A Measurement of the Radiation Field in the CDF Tracking Volume

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(CDF Radiation Monitoring Group)

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Why Measure Radiation?

Motivation

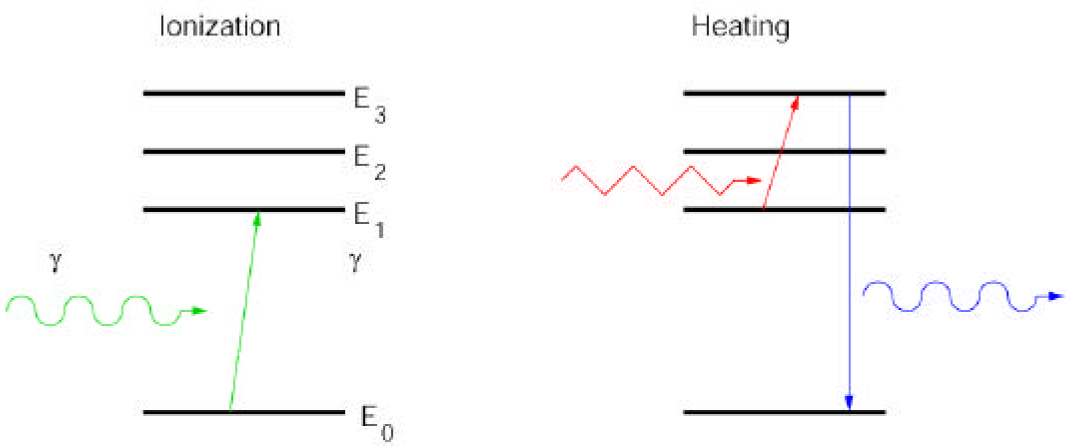
- Correlate information w/ beam
- Predict radiation damage to inner devices

Method: Thermal Luminescent Dosimeters

- TLD features
  - + Continuously integrates radiation
  - + Passive
  - + Large dynamic range 1mRad – 200kRad
  - + On-site TLD reader "fast turn around"
  - + Industry standard
  - – Requires harvesting + reading individual dosimeters
  - – Large amount of handling

Thermal Luminescence

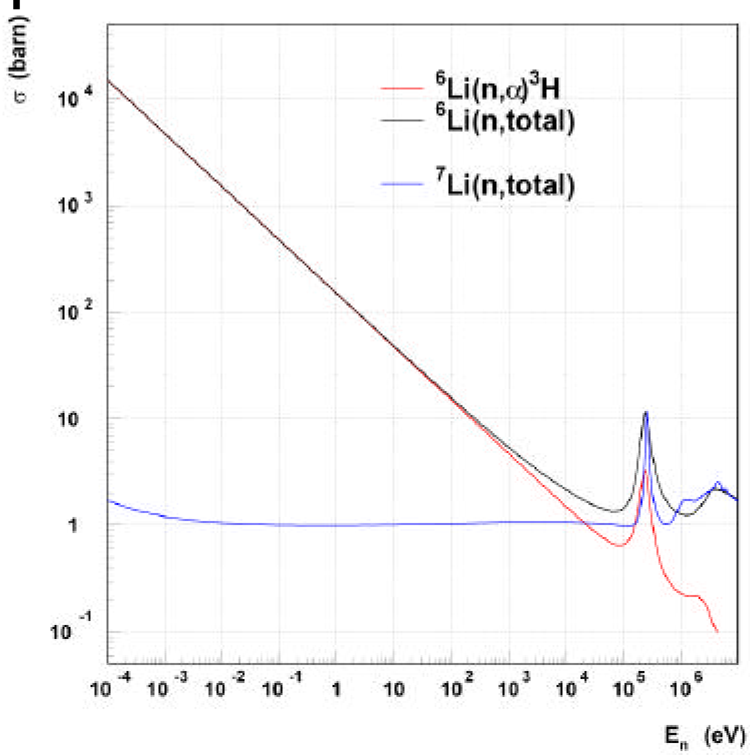
Ionizing radiation



Neutron absorption

$^{6}Li + n \rightarrow {}^{3}H + \alpha$

Detect ionization from ^{3}H



Measurement Technique

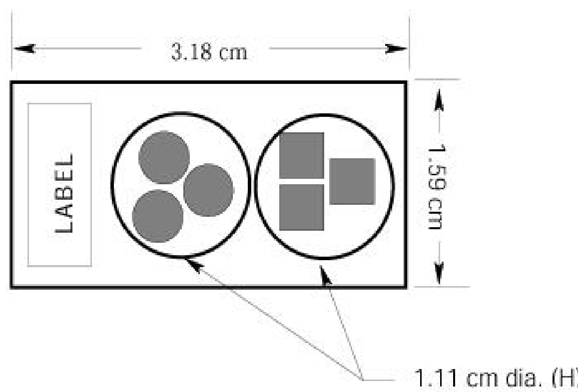
"The Devil is in the details..."

Considerations:

- Redundancy   multiple measurements
- Low mass   light materials
- Low profile   thin materials
- γ, n meas.   2 types of dosimeters

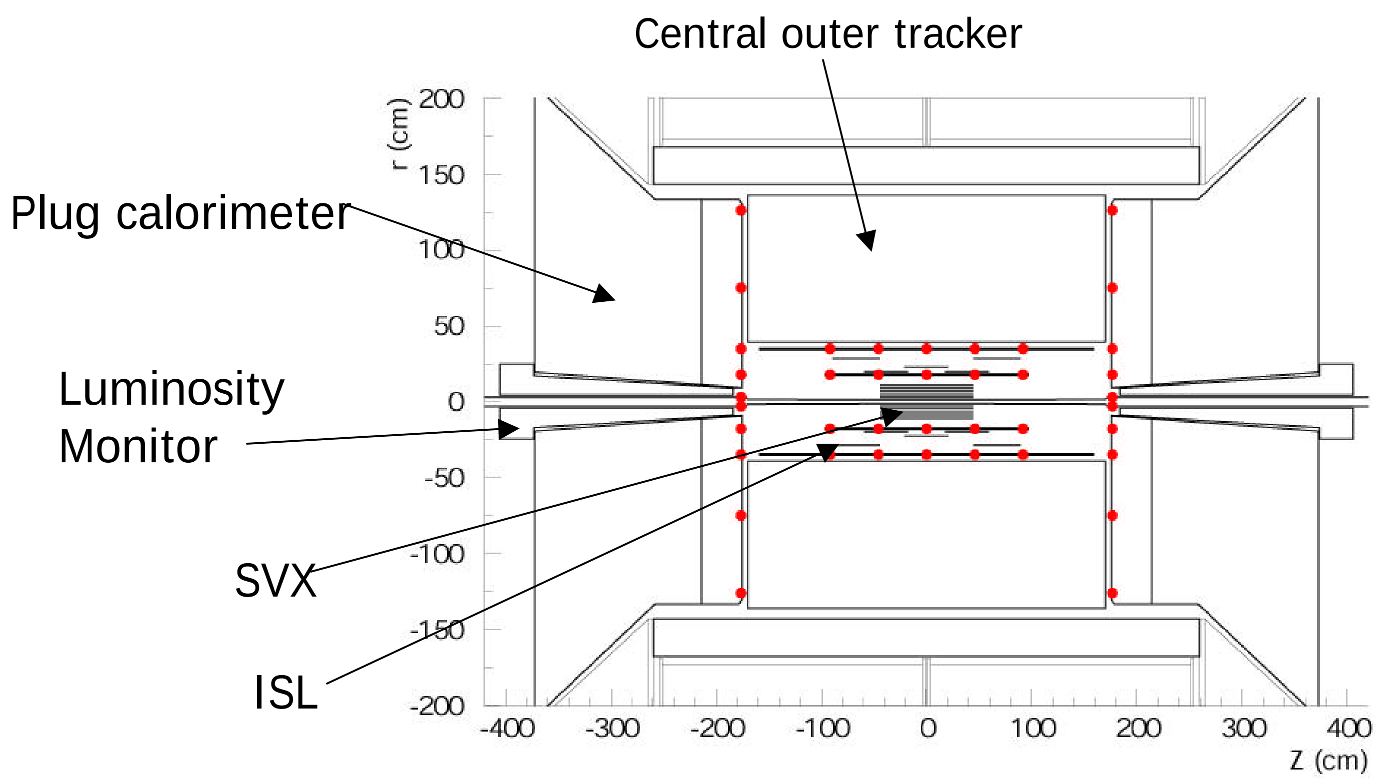
Implementation

0.8mm thick FR-4



- 2 types of dosimeters in a holder
  - TLD-700 ^{7}LiF γ sensitive
  - TLD-600 ^{6}LiF γ, n sensitive
- 3 TLD chips of each type per holder

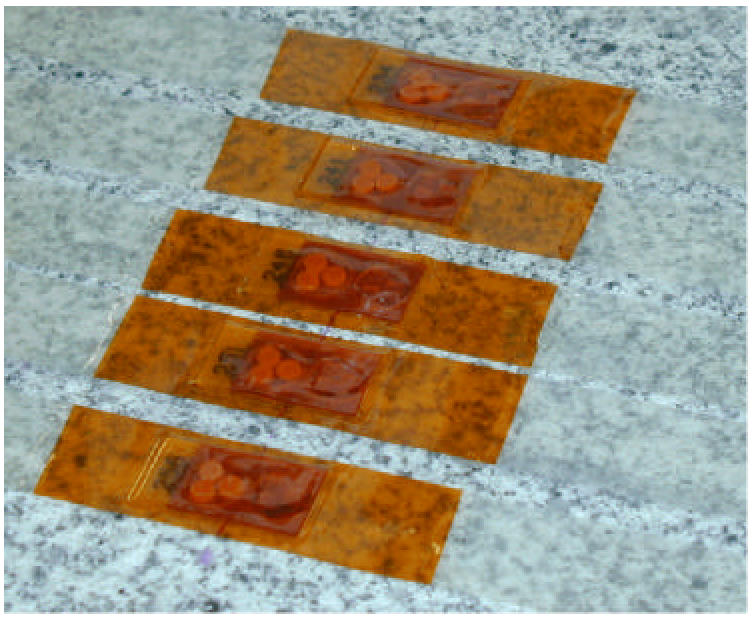
TLD Locations

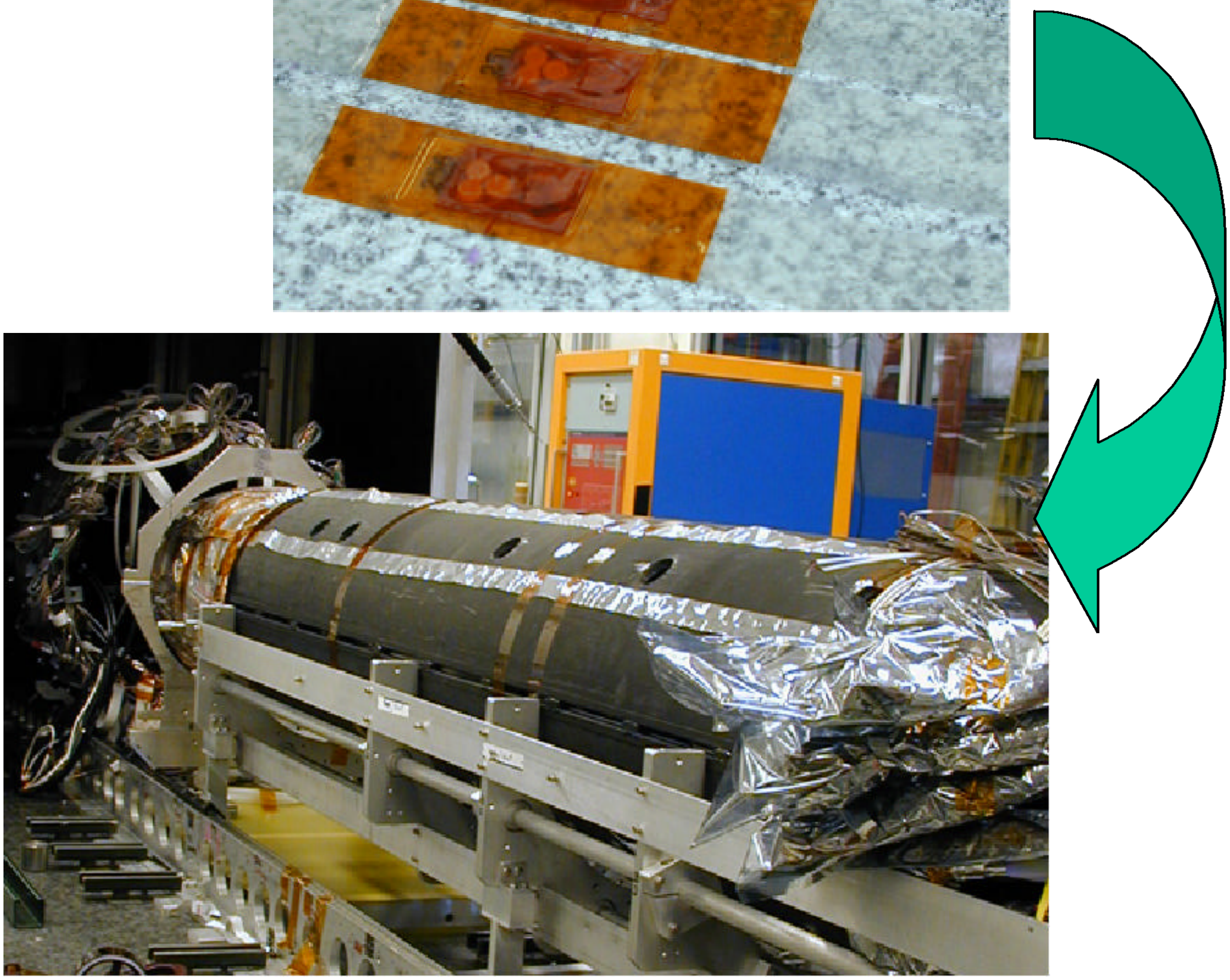


Location	# ϕ	# z	# r	Total # Holders
Plug faces	8	2	5	80
SVX	5	5	1	25
ISL	8	5	1	40
Control				11
Total # TLD chips				916

TLD Locations

How do we install holders?





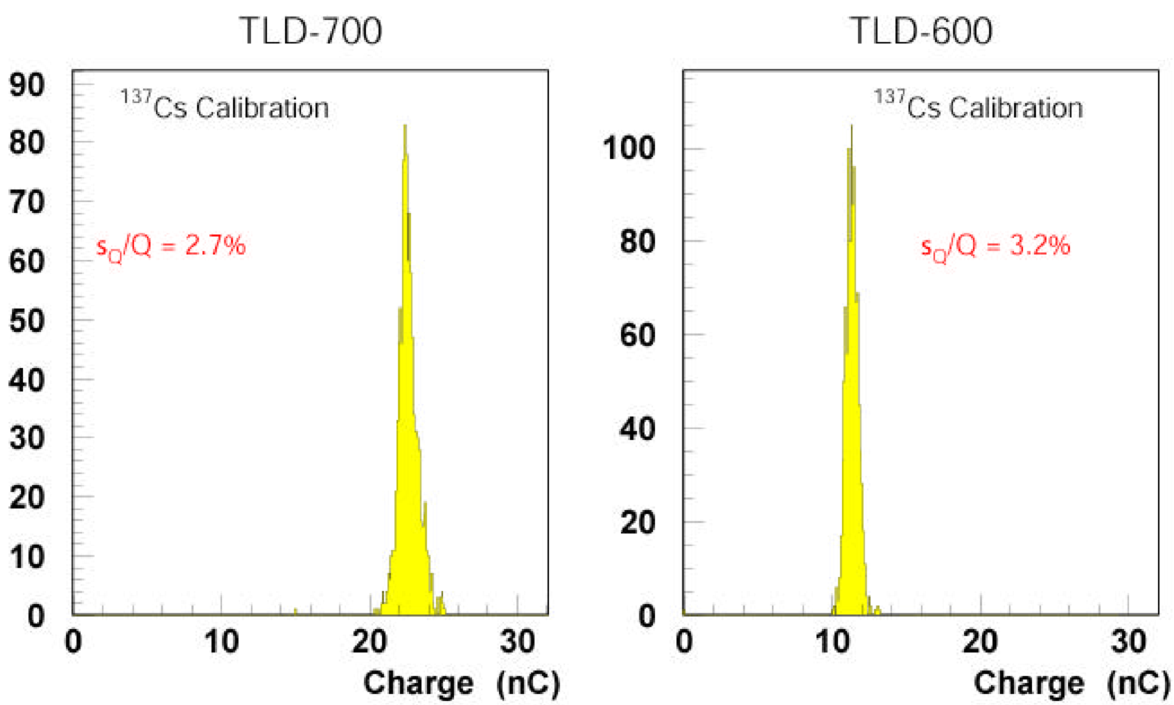
Calibration

All dosimeters of each type from a single batch

- Chip to chip response variation ~3%

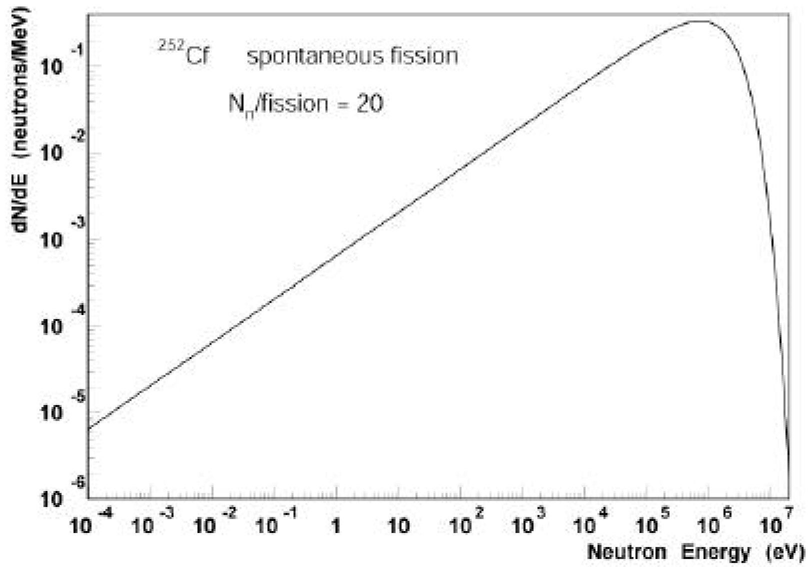
All dosimeters γ response calibrated w/ 1 Rad exposure to a ^{137}Cs source

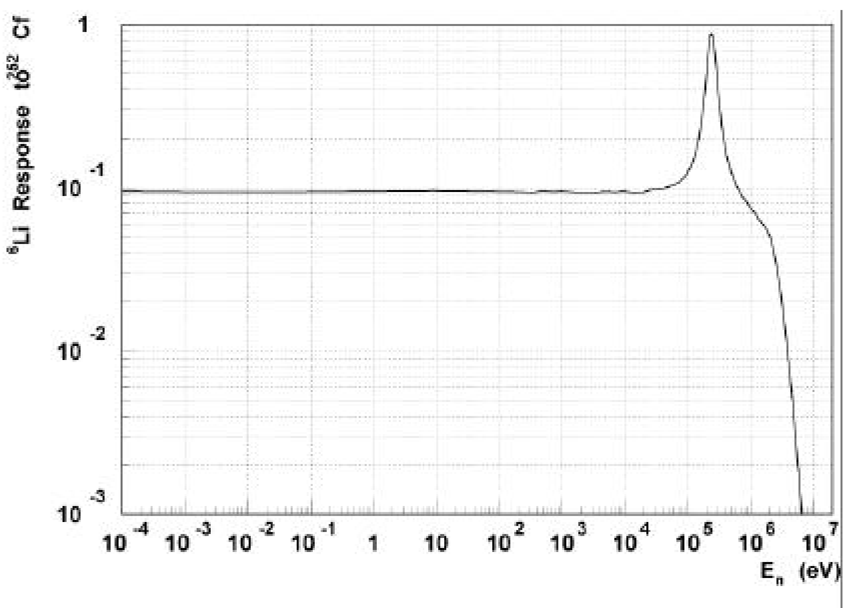
- Reproducibility <1% variation
- Absolute scale ~1% uncertainty



Neutron Calibration

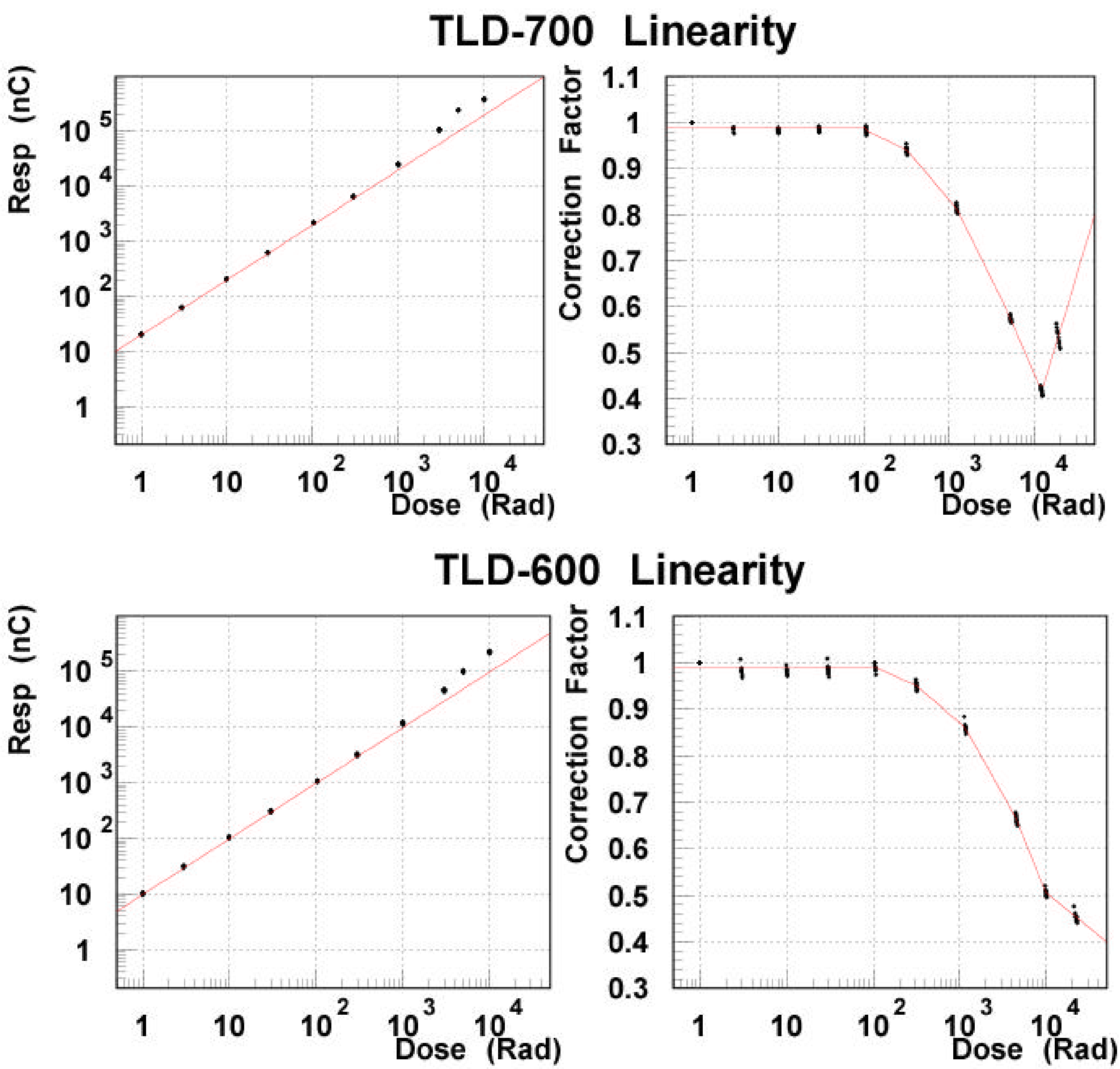
- 10 mRad exposure to ^{252}Cf
  - 15% variation
  - 10% scale uncertainty





TLD Non-linearity

LiF exhibits super linearity ~100Rad



Dosimetry

Ionizing Radiation Dosimetry

$$D_\gamma = C(kR)kR - D_c$$

R	TLD reading (nC)
k	1/(1 Rad response) (Rad/nC)
C(kR)	non-linearity correction
D_C	control dose (Rad)

Neutron Radiation Dosimetry

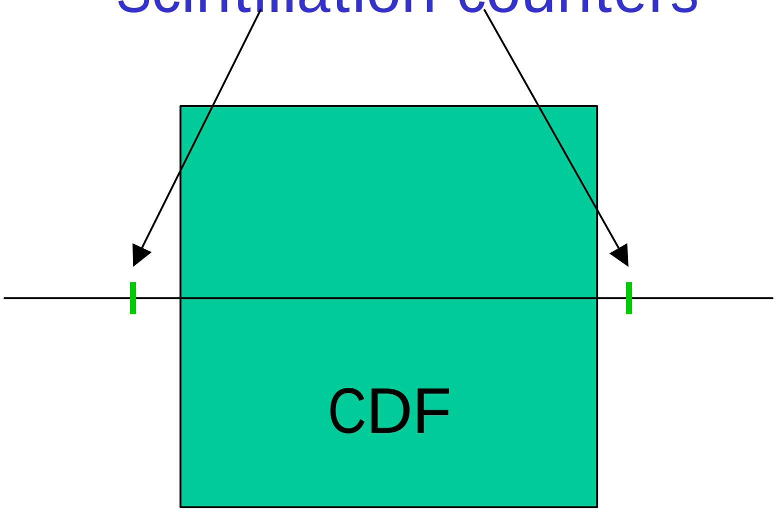
$$D_n = \{C(kR)kR - D_c\} - D_\gamma$$

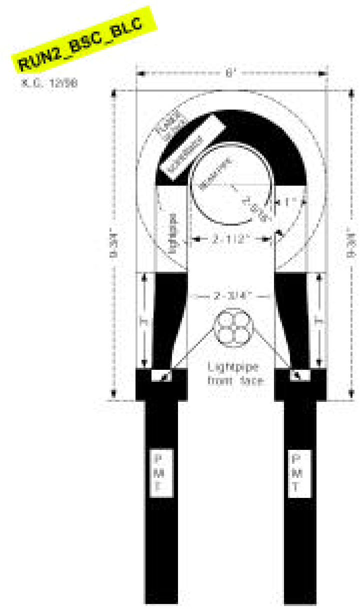
R	TLD reading (nC)
k	1/(1 Rad response) (Rad/nC)
C(kR)	non-linearity correction
D_C	control dose (Rad)
D_γ	ionizing radiation dose (Rad)

Beam Monitoring

Losses (beam shower counters)

Scintillation counters





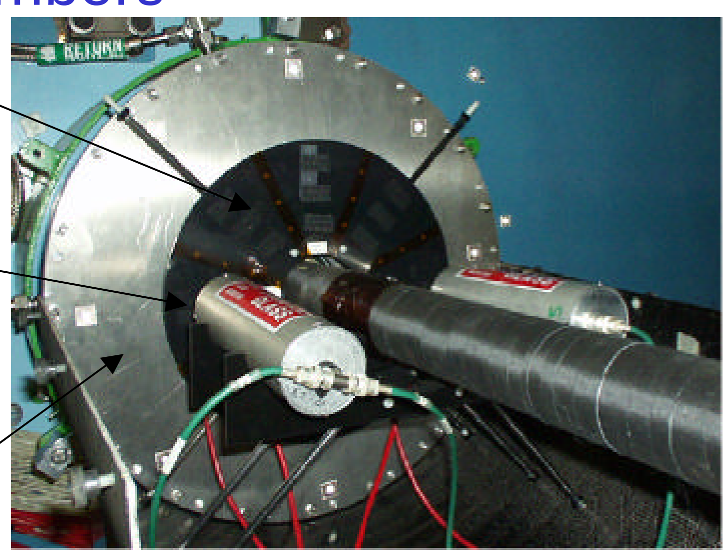
Radiation (beam loss monitors)

Ionization chambers

Wagon wheel (TLDs)

BLMs

Luminosity Monitor



Exposure Statistics

Beam Statistics

	Feb. – May	**May – Oct.**	**Units**
p	0.0703	1.56	10^{19}
Pbar	0.0082	0.137	10^{19}
P-losses	1.06	2.84	10^{9}
Pbar-losses	0.14	0.71	10^{9}
$\int L dt$	0.058	10.7	pb^{-1}

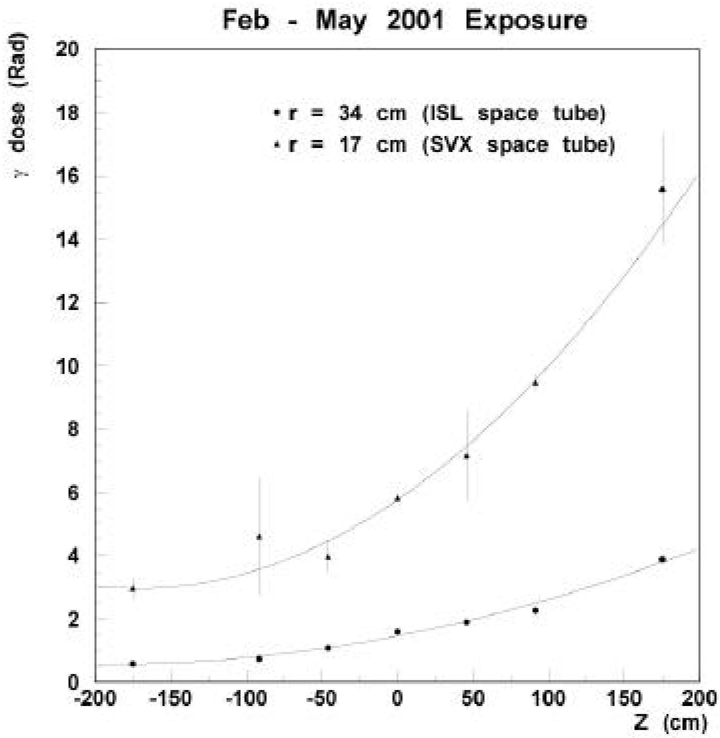
Beam Loss Monitors

	Feb. –	**May**	**May –**	**Oct.**
	Inner	**Outer**	**Inner**	**outer**
Proton	7.0	6.1	85.4	14.0
Pbar	241	224	286	305

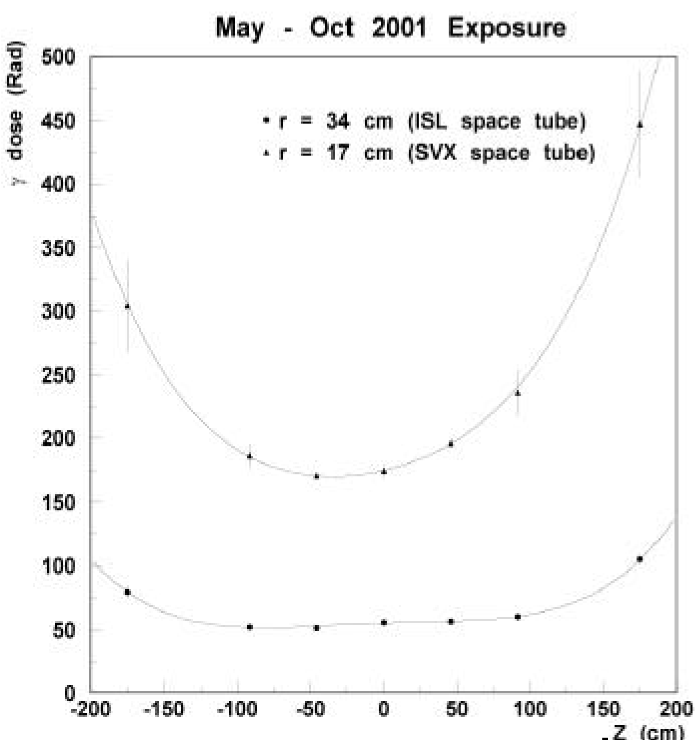
Feb. – May loss dominated
May – Oct. collision dominated
BLMs insensitive to collisions

Data

Loss dominated



protons →

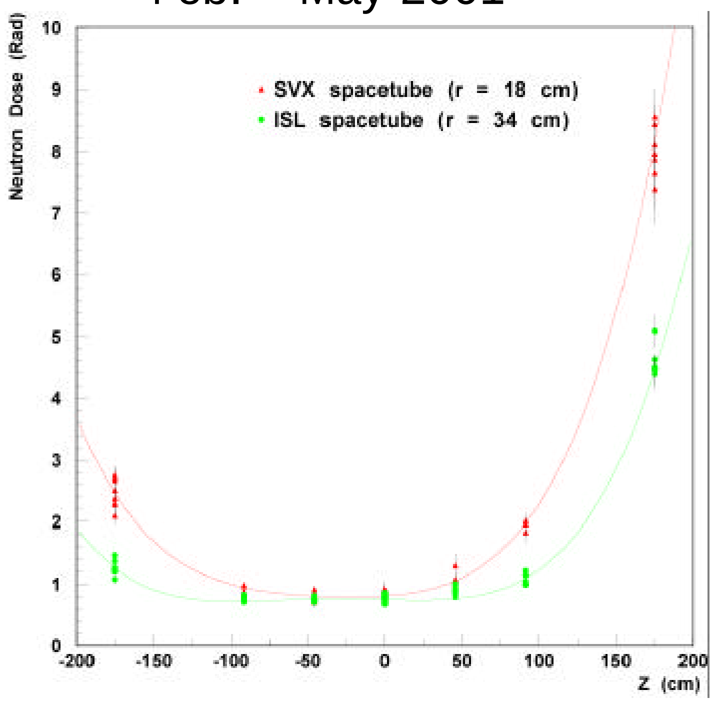


Collision dominated

protons → ← antiprotons

Neutrons

Feb. – May 2001

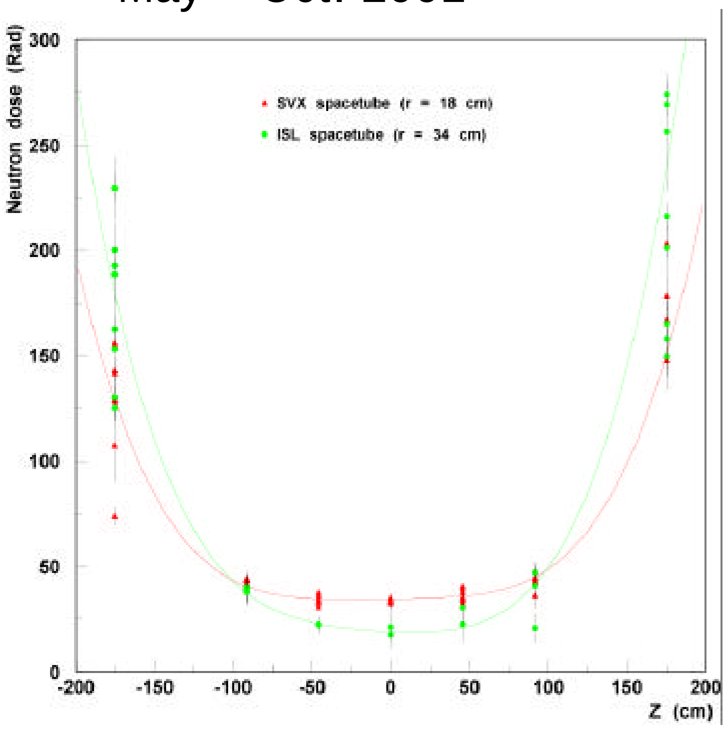


Loss dominated

Scale
1rad=$3.2x10^8 n/cm^2$

protons

May – Oct. 2001



Collision dominated

protons antiprotons

Collisions & Losses

Motivation:

– Dose different for collisions/losses

– Collisions should dominate losses even more in the future

⇨ Better prediction of radiation field

Method: Linear model

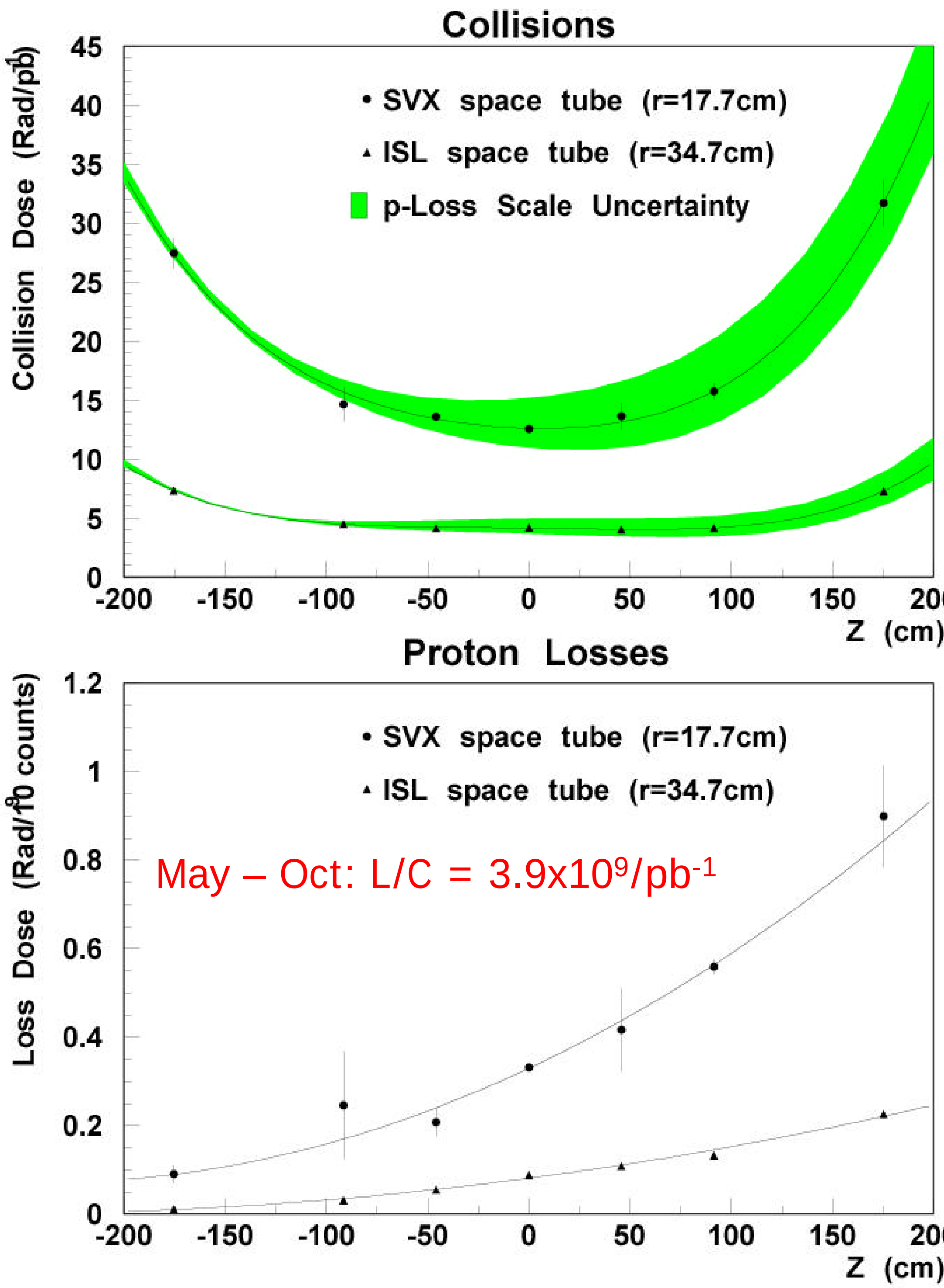
$$D_1 = L_1 d_L + C_1 d_C$$
$$D_2 = L_2 d_L + C_2 d_C$$

L_i	measured losses
C_i	measured collisions (luminosity)
d_L	dose/unit losses
d_C	dose/unit luminosity

Solve for d_L and d_C

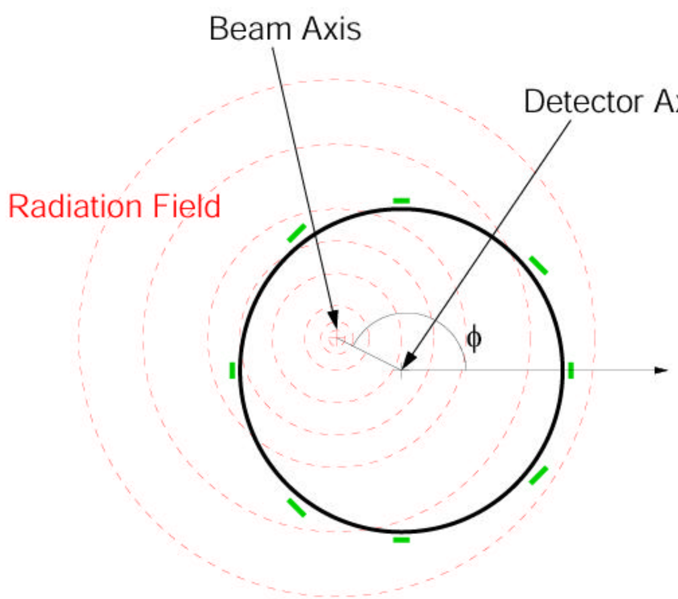
⇨ Unnecessary for neutrons

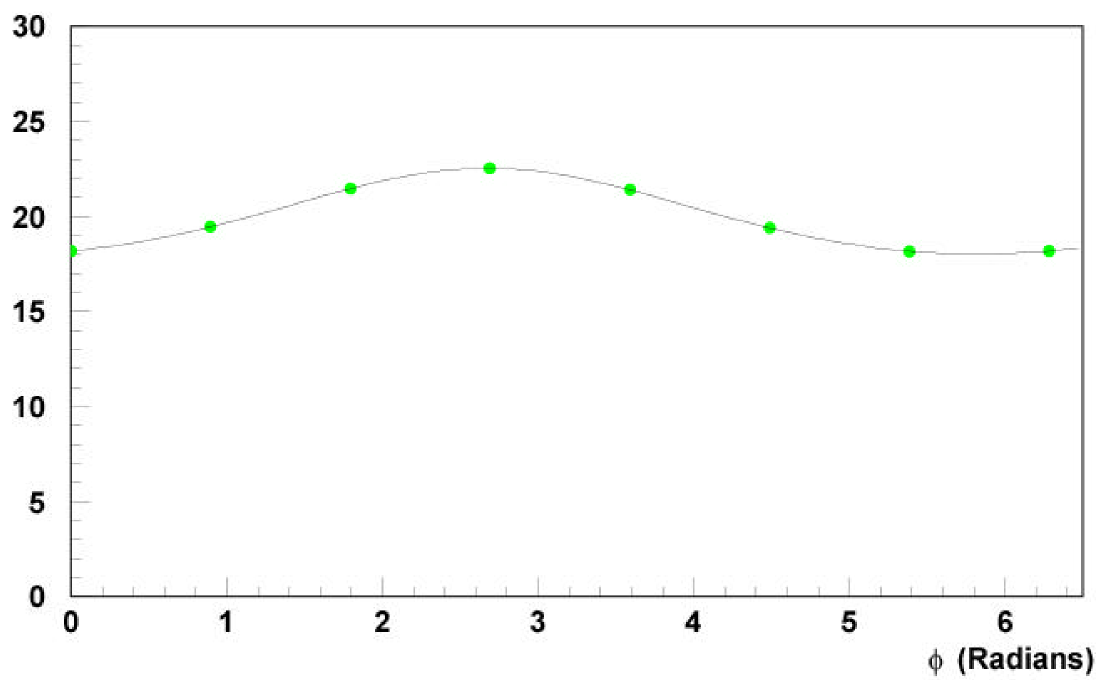
Collisions & Losses



Finding the Beam w/ TLDs

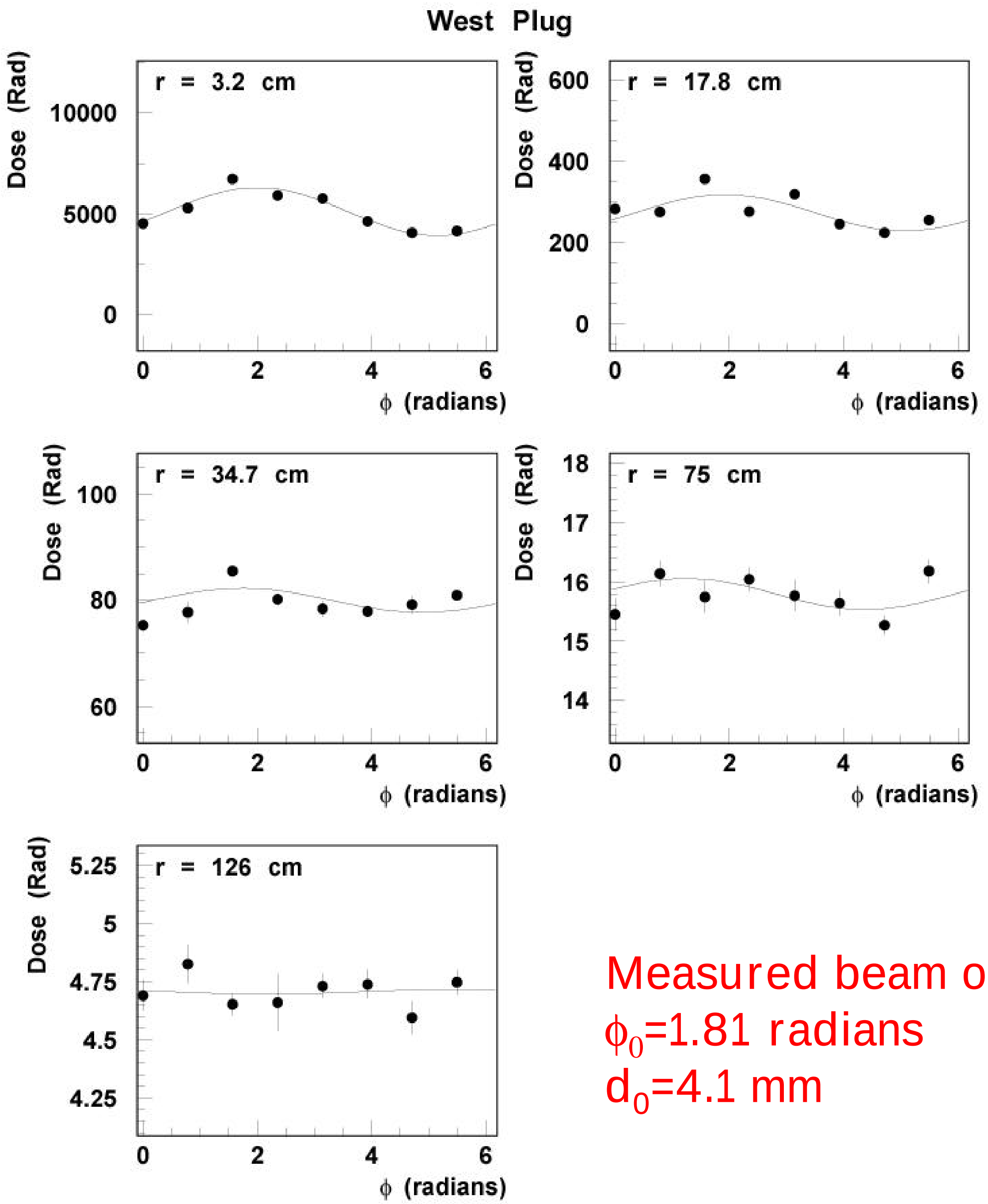
Beam and Detector cylindrically symmetric





Data (Φ)

Fit $A\cos(\phi-\phi_0) + D_{avg}$ ϕ_0: 1.7—2.0



Measured beam offset
ϕ_0=1.81 radians
d_0=4.1 mm

Modeling

Use previous experience to build a simple model of the radiation field*

*D.Amidei, et al NIM **A320** (1994) 73.

Assumptions

- Radiation has cylindrical symmetry about the beam.
- Field follows a power law in 1/r.

Fit the data to the following form:

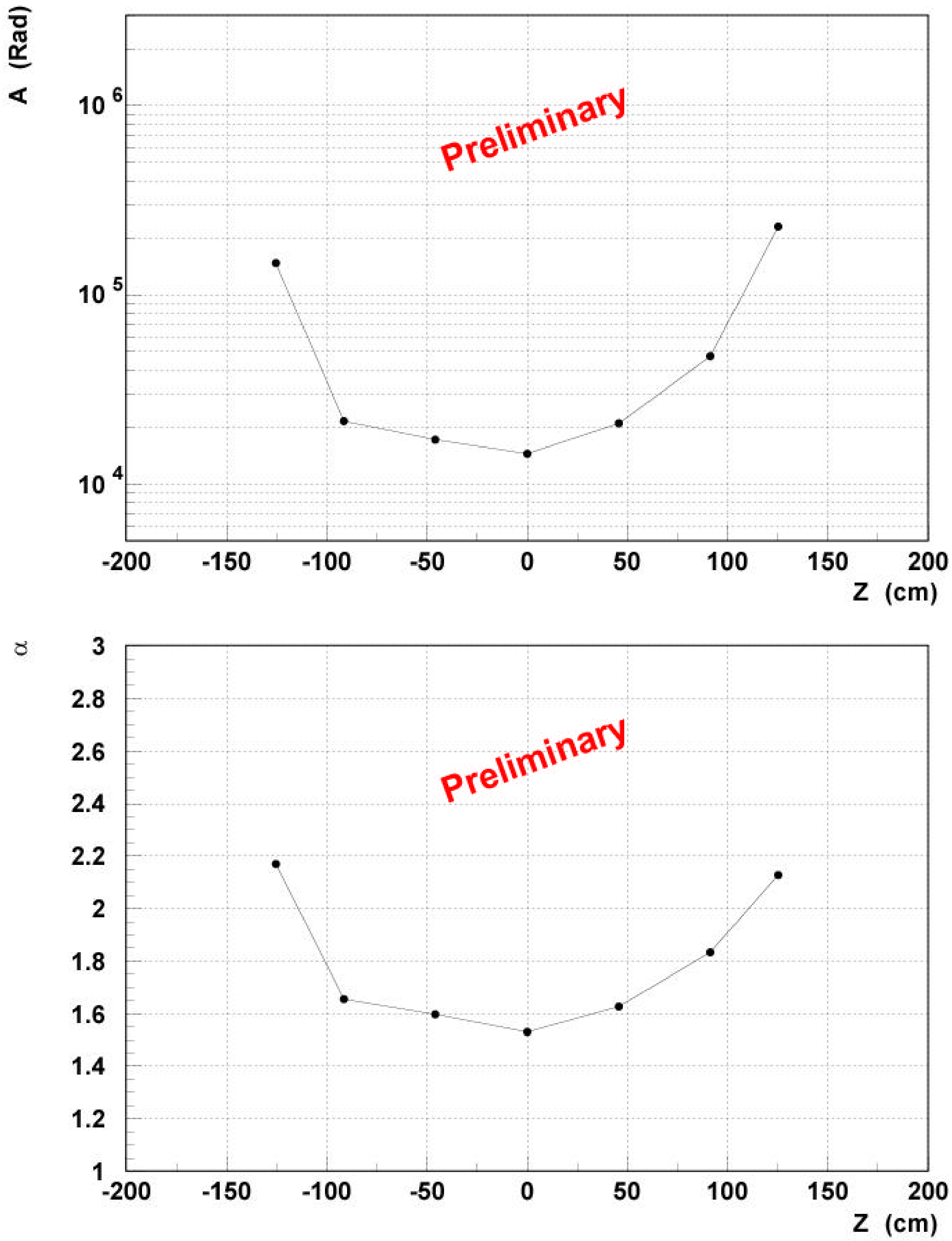
$$D(x,y)=A*\{ (x-x_0)^2+(y-y_0)^2 \}^{-\alpha/2}$$

D(x,y)	radiation dose
A	absolute normalization
(x_0,y_0)	beam position offset
α	power law exponent

Note: Run I radiation damage profile yields α=1.6—1.7.

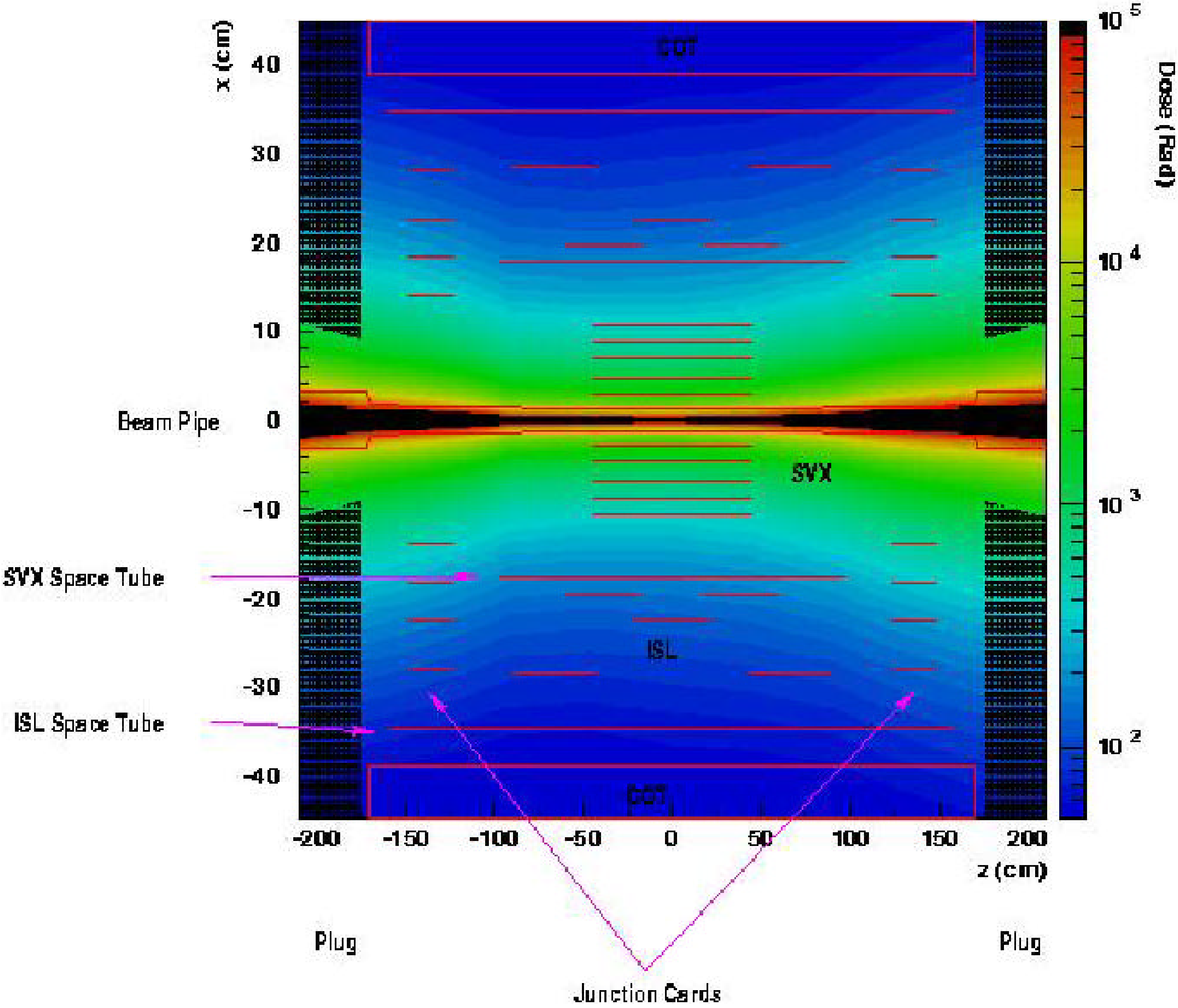
Results

Statistical uncertainties only!



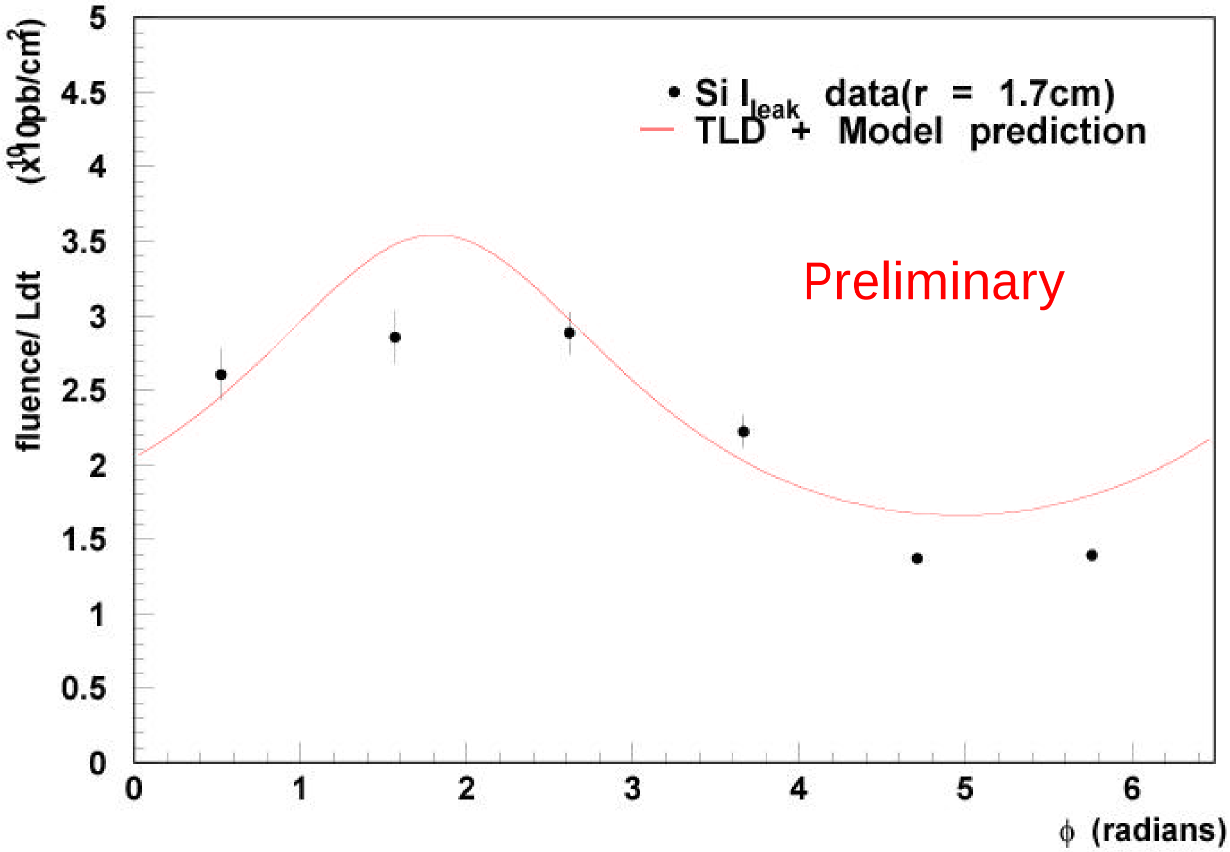
Ionizing Radiation Map

10.7 pb^{-1} delivered luminosity



Silicon Leakage Currents

- Leakage Si current increase rate measurements
  - Correct for temperature (8 →20 C)
  - Include α_{damage}= 3.0 x 10^{-17} A/cm



Summary

- Installed ~1000 TLDs in CDF
  - Photon and neutron measurements
- TLDs yield accurate measurements of radiation environment in CDF
  - γ radiation ~5% uncertainty
  - Separate fields from collisions and losses
  - N radiation ~20% uncertainty
- Qualitative agreement with expectations
  - Beam losses & collisions
  - Neutrons field
- New details emerging
  - Predict radiation for given beam conditions
  - Early prediction of detector lifetime
  - Naïve model from early experience (Tevatron Run I) needs update
- Semi quantitative agreement with Si data