personal and Environmental Protection", Fermilab technical memo, **FERMILAB-TM-1834**, November (2002).