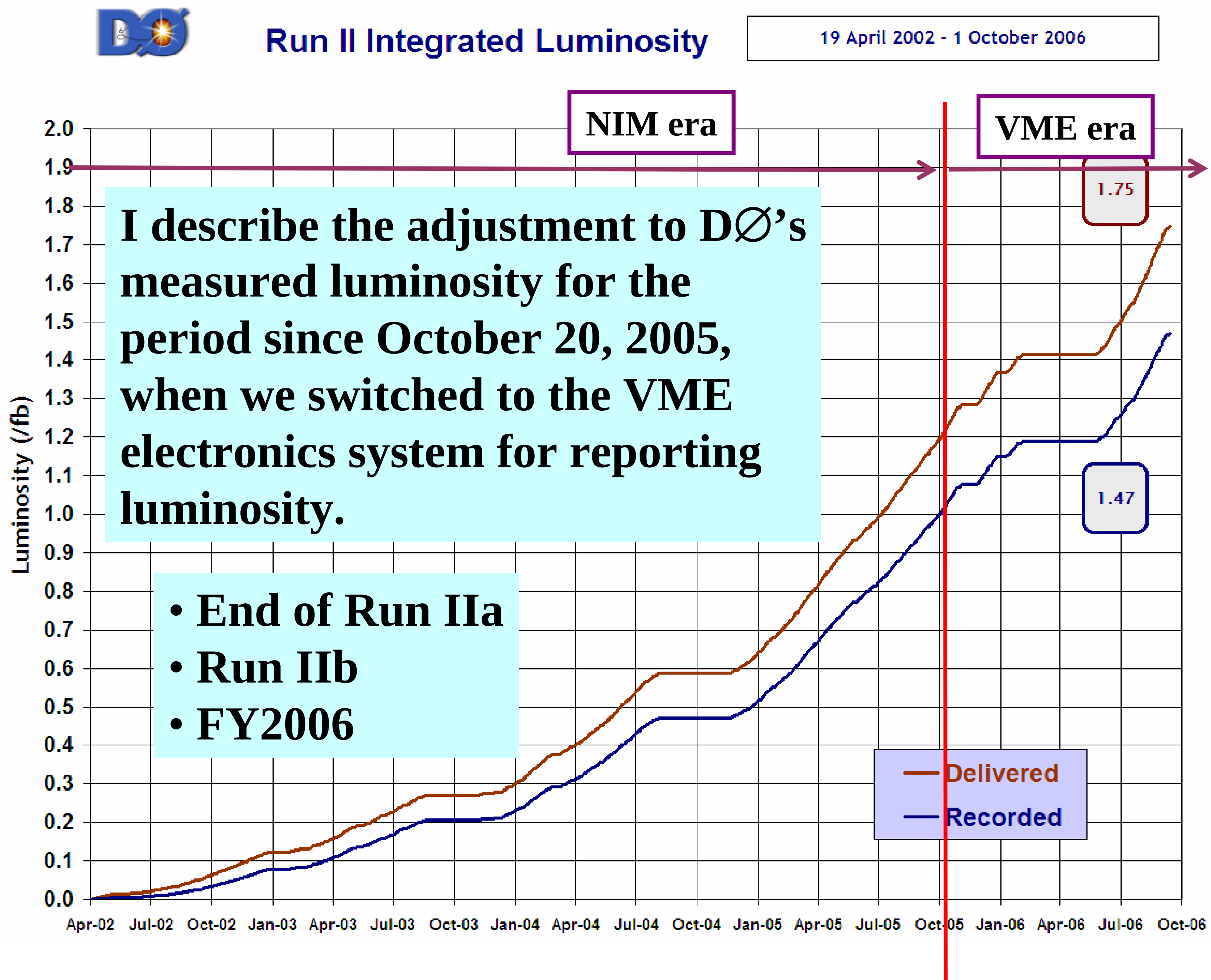
D∅ Luminosity

Adjustments to D∅'s Measured Luminosity for the End of Run IIa and Run IIb

- **What I will talk about**
- **What I won't talk about**
- **Brief overview of luminosity measurement**
- **Summary of adjustment for End of Run IIa and Run IIb**
- **Old vs. new normalization constant determination (Broad strokes – a flavor of the new technique)**
- **Some next steps at D∅**



I describe the adjustment to D∅'s measured luminosity for the period since October 20, 2005, when we switched to the VME electronics system for reporting luminosity.

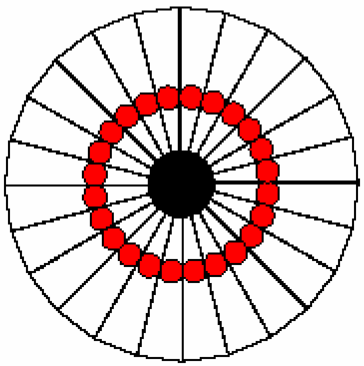
- End of Run IIa
- Run IIb
- FY2006

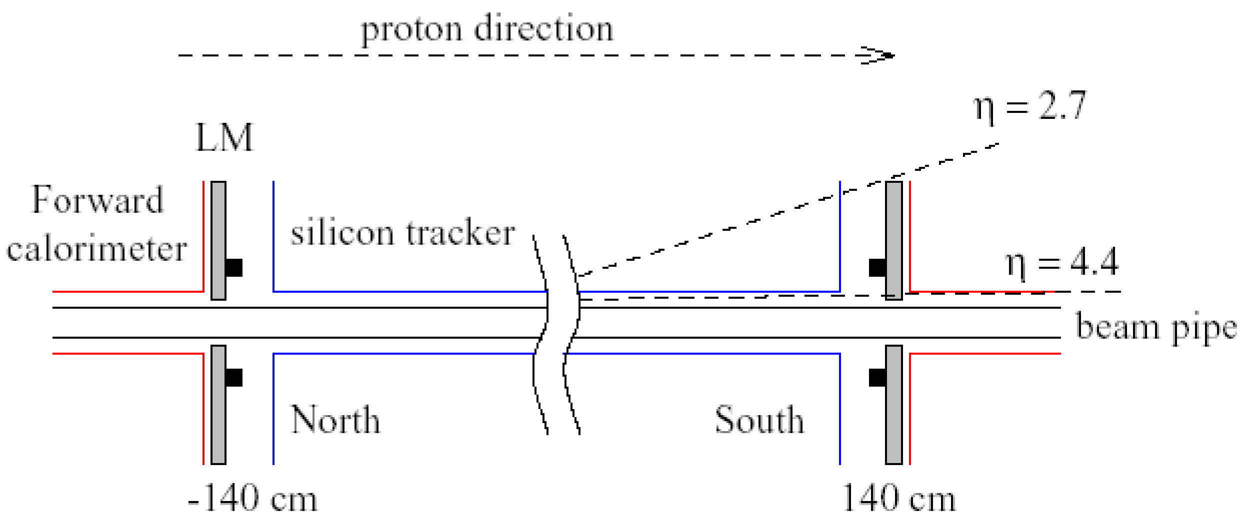
Main Players

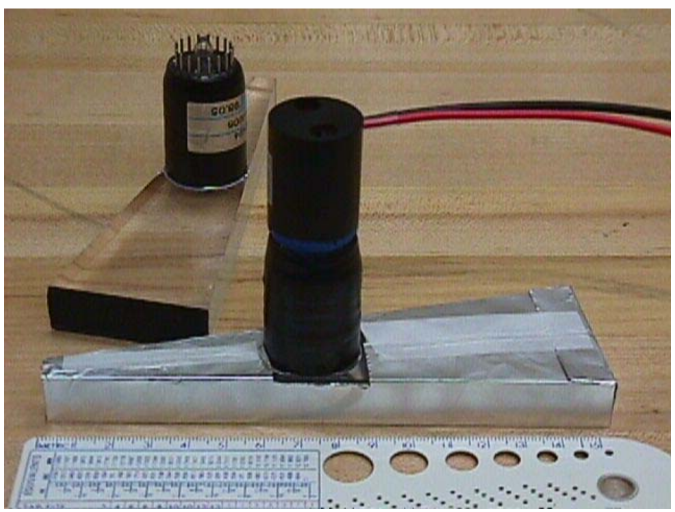
Brendan Casey: Period since October 20, 2005
Greg Snow: Back propagation of adjustment to beginning of Run IIa (not for today)

Each with generous help and input from D∅'s Luminosity Working Group, internal Editorial Board, and many other collaborators

Luminosity Detector

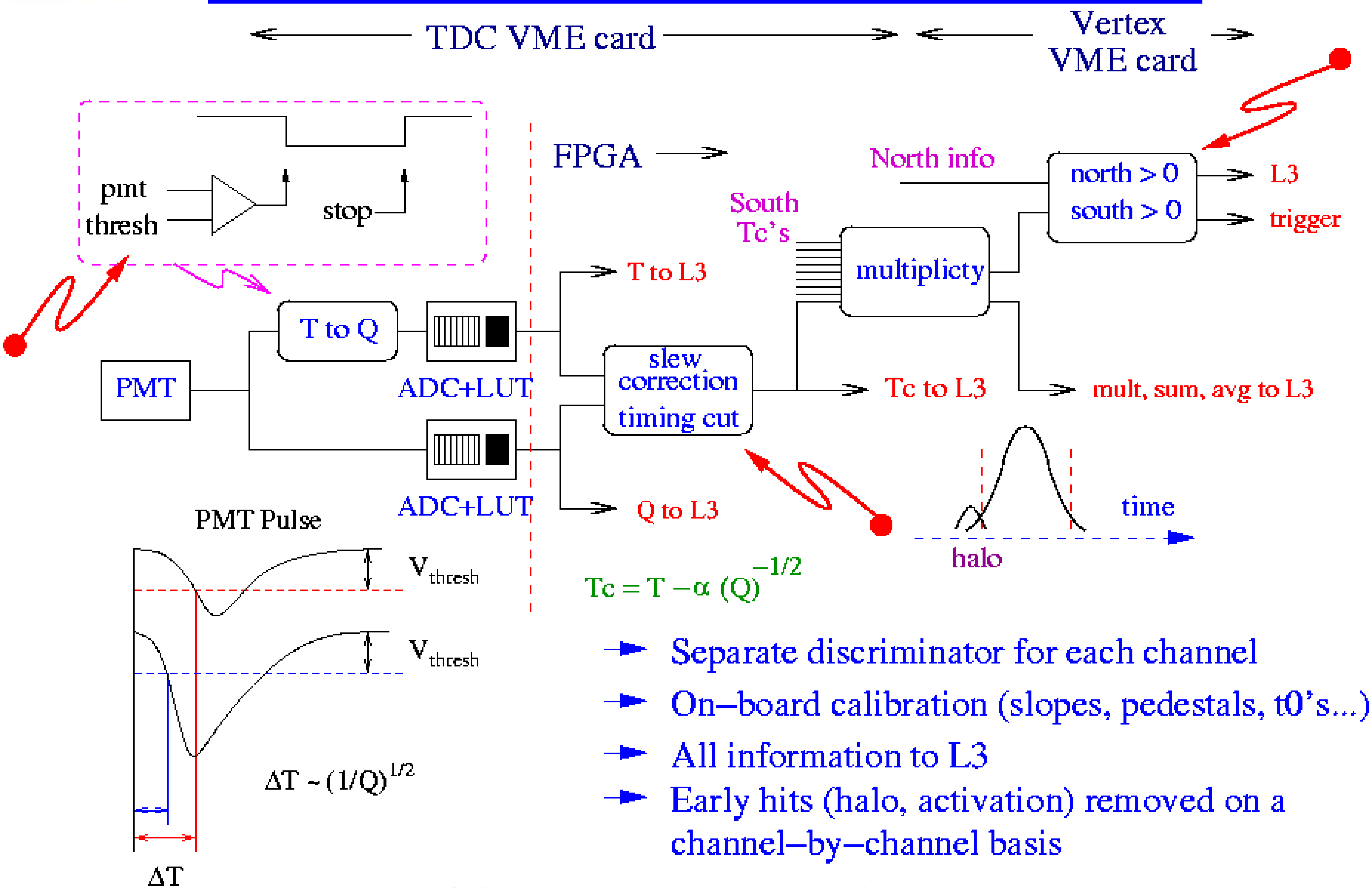






- Two arrays of forward scintillator. 24 wedges per side each read out with mesh PMTs
- Inelastic collisions identified using coincidence of in-time hits in two arrays

Readout System



- Separate discriminator for each channel
- On–board calibration (slopes, pedestals, t0's…)
- All information to L3
- Early hits (halo, activation) removed on a channel–by–channel basis

Measurement Principle

- **Luminosity determined by counting inelastic interactions and normalizing with respect to the inelastic cross section**

$$L = \frac{1}{\sigma^{inelastic}_{p\bar{p},\,effective}} \frac{dN}{dt}(p\bar{p})$$

$$\varepsilon \times \sigma^{\mathbf{inelastic}} = \varepsilon \times \mathbf{(60.7 \pm 2.4\ mb)}$$

CDF/E811 average, extrapolated to 1.96 TeV

ε = efficiency to detect inelastic interaction, including geometric acceptance

- **Avoid difficulties of counting multiple interactions by counting zeros:**

$$P(n=0) = \exp(-\sigma^{inelastic}_{p\bar{p},\,effective} L)$$

(Times a small L-dependent term I will mention later)

The Adjustment

$$P(n=0) = \exp(-\sigma_{p\bar{p},\,effective}^{inelastic} L)$$

- Constant used to date for Run IIa luminosity reporting:

  54.0 mb

- New constant for end of Run IIa:

  48.0 mb

- The change implies an increase in the measured integrated luminosity of +12.5% for end of Run IIa

- The small L-dependent term mentioned earlier actually reduces the adjustment to +12%

  Approx. 196 pb^{-1} delivered $\rightarrow$ 220 pb^{-1} for this period

- Reported to Directorate on September 29 for FY2006 reporting

Run IIb

- **To date in Run IIb, we have been reporting the luminosity with the original Run IIa constant, i.e.**

  54.0 mb

- **A number of changes to the LM system during the shutdown (scintillators replaces, upgraded preamps, more material in front of the LM detectors) calls for a reevaluation of the normalization for Run IIb – in progress (for physics analyses)**

- **However, we are confident enough that the Run IIb constant will be within ~2% of the end-of-RunIIa constant, that we put the end-of-RunIIa constant 48.0 mb online for luminosity reporting starting in Store 4989, 9/29/06, at 23:07**
- **Start of IIb to October 1 delivered: Approx. 340 $pb^{-1} \rightarrow$ 381 pb^{-1}**

Technique Overview I

Before switch to VME:

$$\sigma_{eff} = \varepsilon A \sigma = \varepsilon \; (A_{SD} \; \sigma_{SD} + A_{DD} \; \sigma_{DD} + A_{ND} (\sigma - \sigma_{SD} - \sigma_{DD}))$$

From zero bias data (ε)

From MC (A_{SD})

From independent measurements (σ_{SD}, σ_{DD})

Now:

No factorization of efficiency and acceptance

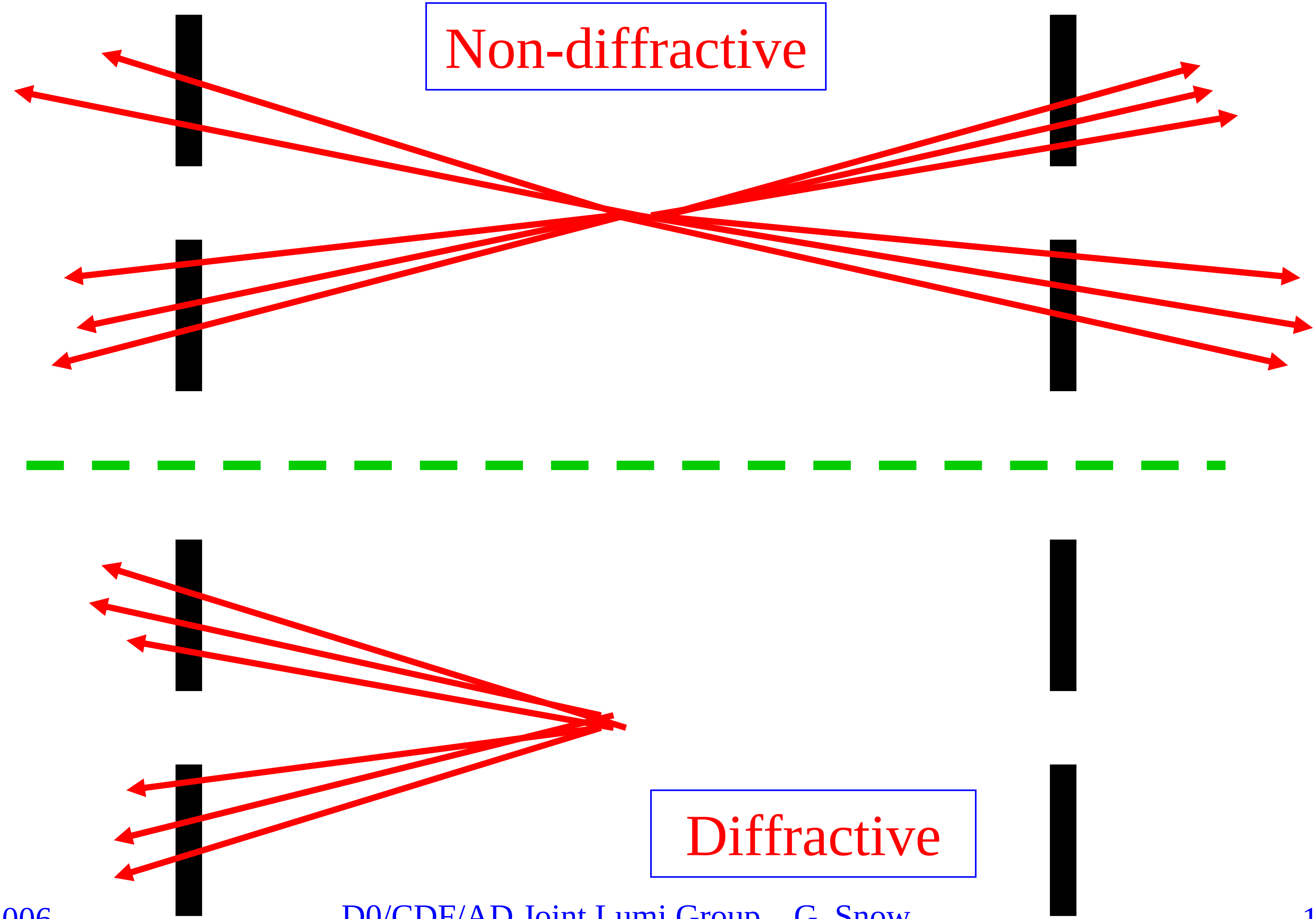
Put all sources of inefficiency in MC and combine efficiency and acceptance

Use our data **(multiplicity distributions)** vs. MC to determine proper weighting of diffractive content.

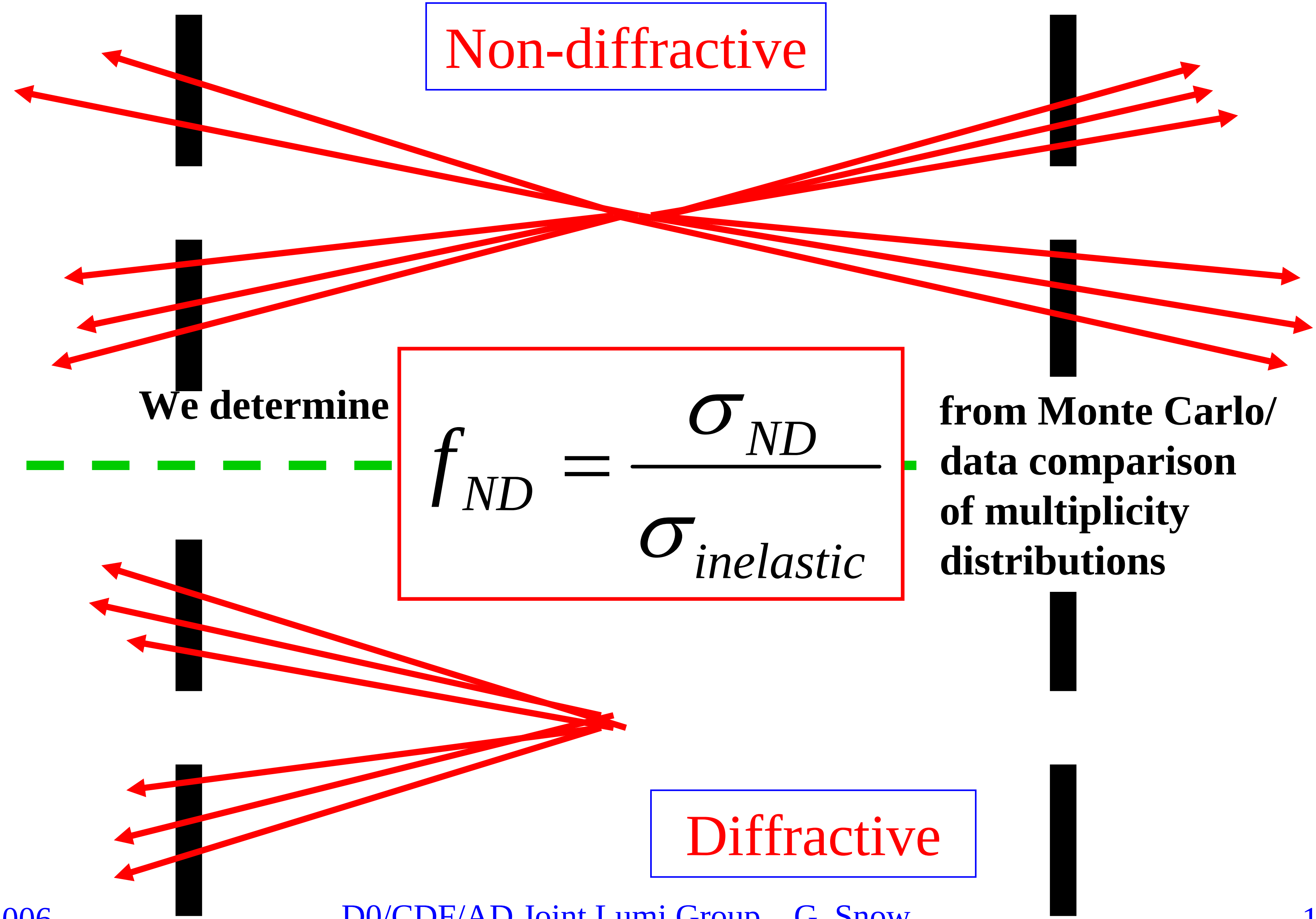
$$\sigma_{eff} = \varepsilon A \sigma = (A_{SD} f_{SD} + A_{DD} f_{DD} + A_{ND} f_{ND})\sigma$$

$$\textit{and constrain } f_{SD} + f_{DD} + f_{ND} = 1$$

Technique Overview II

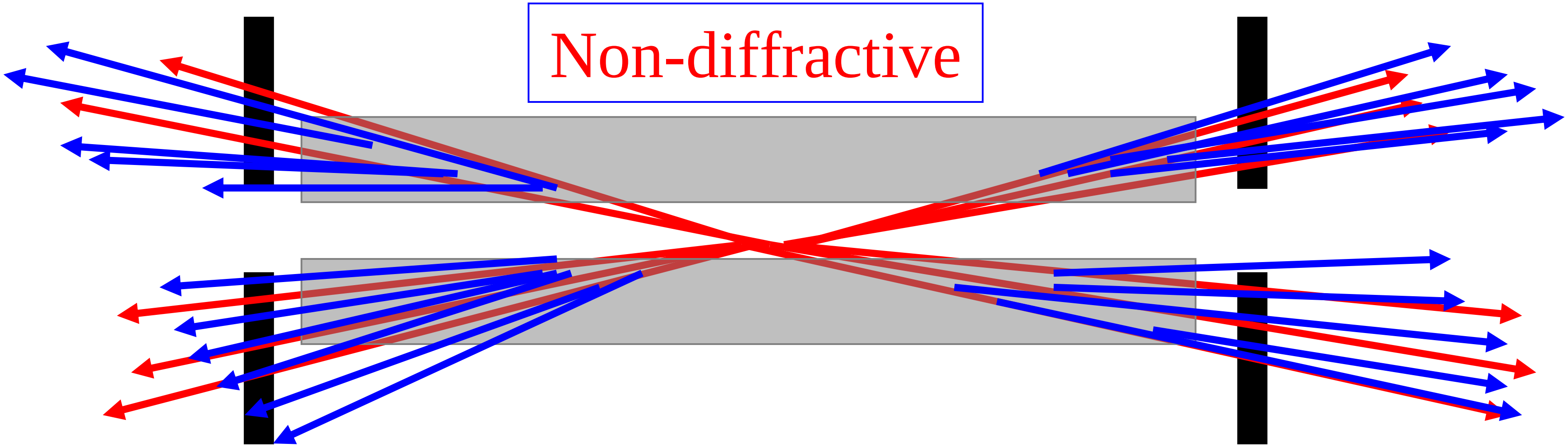


Technique Overview III

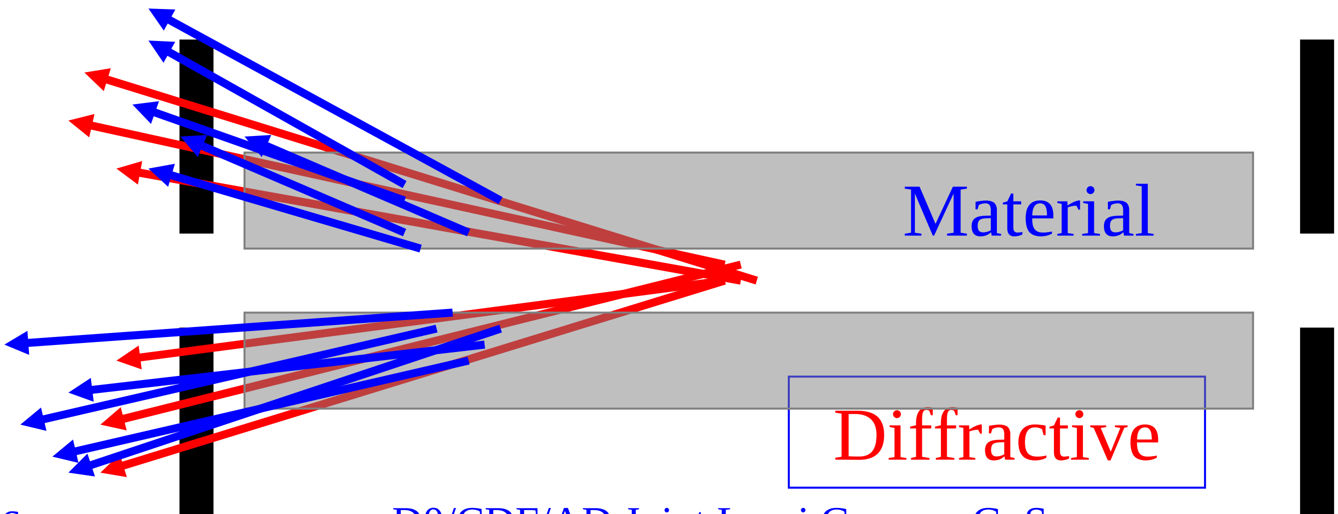


We determine $f_{ND} = \frac{\sigma_{ND}}{\sigma_{inelastic}}$ from Monte Carlo/ data comparison of multiplicity distributions

Technique Overview IV

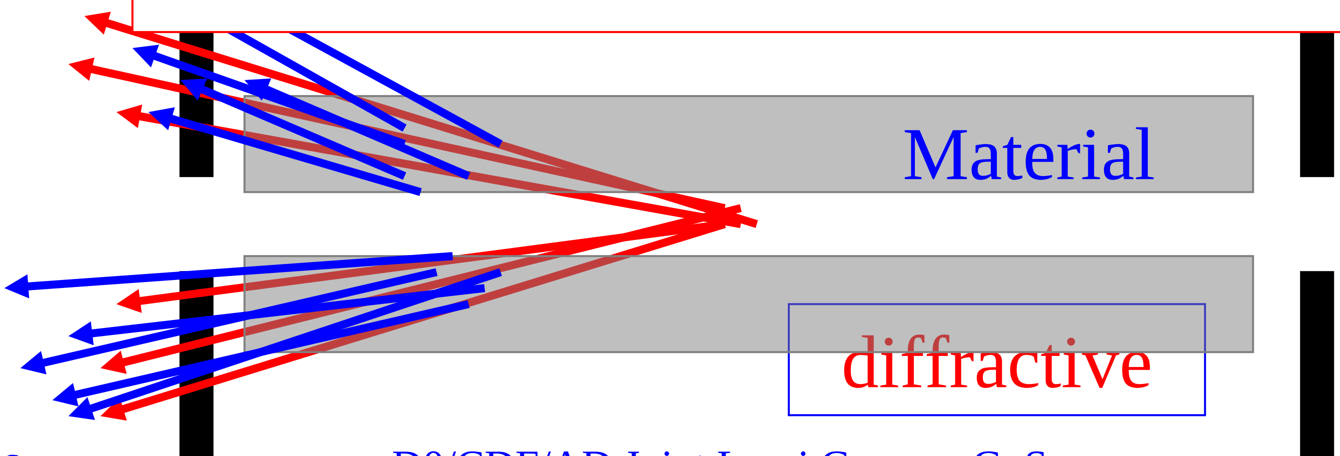


Material in front of detectors can make more particles



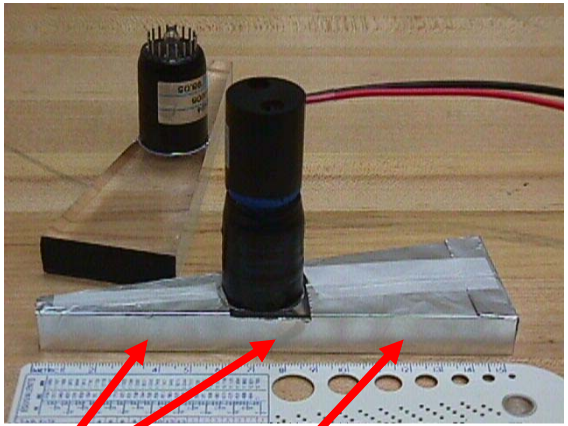
Technique Overview V

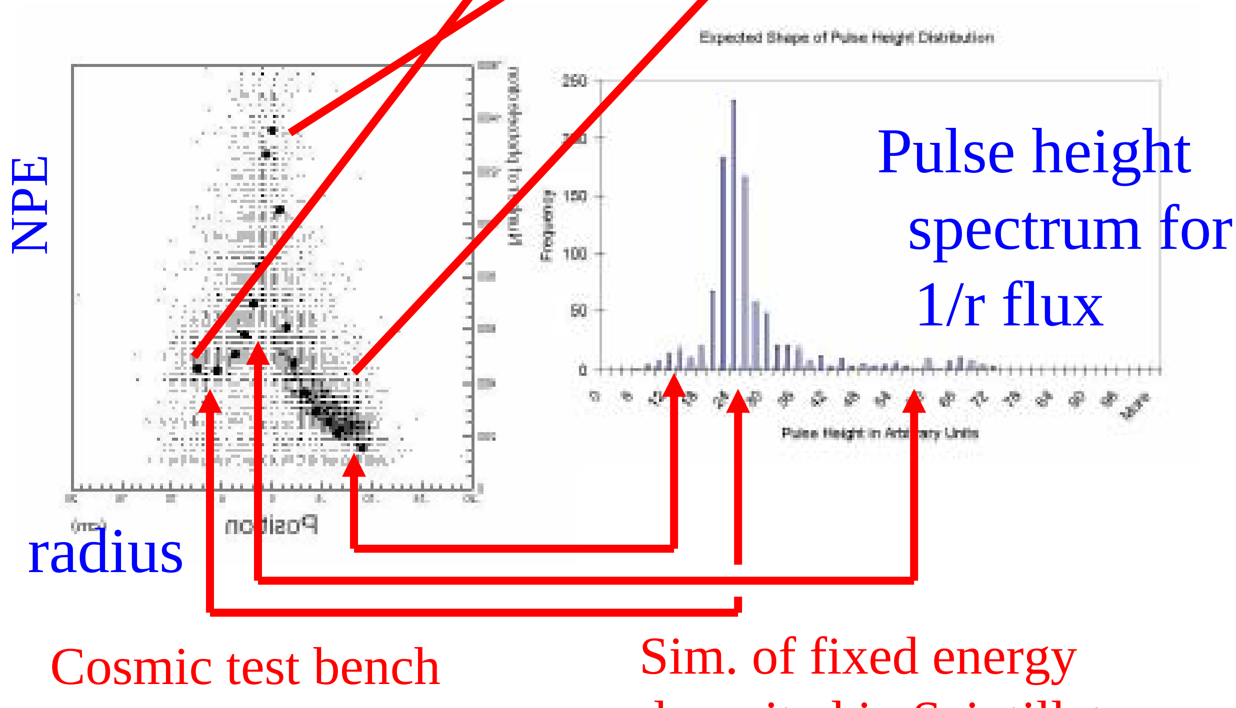
- Good material description important for modeling multiplicity in LM detectors
- However:
  - Counting rate is insensitive to this as long as we are efficient for single particles
  - Material description cannot ruin a true zero, since no particles shower



Scintillator Response

- Triangular geometry with PMT glued to center of scintillator.
- r < r (PMT): most light focused towards PMT, fairly uniform MIP signal
- r ~ r(PMT): very large pulse
- r > r(PMT): light not focused toward PMT, decreasing NPE at PMT with increasing r

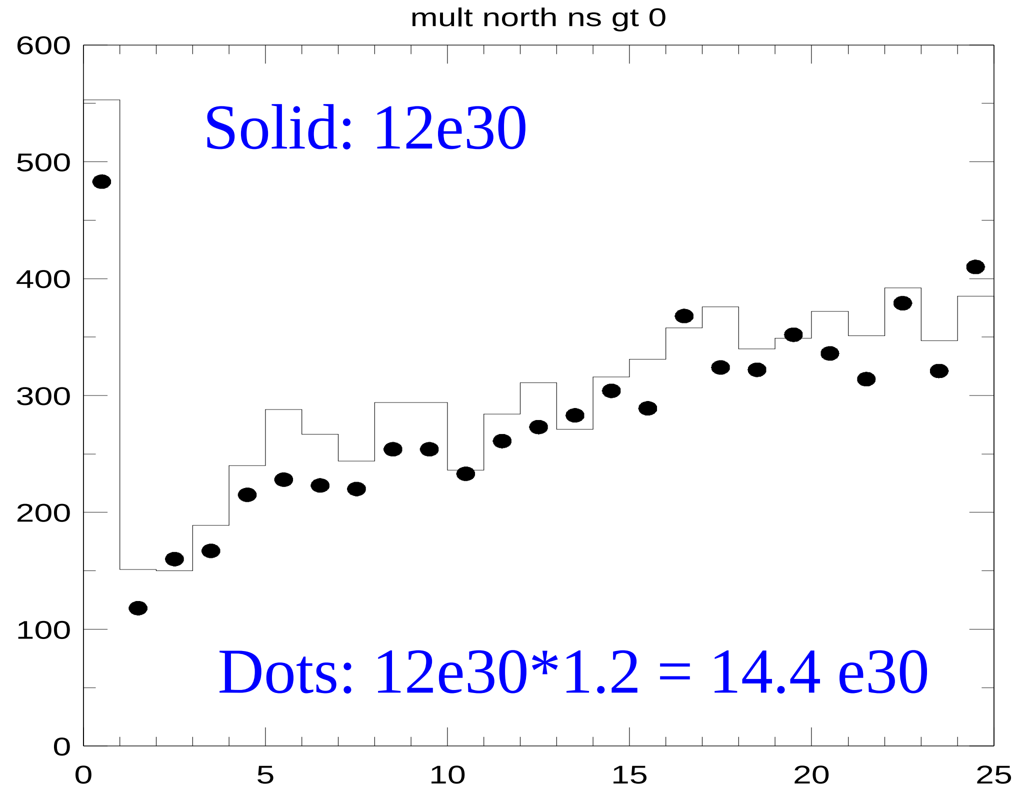




Multiple Interactions in MC

- Even at lowest Run II luminosities we have to model multiple interactions.
- Three MC samples
  - ND: non-diffractive
  - SD: single diffractive
  - DD: double diffractive
- Choose a luminosity
  - This sets the Poisson mean of the above three processes
- Throw a Poisson random number for each crossing for each process
- Loop over many MC entries for each process to simulate a single crossing

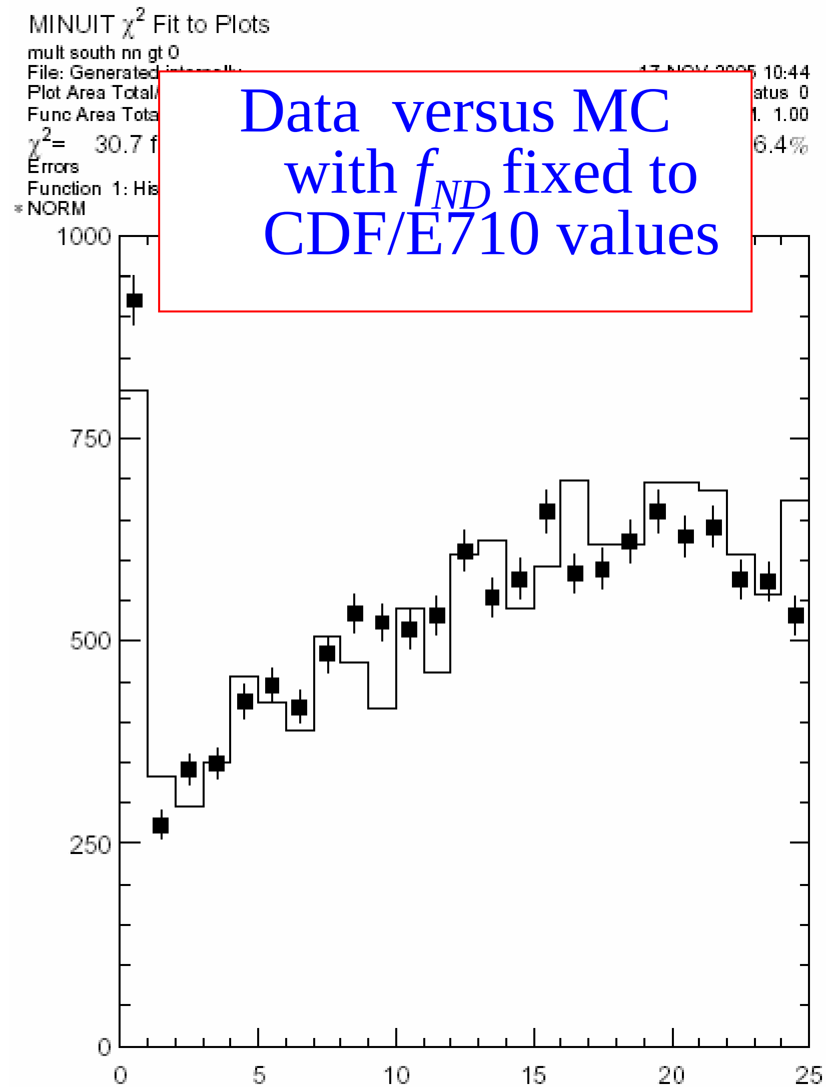
MC including multiple interactions



Turns out to be next dominant systematic after inelastic x-section

Non-diffractive Fraction

- Have measurements of single and double diffractive x-sections
  - From CDF/E710/E811
- Distinctions between processes are not well-defined and experiment-dependent
- We are not really after the true non-diffractive fraction. We are after the proper weight to use for the different PYTHIA processes we generate.



Detector multiplicity, one side

Non-diffractive Fraction

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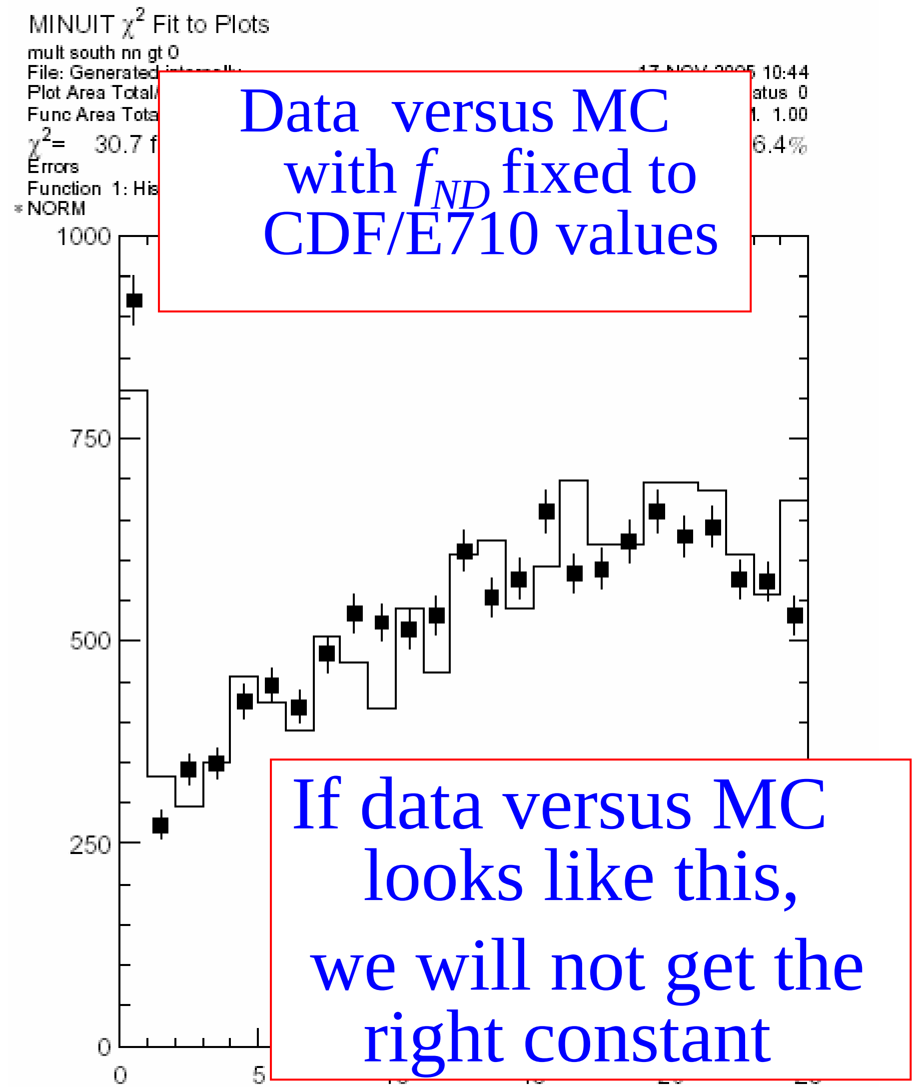
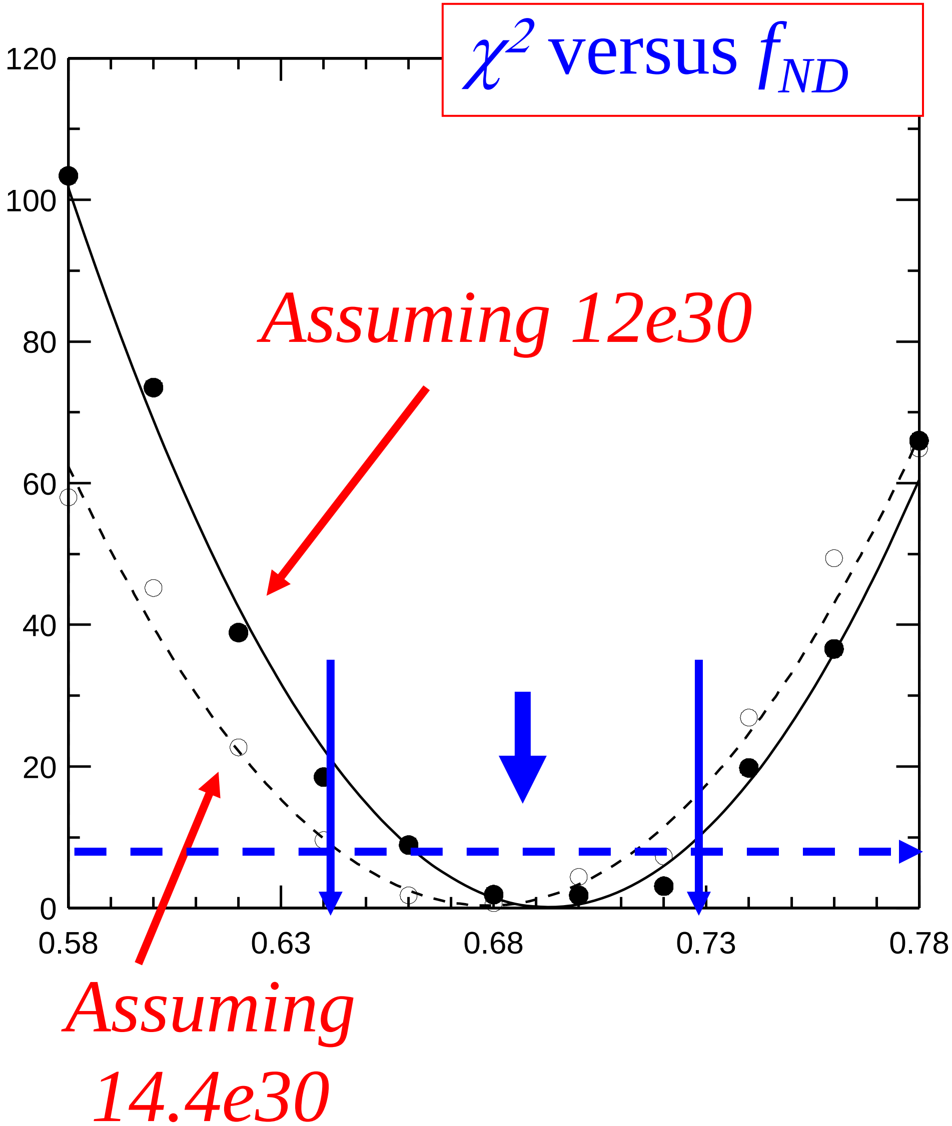


Data versus MC with f_{ND} fixed to CDF/E710 values

If data versus MC looks like this, we will not get the right constant

f_{ND} Determination



Look at χ^2 for fits to north and south

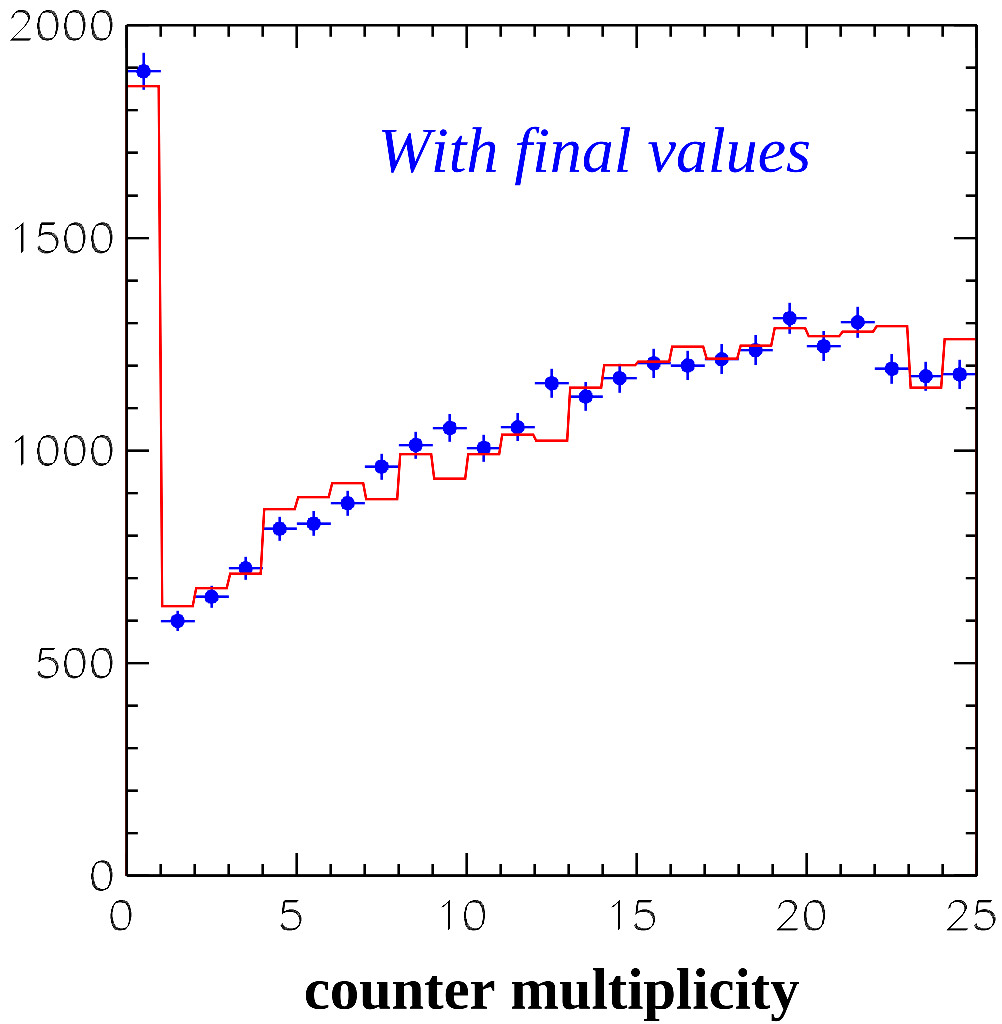
Look only at the fraction of events in the zero bin

(removes most of the dependence on material model)

Not enough info to determine single diffractive to double diffractive ratio.

Take experimental value +/- 3 σ

MC versus Data



f_{ND} Cross-checks

Fit parameters	non-diffractive fraction
final	0.687 ± 0.044
12e30 fit, opposite side mult > 0, 2 bin fit	0.695
14e30 fit, opposite side mult > 0, 2 bin fit	0.678
12e30 fit, opposite side mult > 0, 25 bin fit	0.685
12e30 fit, opposite side mult > 1, 25 bin fit	0.690
14e30 fit, opposite side mult > 0, 25 bin fit	0.658
14e30 fit, opposite side mult > 1, 25 bin fit	0.665
43e30 fit, opposite side mult > 0, 25 bin fit	0.693
12e30 fit, opposite side mult > 0, 2 bin fit, $f_{DD} = 0$	0.695
12e30 fit, opposite side mult > 0, 2 bin fit, $f_{SD} = 0$	0.706
12e30 fit, opposite side mult > 0, 2 bin fit, 0.3 X_0 added	0.687
Pythia calculation	0.662
E710, E811, CDF measurements	0.723

Final Numbers

	default	thresholds	in-time	material	MIP location	light-yield modeling
non-diffractive	0.981 ± 0.001	± 0.003	± 0.001	$\pm 0.006(5)$	$\pm 0.004(4)$	± 0.004
single diffractive	0.330 ± 0.004	± 0.007	± 0.001	$\pm 0.022(25)$	$\pm 0.003(11)$	± 0.001
double diffractive	0.436 ± 0.005	± 0.008	± 0.003	$\pm 0.019(30)$	$\pm 0.014(14)$	± 0.005
inelastic	0.784 ± 0.001	± 0.004	± 0.007	$\pm 0.003(7)$	$\pm 0.005(4)$	± 0.003

non-diffractive efficiency	0.981 ± 0.009
single diffractive efficiency	0.330 ± 0.024
double diffractive efficiency	0.436 ± 0.026
f_{ND}	0.687 ± 0.044
$f_{SD}/(f_{SD} + f_{DD})$	0.57 ± 0.21
inelastic efficiency	0.792 ± 0.029
inelastic cross-section	60.7 ± 2.4 mb
effective cross-section	48.0 ± 2.6 mb

Comparison with previous

$$\sigma_{eff} = \varepsilon A \sigma = \varepsilon\ (A_{SD}\ \sigma_{SD} + A_{DD}\ \sigma_{DD} + A_{ND}(\sigma - \sigma_{SD} - \sigma_{DD}))$$

From zero bias data

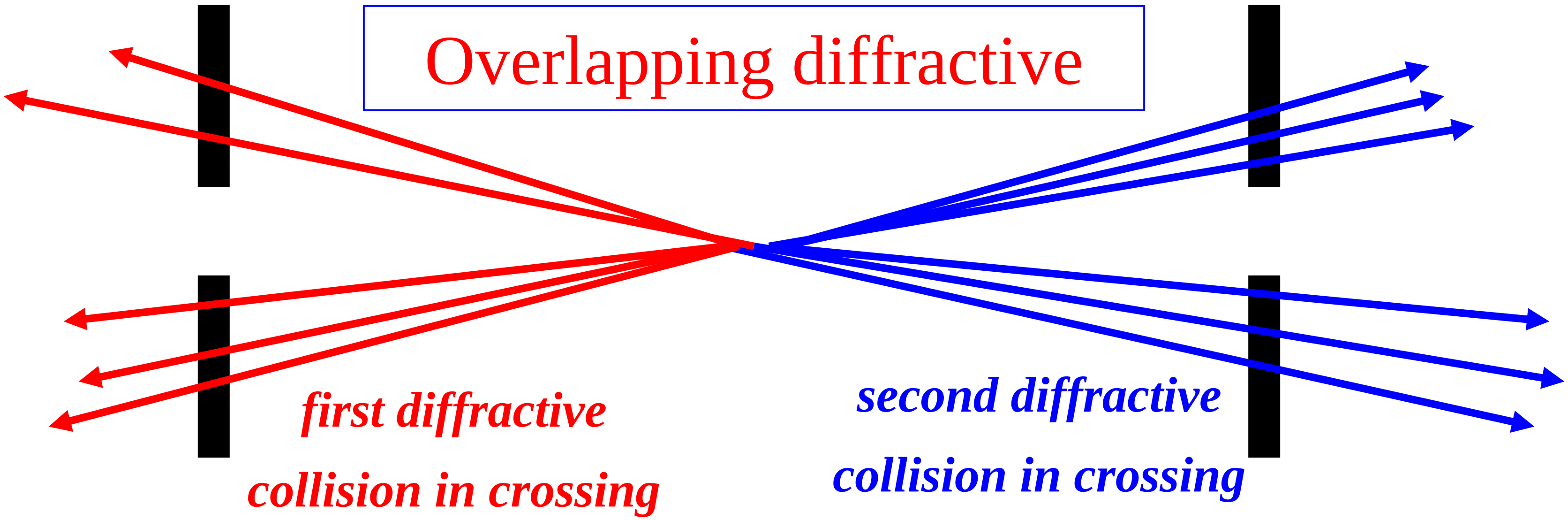
From MC

From independent measurements

- Before we used the non-diffractive fraction measured by other experiments. We knew this could be wrong but at the time we had nothing better to go with and no indication that it was not the correct thing to do. We tried to inflate the error to cover all reasonable ranges.

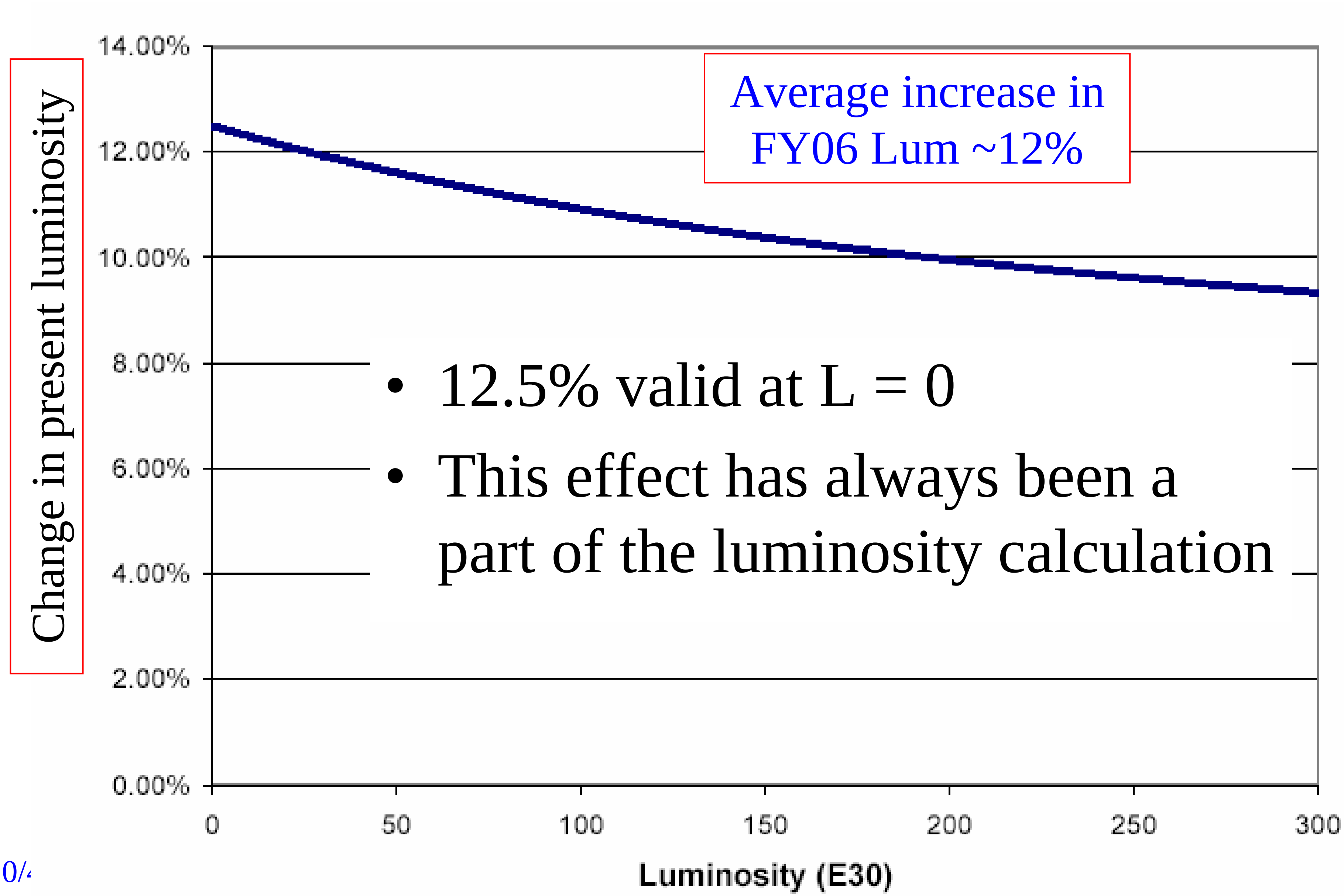
- Roughly, the differences were:
  - The weightings of the 3 inelastic processes were incorrect for D∅'s Monte Carlo since, now, we see they lead to multiplicity distributions that do not match the data.

L-Dependent Correction for:



- **Effectively a new process that turns on at high luminosity when we have many interactions per crossing**
- **Acceptance increases at higher luminosity:**
  - **Over-estimate luminosity if you don't take this into account**

The L-Dependent Correction

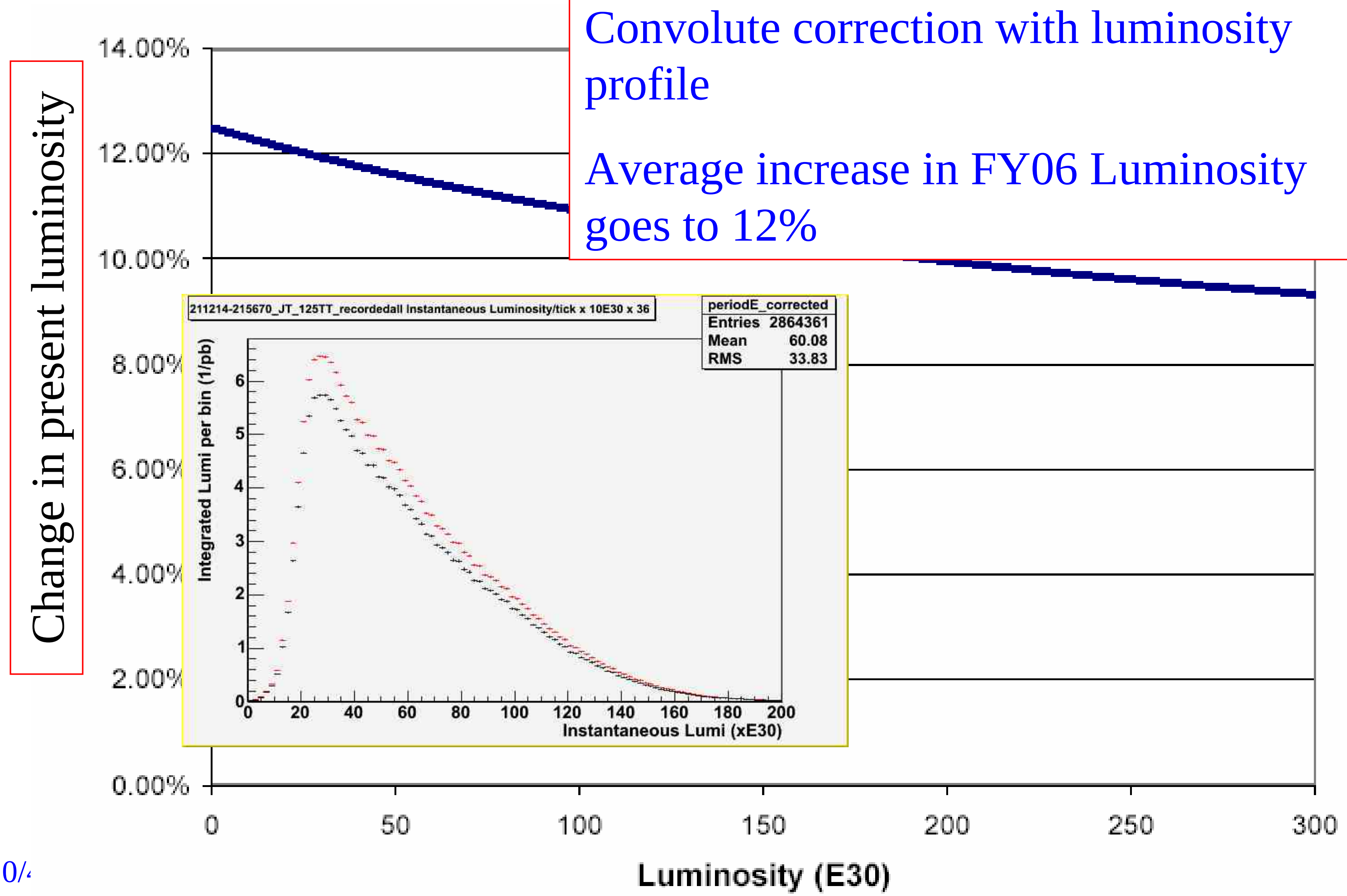


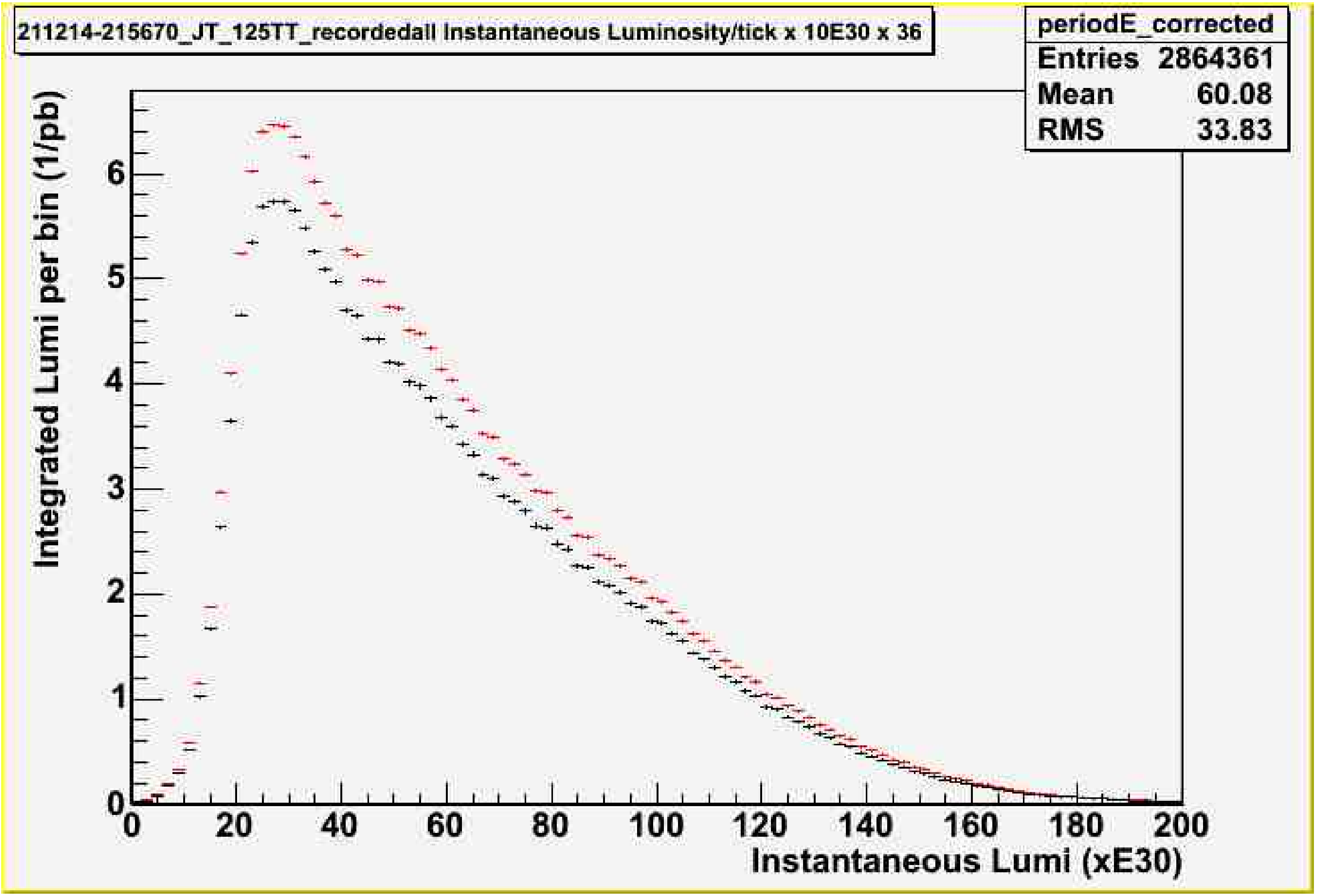
- 12.5% valid at L = 0
- This effect has always been a part of the luminosity calculation

The L-Dependent Correction

Convolute correction with luminosity profile

Average increase in FY06 Luminosity goes to 12%




211214-215670_JT_125TT_recordedall Instantaneous Luminosity/tick x 10E30 x 36
periodE_corrected
Entries 2864361
Mean 60.08
RMS 33.83
Integrated Lumi per bin (1/pb)
0
1
2
3
4
5
6
0
20
40
60
80
100
120
140
160
180
200
Instantaneous Lumi (xE30)

Some Next Steps at D∅

- **Complete collaboration review of back propagation of today's adjustment to all of Run IIa**
- **Cross check adjustment with certain physics processes**
- **Document adjustment in Fermilab TM – reference for our physics analyses, laboratory**
- **Complete detailed Run IIb normalization exercise for physics analyses**