Run 2B Luminosity Measurement

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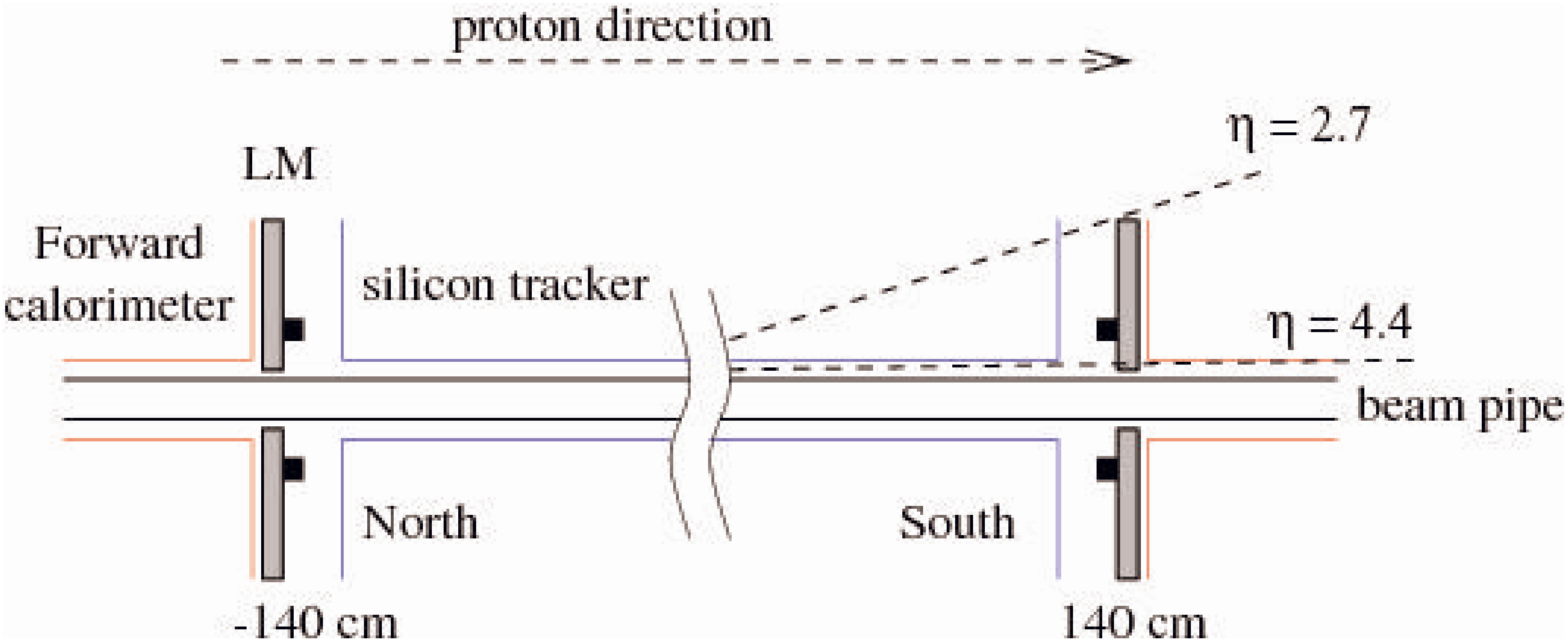
Introduction

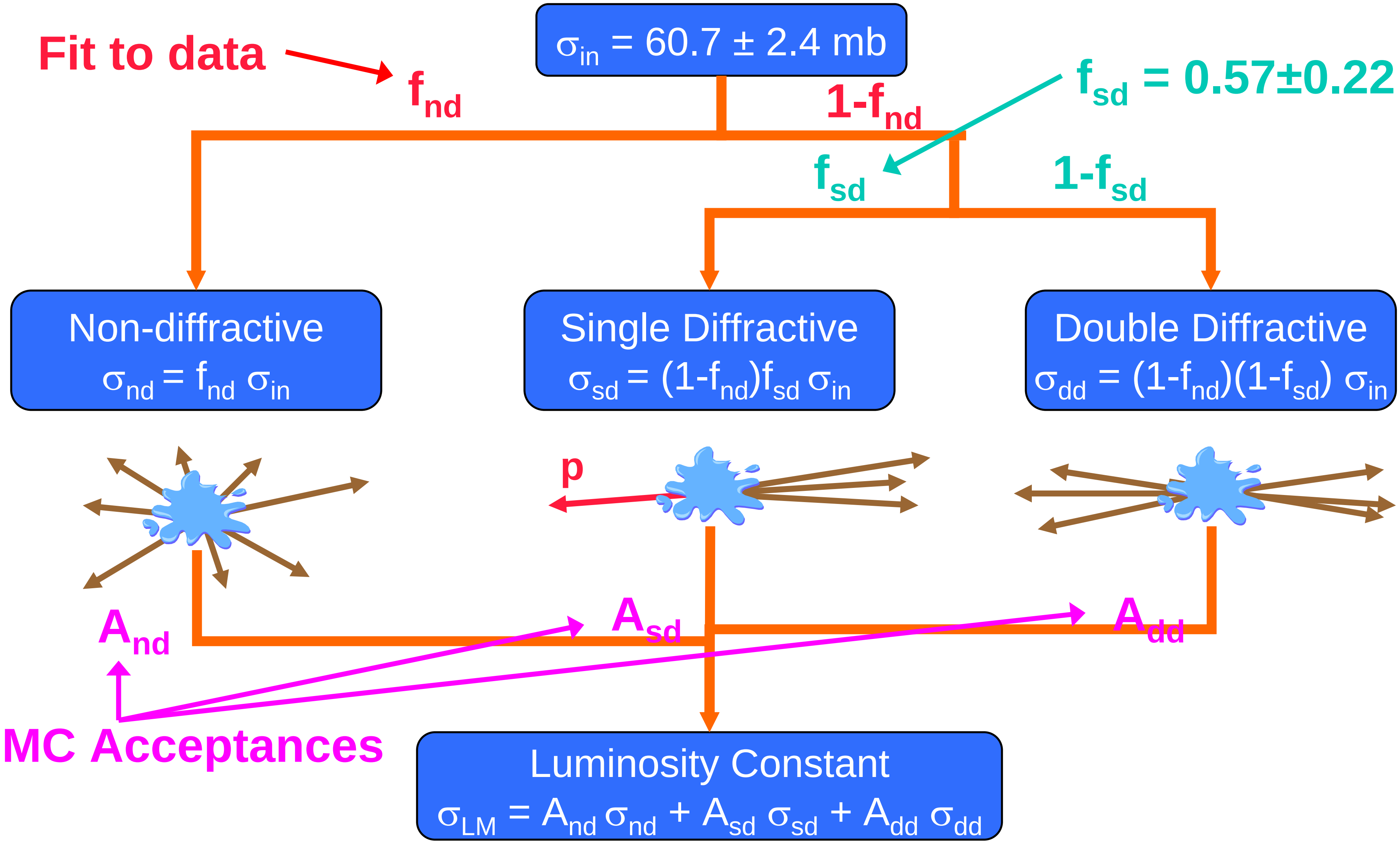
- At ~13:43 on November 17, 2009, DØ changed it's luminosity measurement to implement a new evaluation of the "Luminosity Constant" that determines the luminosity normalization
- New Luminosity Constant provides a significant reduction in the DØ contribution to the luminosity uncertainty
- New Luminosity Constant also accounts for Run 2b detector changes (earlier studies demonstrated this is a small effect compared to uncertainties in the Run 2a Luminosity Constant)
- DØ also implemented an improved treatment of Luminosity Monitor backgrounds

Luminosity Constant

- Luminosity Constant is an effective cross section that relates the measured rate for N-S coincidences in Luminosity Monitor (LM) counters to the DØ luminosity

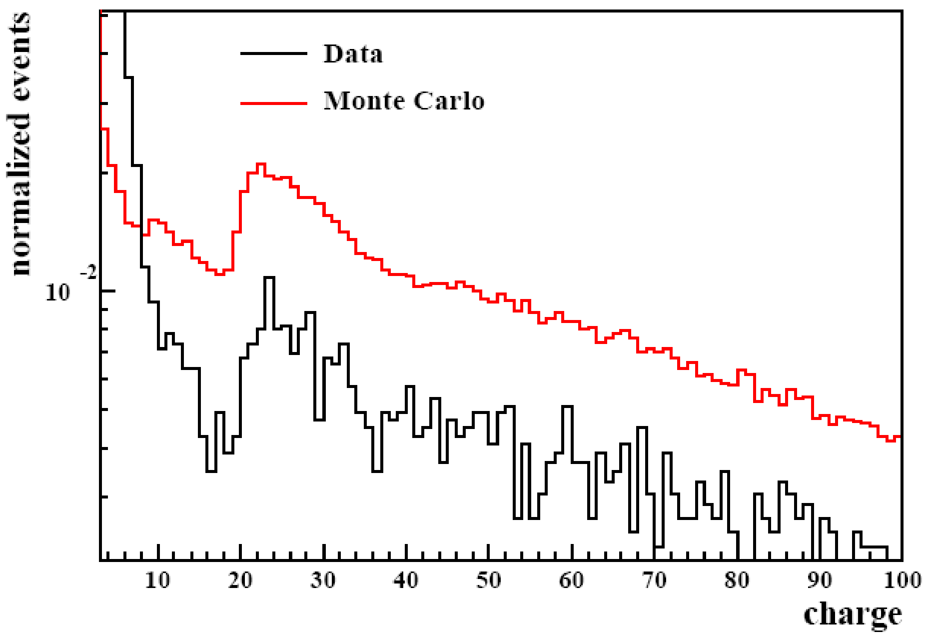


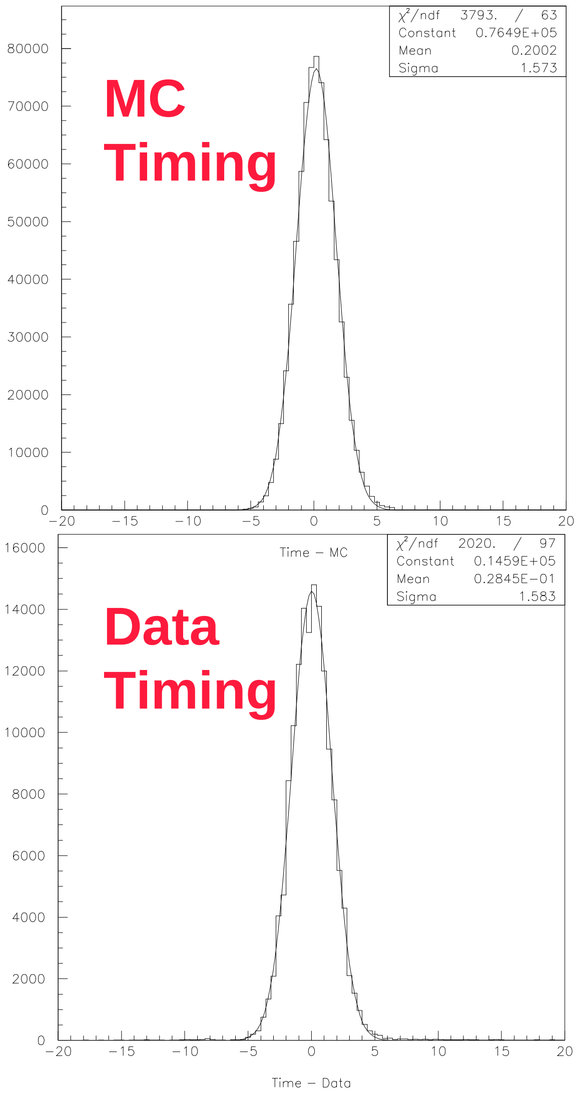
Luminosity Constant Pictorial Guide



Charge and Timing Distributions Tuned

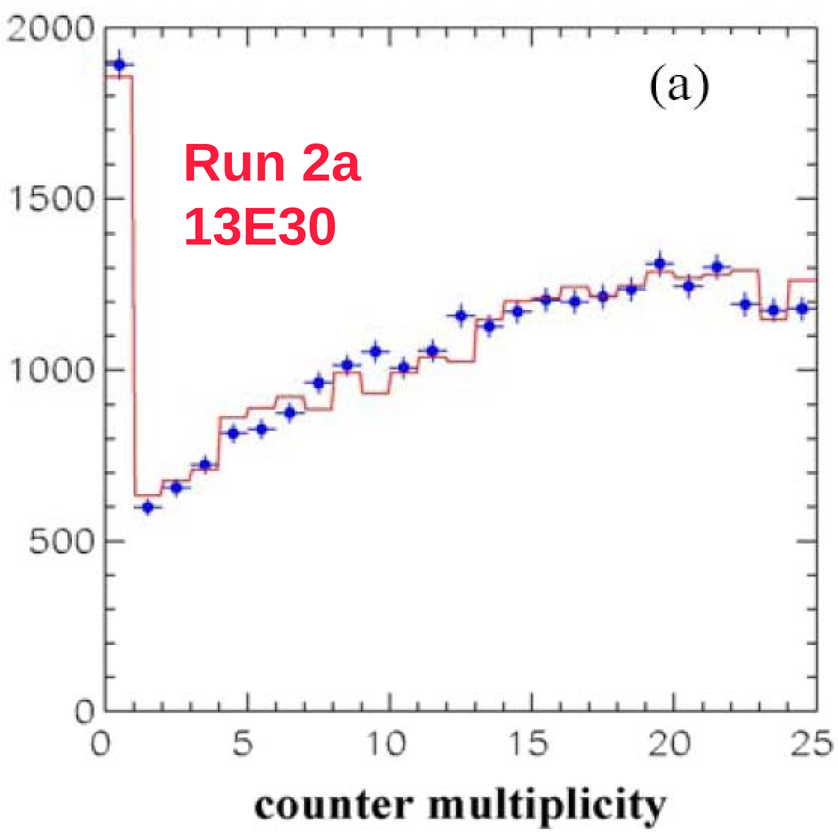
- MIP peak used to normalize MC charge distribution
  - Discriminator threshold is 0.35 MIP
- MC timing distribution smeared to match data

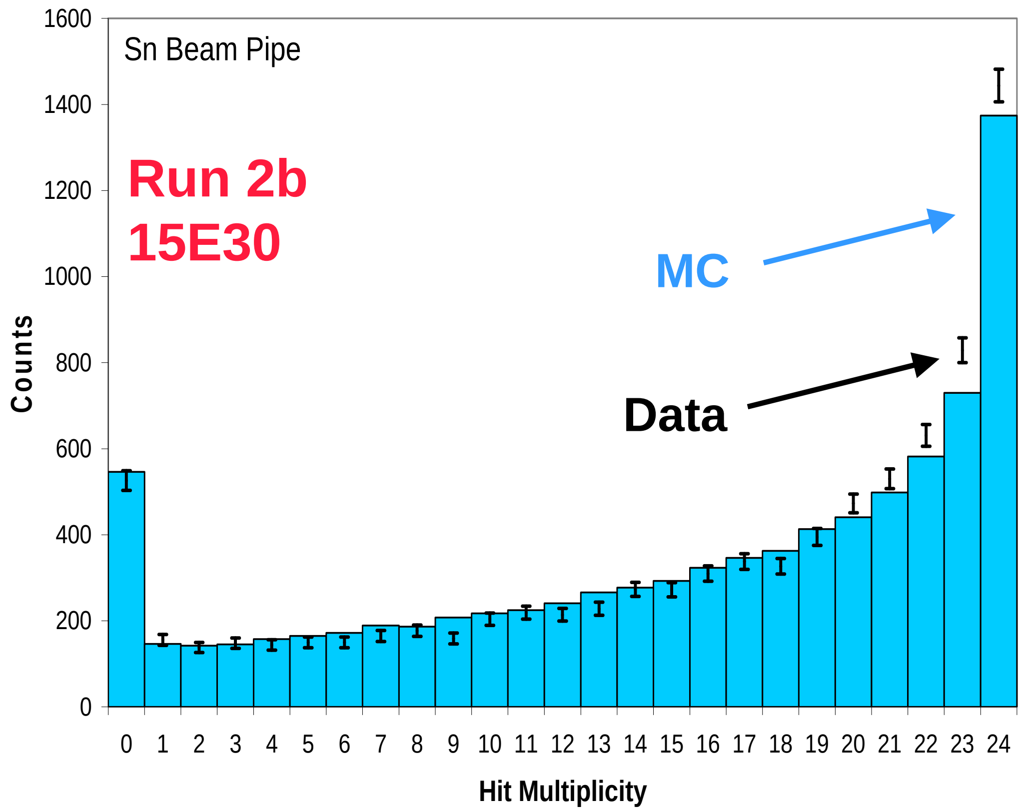




LM Counter Multiplicity Distribution

- Significantly higher LM multiplicity observed in Run 2b
  - Set beam pipe material to tin to match observed multiplicity distribution
  - Be/Sn difference taken as a systematic uncertainty





LM Acceptance

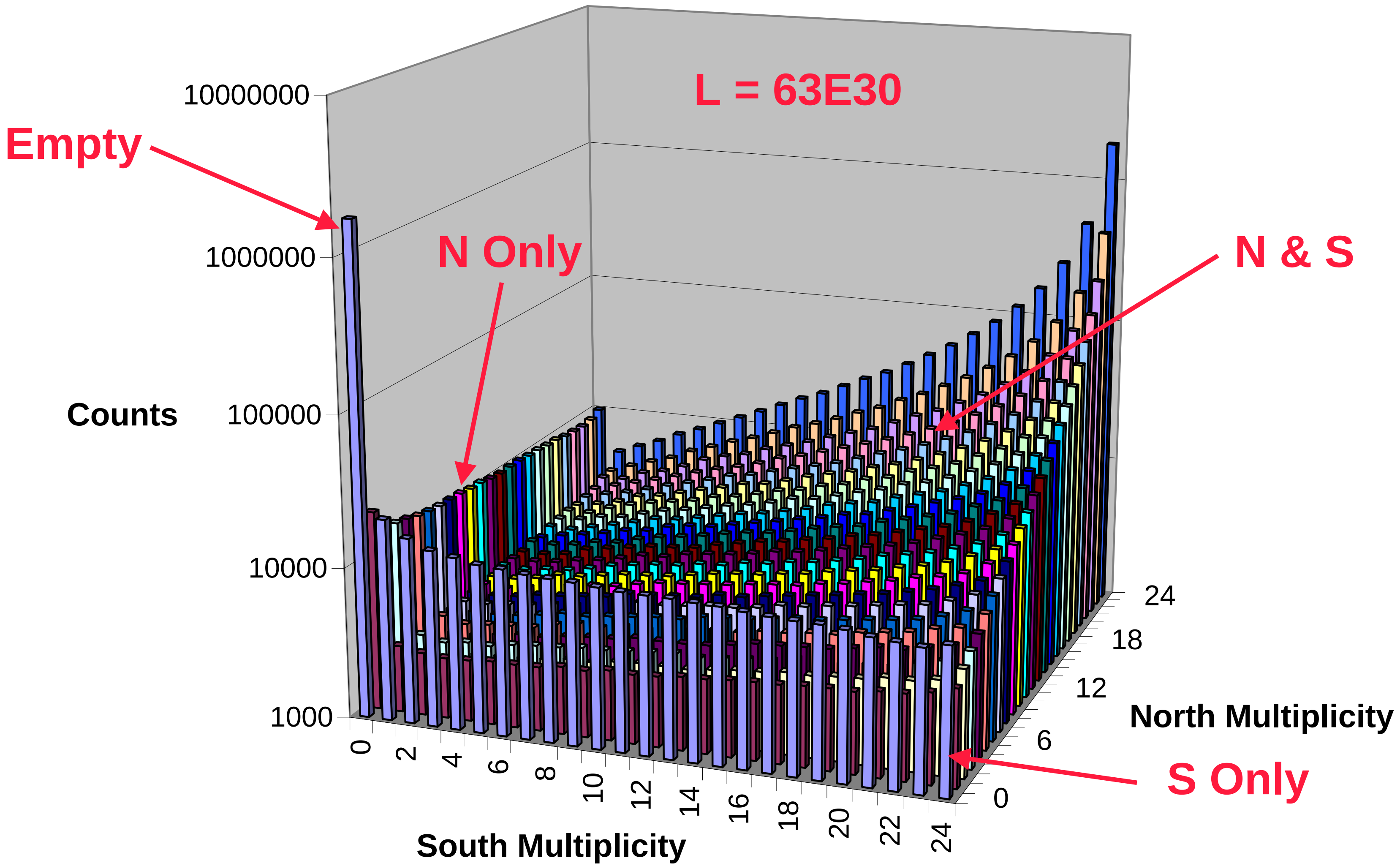
- Simulate non-diffractive, single diffractive, and double diffractive processes using Pythia
  - Use Rick Field's Tune A parameter set (same as for Run 2a analysis)
- Count number of resulting MC hits in the north, south LM detectors
- Classify events based on whether they have >0 hits in N/S
- Errors shown are from MC statistics (~10K events / sample)

Acc	Non-Diffractive	Single Diffractive	Double Diffractive
N & S	$A_{nd} = 0.9924 \pm 0.0009$	$A_{sd} = 0.3263 \pm 0.0047$	$A_{dd} = 0.4996 \pm 0.0050$
N Only	$A_{nd}^{N} = 0.0048 \pm 0.0007$	$A_{sd}^{N} = 0.2236 \pm 0.0042$	$A_{dd}^{N} = 0.2027 \pm 0.0040$
S Only	$A_{nd}^{S} = 0.0026 \pm 0.0005$	$A_{sd}^{S} = 0.2250 \pm 0.0042$	$A_{dd}^{S} = 0.2120 \pm 0.0041$
Empty	0.0002 ± 0.0001	0.2251 ± 0.0042	0.0857 ± 0.0028

Non-Diffractive Fraction f_{nd}

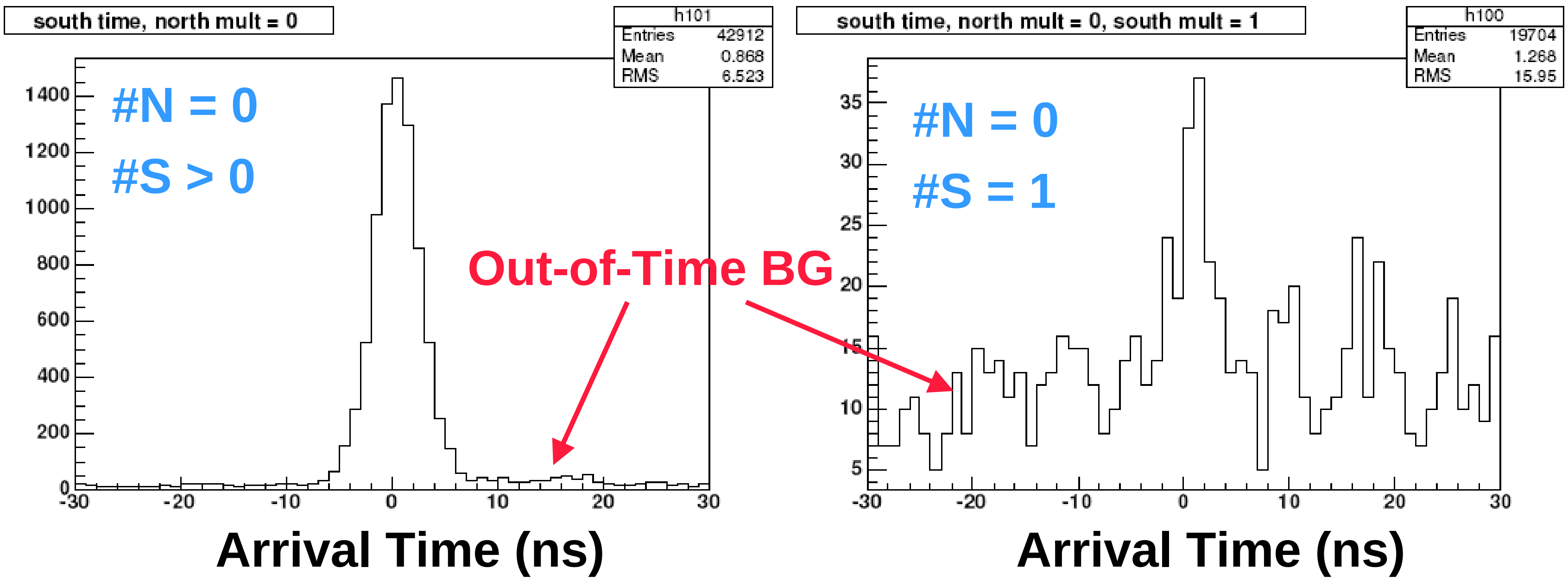
- Determine non-diffractive fraction by fitting the observed ratio of single-sided / double-sided beam crossings
  - Single sided events are predominantly from diffractive processes
- Development of a hardware histogramming capability in the LM electronics has allowed a substantial improvement in the Luminosity Constant precision
  - Allows high statistics 2D multiplicity distributions to be acquired
  - Statistics increased by 3 orders of magnitude
  - Much better understanding and treatment of LM background

Example 2D Multiplicity Histogram



Out-of-Time Background

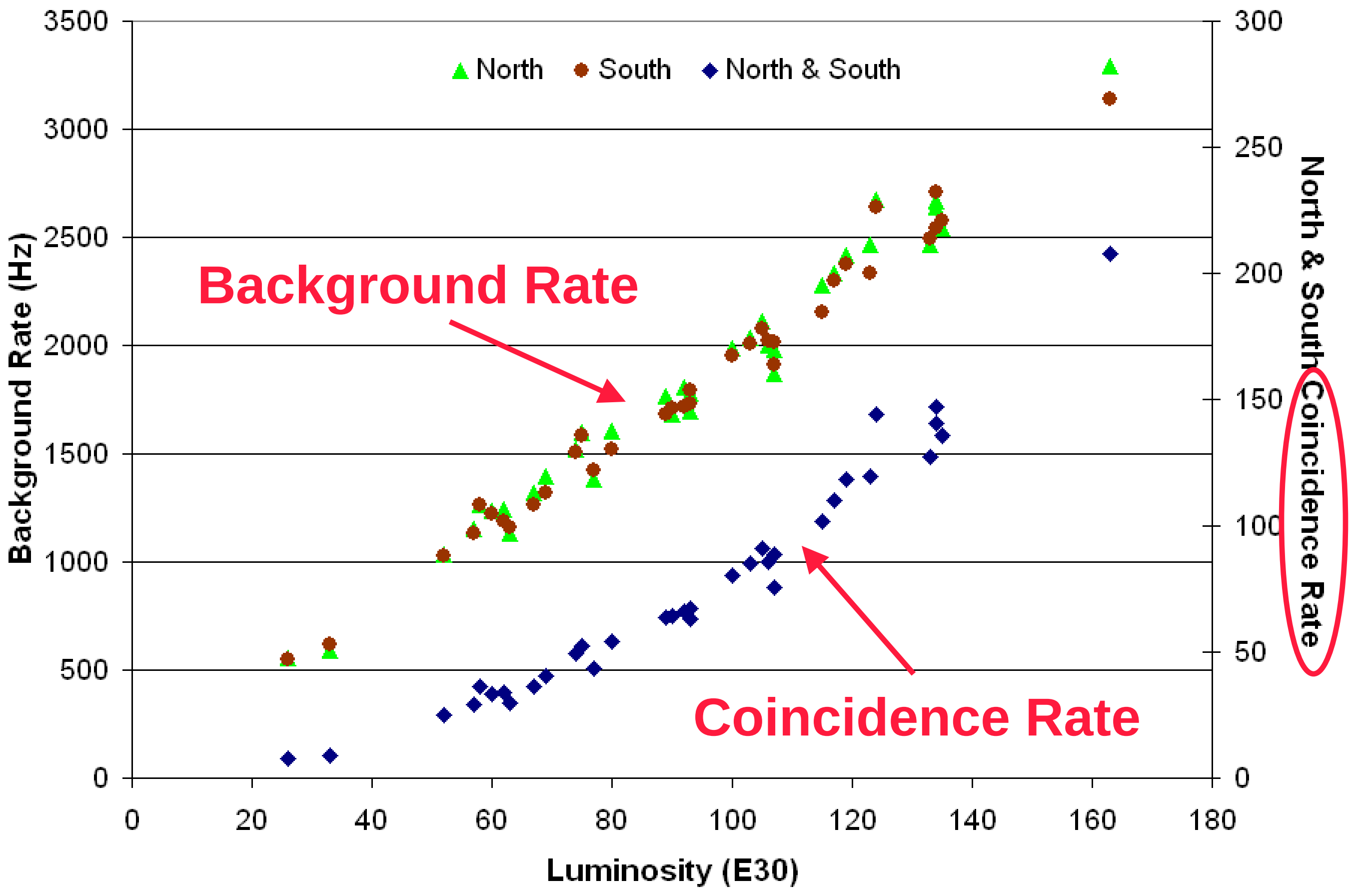
- There is a well established out-of-time background



- Source of background is not clear
  - Correlates with luminosity ⇒ byproduct of previous collisions
  - Background grows with lower threshold ⇒ ~1 MeV of energy deposit
  - Slow neutrons? Activation?

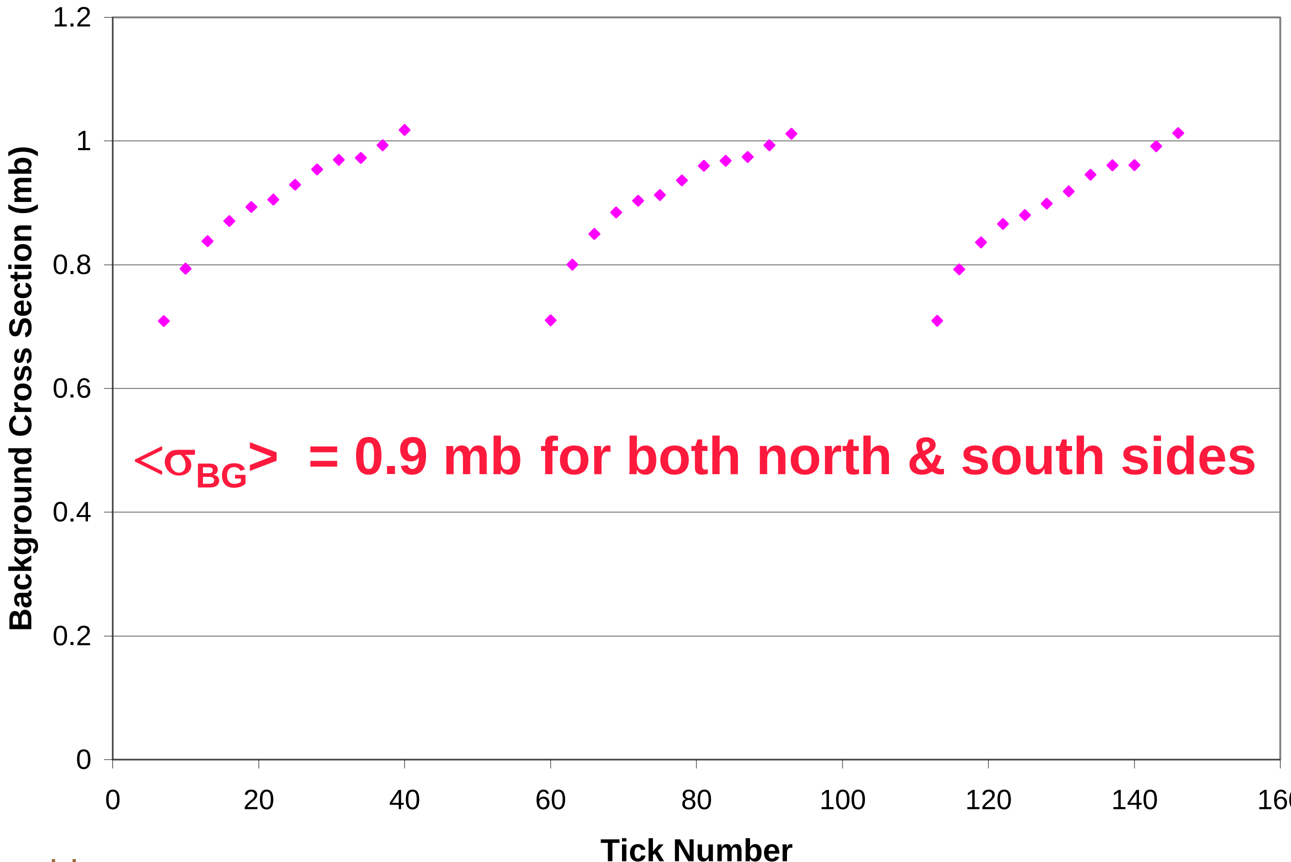
Background Rate in Tick 6

- Background rate scales linearly with luminosity
- N-S rate consistent with random coincidences



Effective Background Cross Section

- Background can be taken as an effective cross section
  - BG is tick dependent due to cumulative effect of previous beam xings
  - See DØ Note 5946 for further details on background study



Unfolding BG Multiplicty Distribution

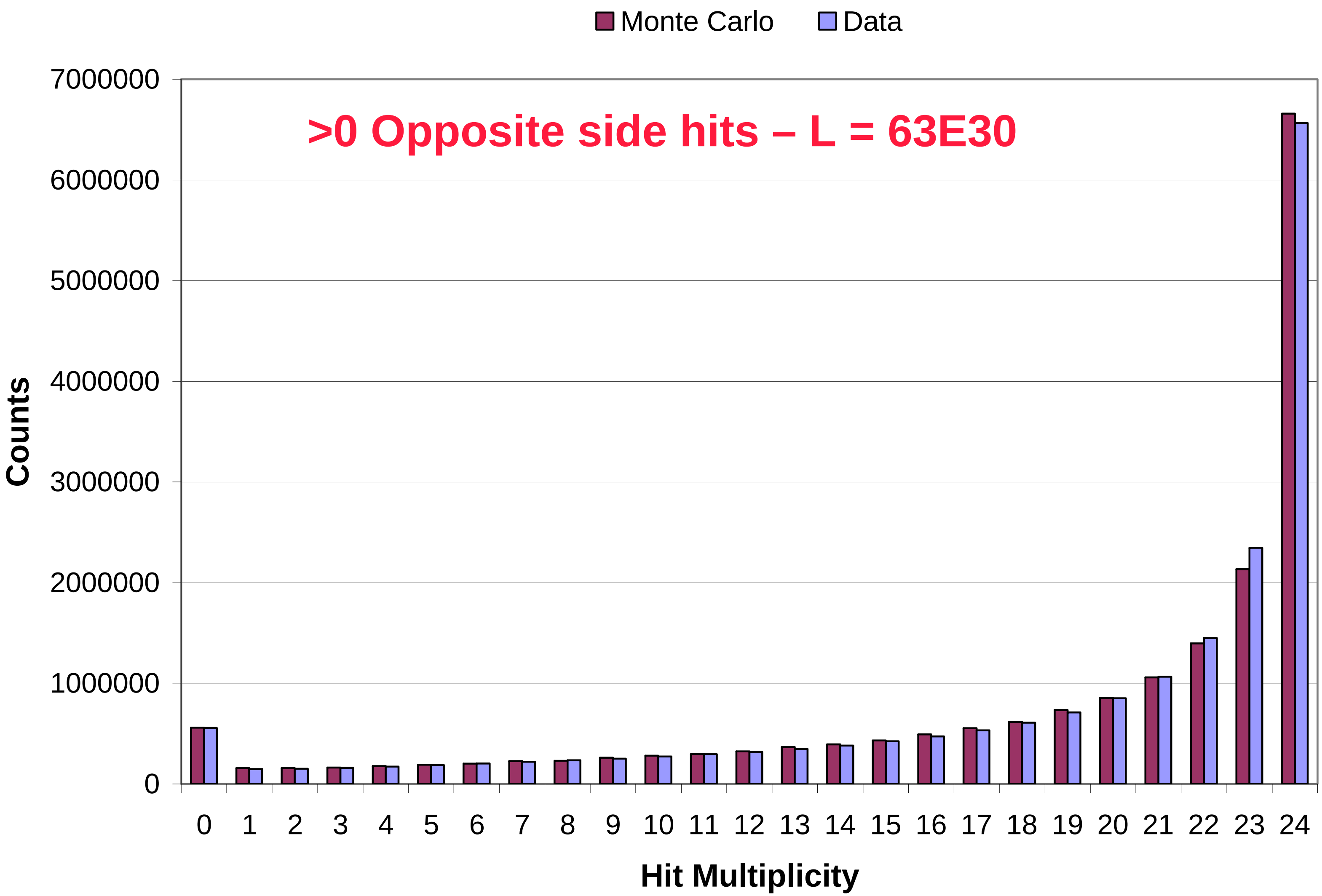
- What we measure in our data is the convolution of the multiplicity distributions for signal and background

$$D_{ij} = \sum_{\substack{l=0 \\ m=0}}^{\substack{l \le i \\ m \le j}} \sum_{\substack{p=0 \\ q=0}}^{\substack{p \le i \\ q \le j}} S_{lm} B_{pq} f_{lpi} f_{mqj} \Theta(l+p-i)\Theta(m+q-j)$$

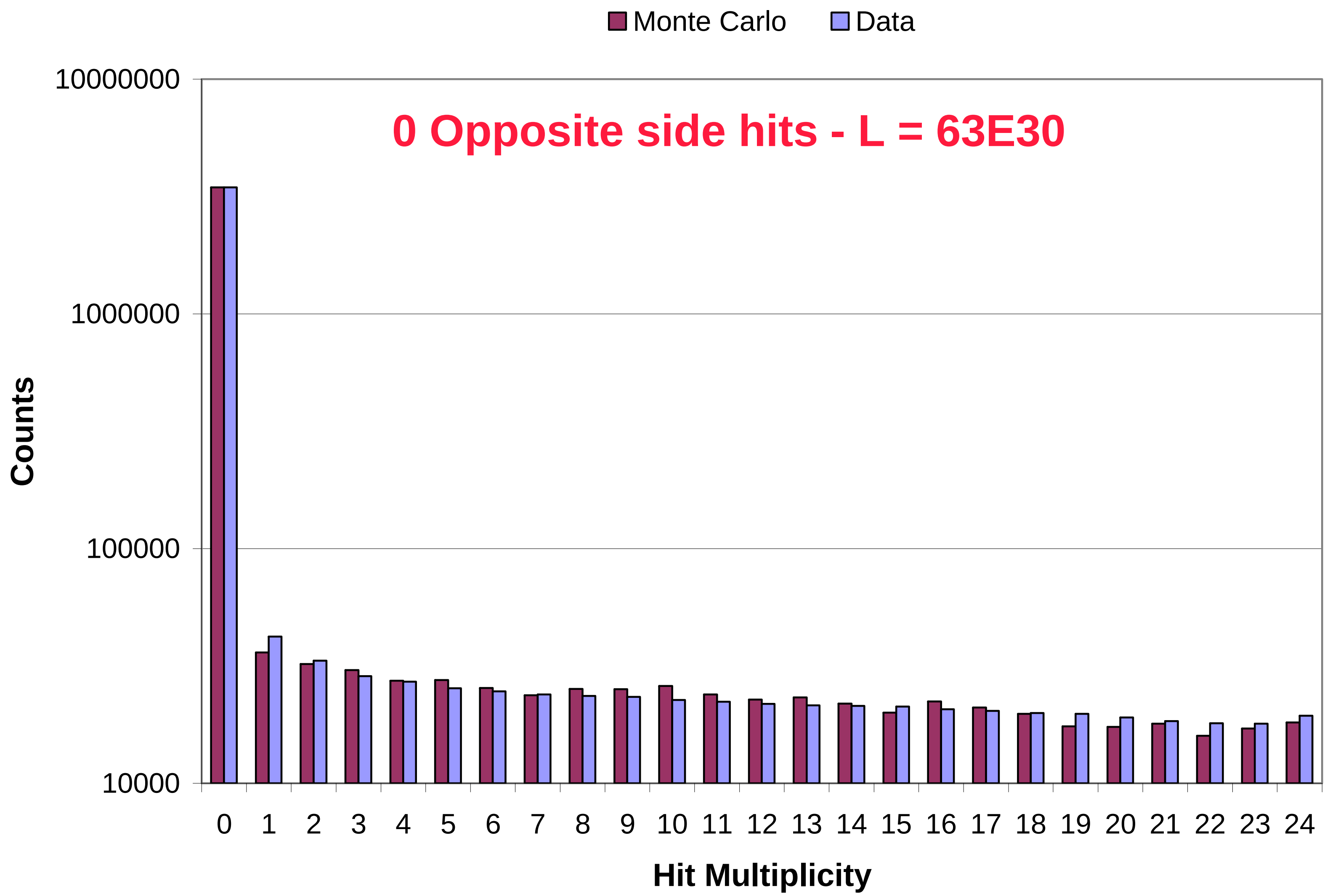
$$f_{lpi} = \frac{l!\,p!\,(N-l)!\,(N-p)!}{(l+p-i)!\,(i-p)!\,(i-l)!\,(N-i)!\,N!}$$

  - D_{ij} – Observed probability for having *i* north hits and *j* south hits
  - S_{lm} – Probability of having *l* north signal hits and *m* south signal hits
  - B_{pq} – Probability of having *p* north BG hits and *q* south BG hits
  - f_{lpi} – Probability of having i counters hit by *l* signal hits and *p* BG hits
- Solve for the signal multiplicity distribution S_{lm}
  - See DØ Note 5904 for further details on BG unfolding procedure

Example Unfolded Multiplicity Distribution

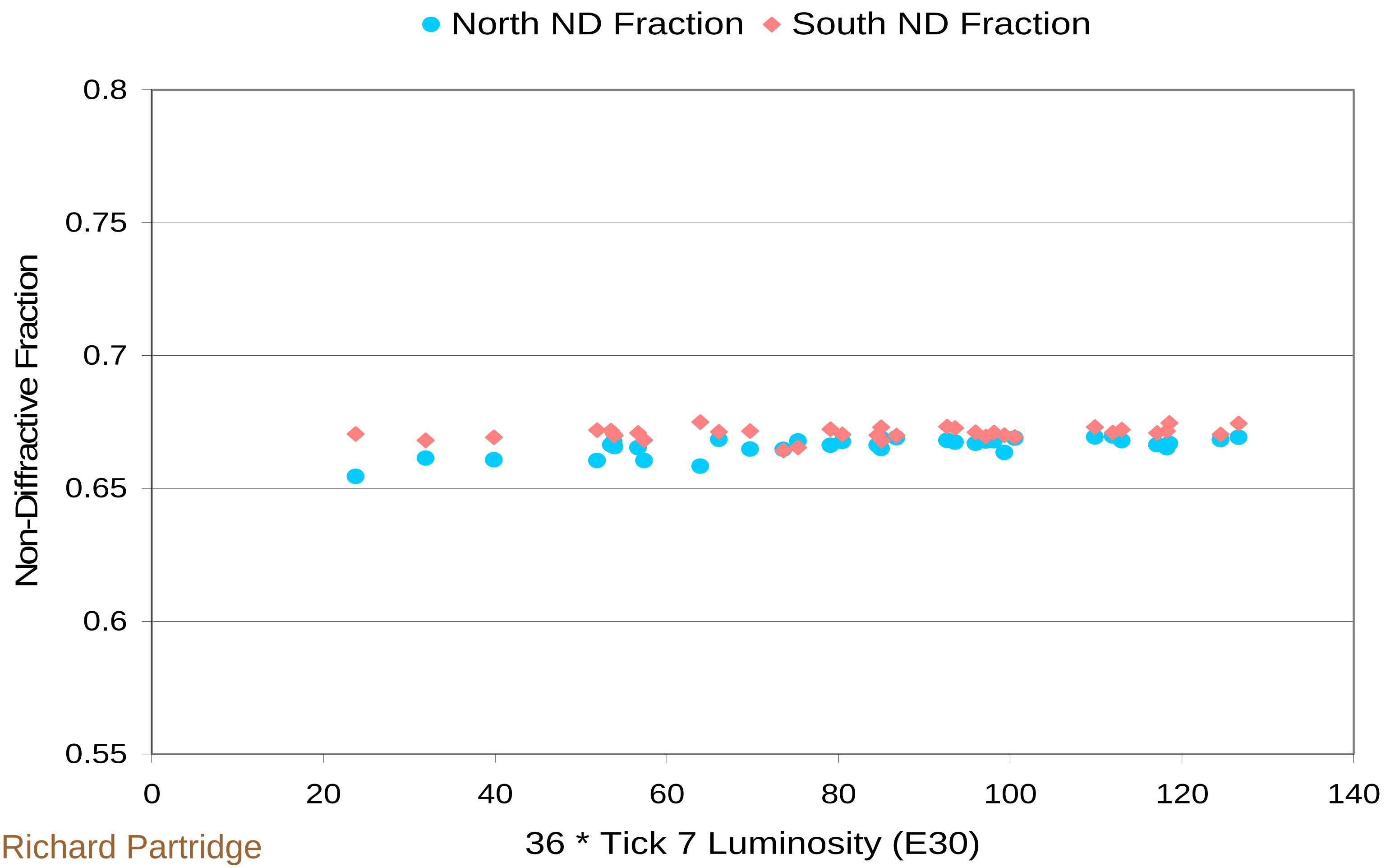


Example Unfolded Multiplicity Distribution



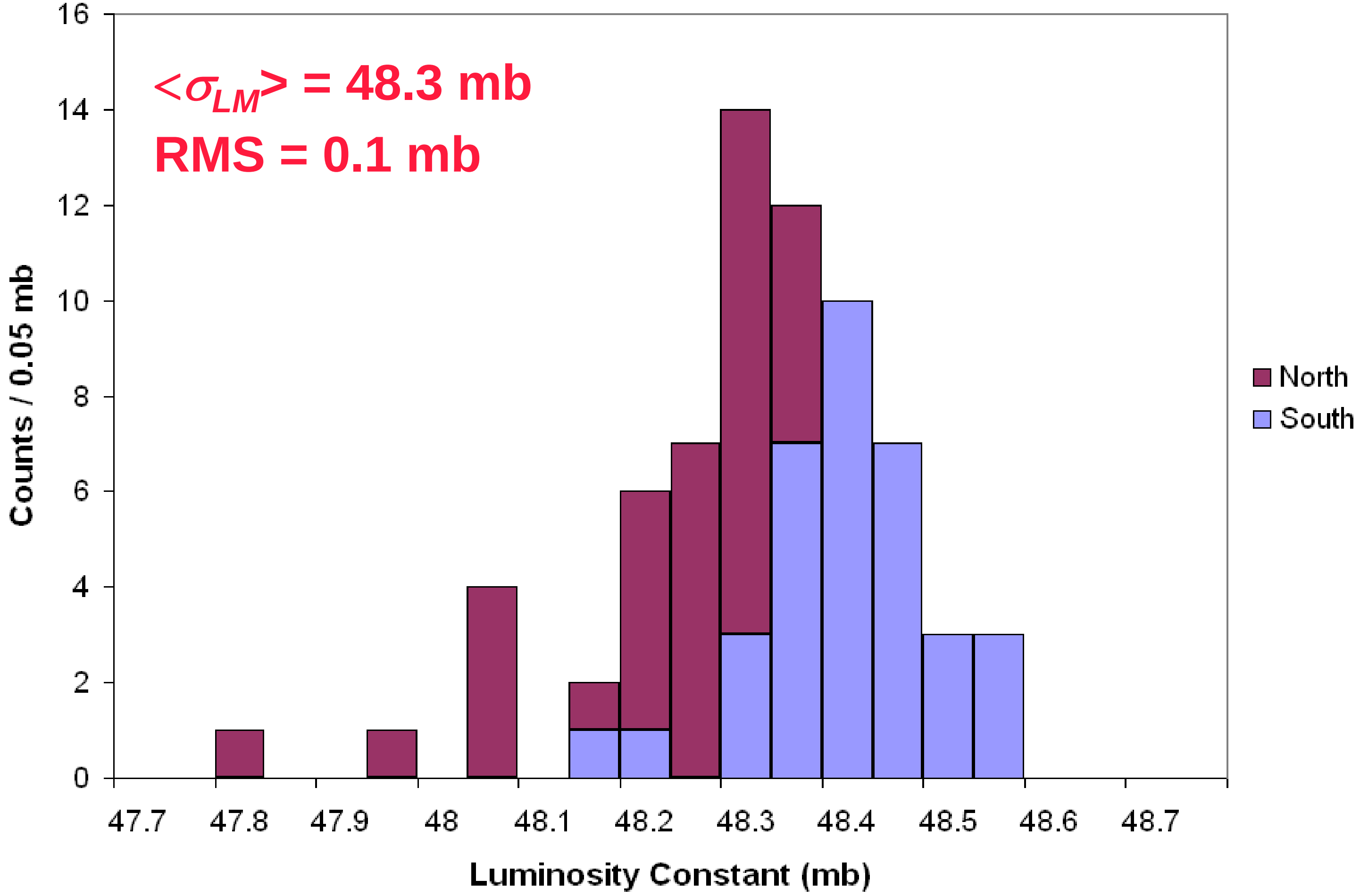
Non-Diffractive Fraction Measurements

- Run 2a: f_{nd} = 0.687 ± 0.044 (stat. + syst.)
- Run 2b: f_{nd} = 0.668 (stat. < 0.001; syst. propagated to σ_{LM})



Luminosity Constant

$$\sigma_{LM} = \sigma_{inel}\left[f_{nd}A_{nd} + (1-f_{nd})f_{sd}A_{sd} + (1-f_{nd})(1-f_{sd})A_{dd}\right]$$



Luminosity Constant Uncertainty

Source	Uncertainty
Inelastic Cross Section	±1.91 mb
Single Diffractive Fraction	±0.43 mb
Time Variation / Radiation Damage	±0.24 mb
GEANT Energy Cutoffs	±0.24 mb
Monte Carlo Material Model	±0.16 mb
Light Collection / Radiation Damage	±0.09 mb
North / South Difference	±0.08 mb
Luminosity Dependence	±0.08 mb
Monte Carlo Statistics	±0.06 mb
PDF Choice	±0.06 mb
Pythia Tune	±0.04 mb
Background Unfolding	±0.03 mb
GEANT Hadronic Model	±0.03 mb
Seasonal Timing Variation	±0.02 mb
Charge Threshold	±0.01 mb

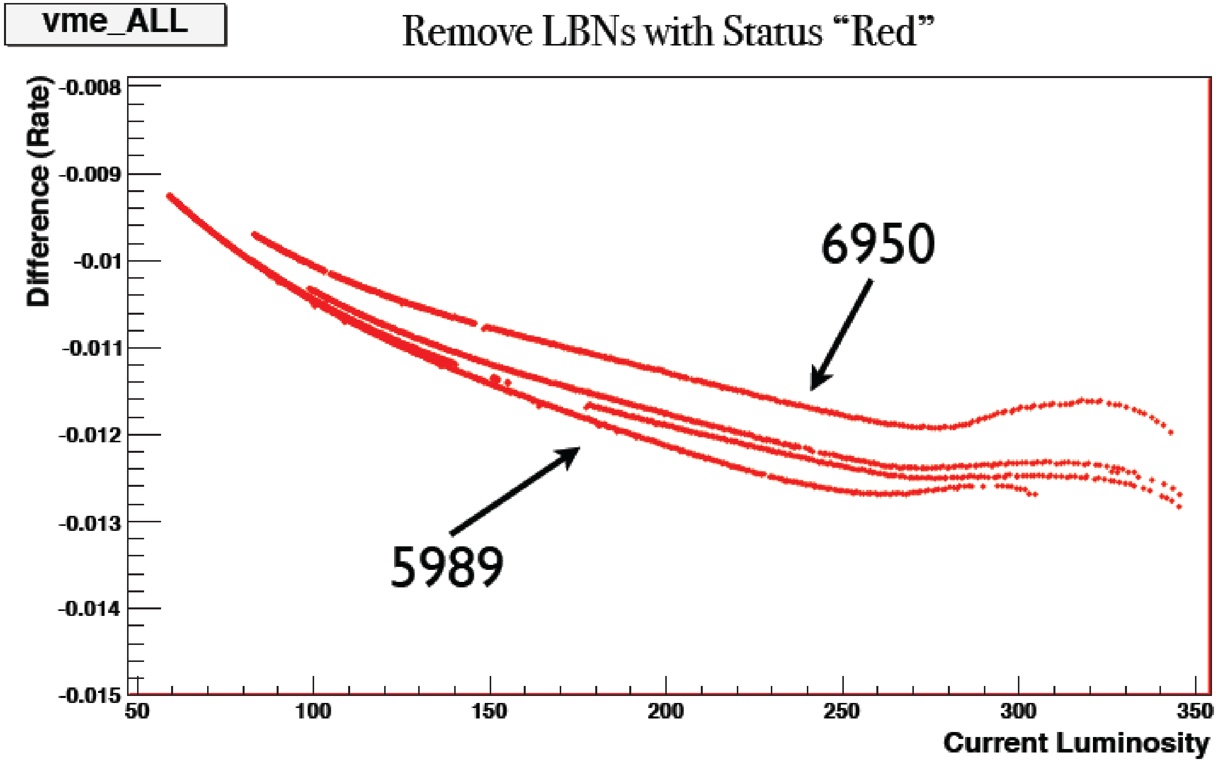
σ_{LM} = 48.3 ± 2.0 mb (4.2% relative error)

Top 5 Uncertainties

- Inelastic cross section – 1.91 mb
  - Set by CDF / DØ agreement on to average CDF / E811 cross sections
- Single diffractive fraction – 0.43 mb
  - Single diffractive fraction varied by 0.57 ± 0.21 (same as 2a analysis)
  - Provides substantial, but not implausible, variation in σ_{sd}
- Time variation / Radiation Damage – 0.24 mb
  - Assign an 0.5% uncertainty due to time-variation in lumi measurement
  - Periodic PMT high voltage changes made to compensate for radiation damage change luminosity by <0.5%
- GEANT energy cutoffs – 0.24 mb
  - Effect of running the MC with lower energy cutoffs
- Monte Carlo material model – 0.16 mb
  - Effect of changing beam pipe material from Beryllium to Tin
- All other systematic errors < 0.1 mb

Change in Measured Luminosity

- Using Run 2b Luminosity Constant for Run 2b data reduces measured luminosity by 0.6%
- Improved background subtraction reduces measured luminosity by an additional 0.3% - 0.7%



Run 2b Luminosity Constant Summary

- The Run 2b Luminosity Constant is found to be:

$$\sigma_{LM} = 48.3 \pm 1.9 \pm 0.6\,\text{mb} \;\; (\text{Run 2b})$$

  - 1st error correlated with CDF; 2nd error specific to DØ measurement
- Total uncertainty decreased from 6.1% to 4.2%
  - DØ-specific uncertainty decreased from 4.6% to 1.3%
- Implementation of the new Luminosity Constant and improved background treatment reduce the DØ luminosity measurement by 0.9% - 1.1%
- Stability of DØ luminosity estimated to be ±0.5%
  - PMT HV changes and scintillator replacement compensate for radiation damage and PMT aging
  - Stability checked by measurements of forward muon yield, HV and threshold scans, and cross check with alternative luminosity measures