The Run II DØ Calorimeter Electronics Upgrade and its Performance

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for the DØ Collaboration

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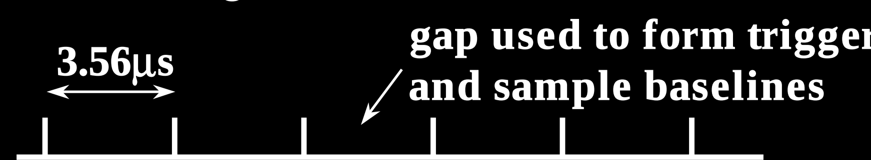
Tevatron Run II

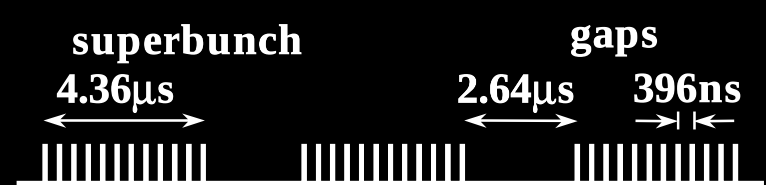
- Successful Run I (1992-1996)
- Run II upgrade
  - $\sqrt{s}$: 1.8 TeV $\rightarrow$ 1.96 TeV
  - Luminosity plans to FY2009:

    4.4 fb^{-1} (base) – 8.6 fb^{-1} (design)

    Run I delivered luminosity ~ 120 pb^{-1}
  - Bunch structure: smaller bunch crossing time



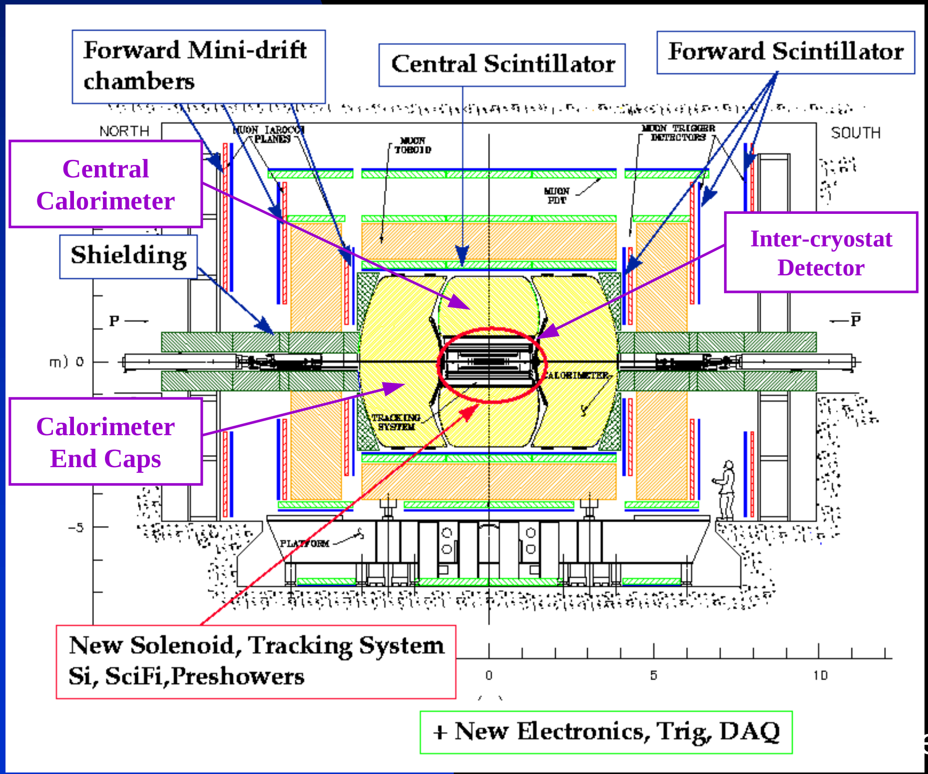
Run I 6x6



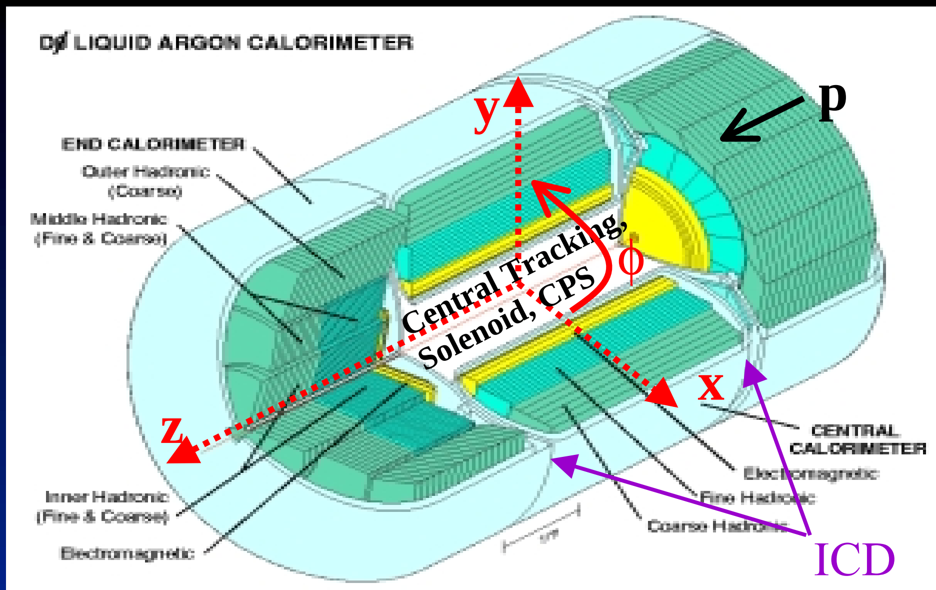
Run II 36x36

DØ Upgrade

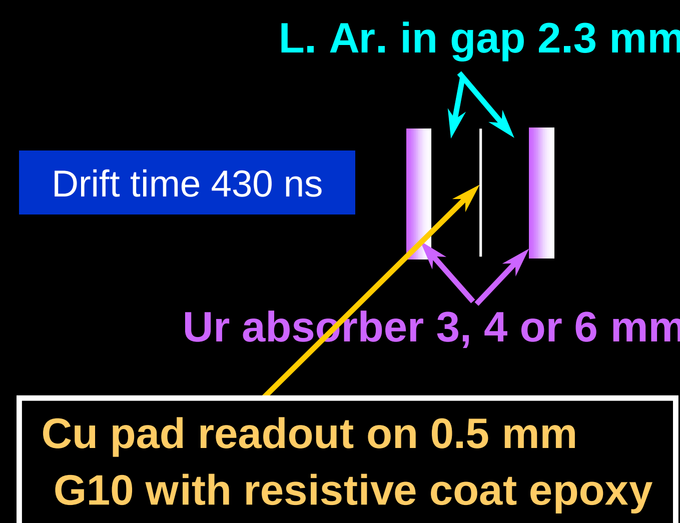
- Upgrade Calorimeter readout electronics
- Silicon and Fiber tracker with 2T solenoid magnetic field for central tracking and momentum measurement
- Add Preshower detectors
- Add scintillator detector in muon system for faster trigger
- Pipelined 3-level trigger and new Data Acquisition system



Calorimeter Overview



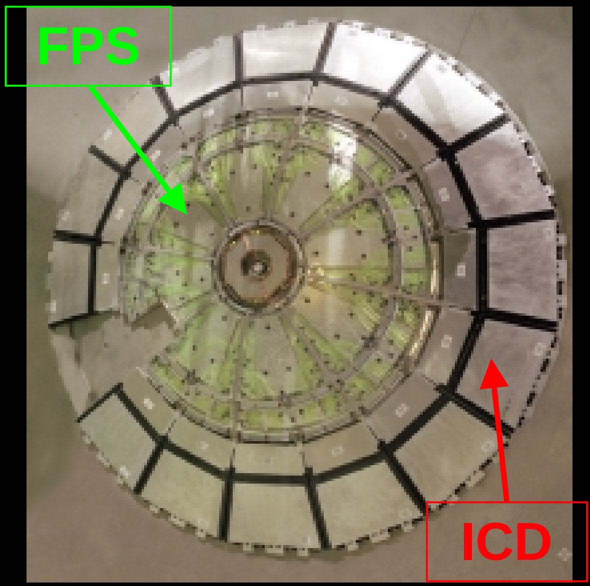
- Liquid argon sampling
  - Stable, uniform response, rad. hard, fine spatial seg.
  - L. Ar. purity important
- Uniform, hermetic with full coverage
  - $|\eta| < 4.2$ ($\theta \approx 2°$), $\lambda_{int} > 7.2$ (total)
- Uranium absorber (Cu or Steel for coarse hadronic)
  - Compensating e/π response, dense $\Rightarrow$ compact
- Run I Energy Resolution (from test beam)
  - e: $(\sigma_E/E)^2 = (15\%)^2/E + (0.3\%)^2$ (e.g. 3.4% @ 20 GeV)
  - π: $(\sigma_E/E)^2 = (45\%)^2/E + (4.0\%)^2$ (e.g. 11% @ 20 GeV)



Intercryostat Detector (ICD)

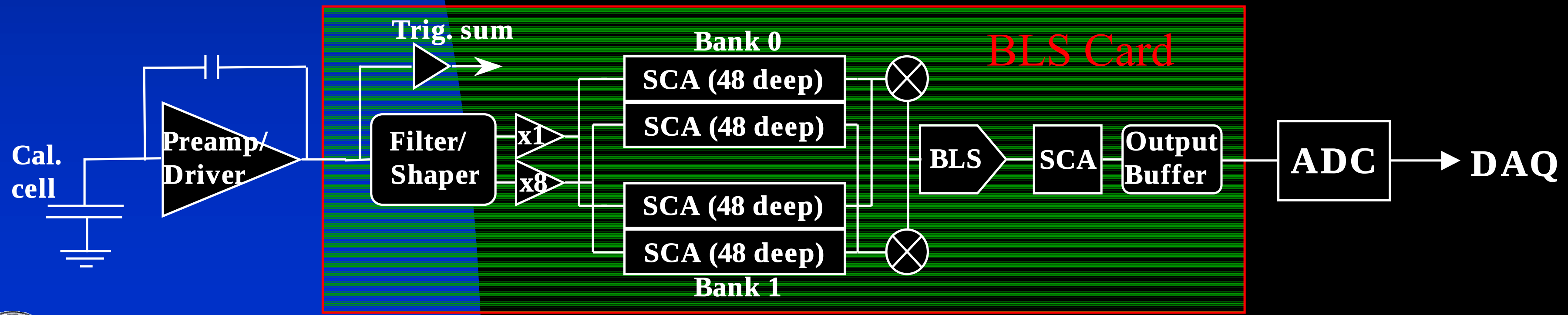
- Objectives
  - Improve coverage for the region $1.1 < |\eta| < 1.4$
  - Improve jet energy and missing energy
  - Maintain the performance in the presence of a magnetic field and additional material
- Design
  - Scintillator based with phototube readout similar to Run I design. Re-use existing PMT's.
  - 16 *supertile* modules per cryostat with a total of 378 scintillator tiles
  - WLS fiber read out of scintillator tiles
  - Clear fiber light piping to region of low field

    ~ 40-50% signal loss over 5-6m fiber
  - Readout/calibration scheme for electronics same as for L. Ar. Calorimeter but with adapted electronics and pulser shapes
  - LED pulsers used for PMT calibration
  - Relative yields measured > 20 p.e./m.i.p.



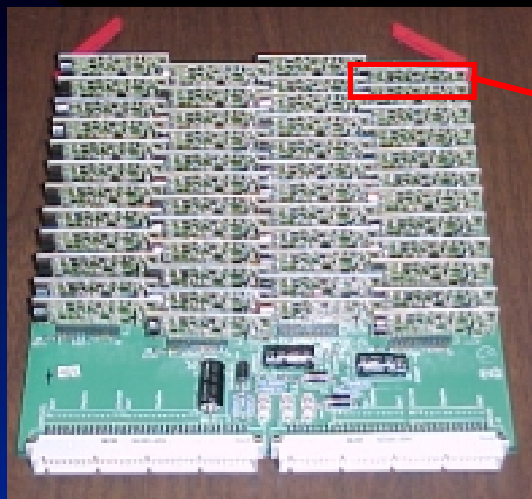
Upgrade of Calorimeter Readout

- Objectives and performance criteria
  - Accommodate reduced minimum bunch spacing from 3.56 μs to 396 ns
  - Storage of analog signal for 4 μs for L1 trigger formation
  - Generate trigger signals for Calorimeter L1 trigger
  - Maintain present level of noise and pile-up performance
- Update for 55,000 readout channels
  - Replace signal cables from cryostat to preamps (110Ω → 30Ω for impedance match)
  - Replace preamplifiers, shapers, baseline subtraction circuitry (BLS)
  - Add analog storage (48-element deep Switched Capacitor Array (SCA))
  - Replace timing and control system
  - Replace calibration system (new calibration pulser + current cables)
  - Keep Run I ADCs, crates and most cabling to minimize cost and time

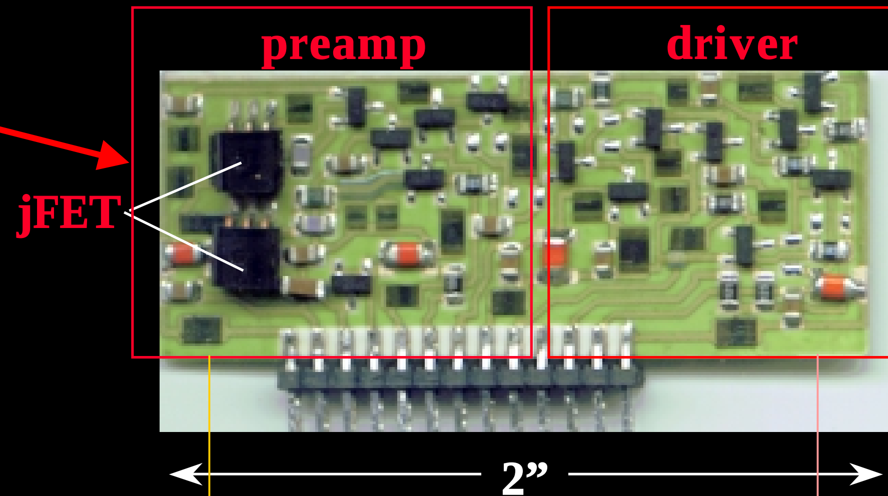


Preamplifier

1152 boards



55296 hybrids



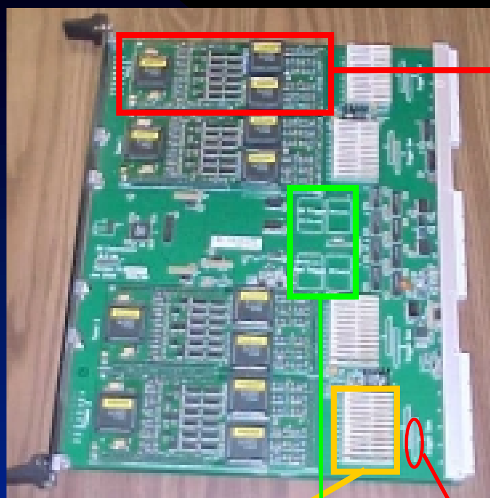
- New calorimeter preamp
  - Hybrid on ceramic, 14 species + 1 for ICD
  - 48 preamps on a motherboard
  - New low-noise switching power supplies in steel box

Similar to Run I version except
- Dual jFET front-end
- Compensation for detector capacitance
- Faster recovery time

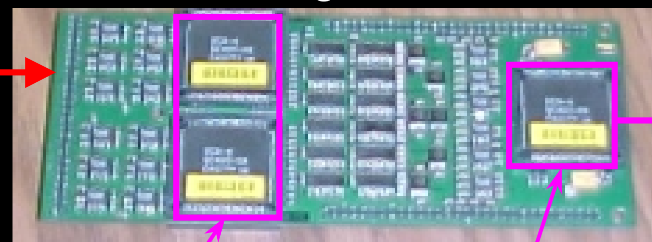
New output driver for terminated signal transmission

BLS and SCA

1152 BLS boards



4608 daughter-cards



23040 SCAs

L1 SCAs (2+2) L2 SCA

Array of 48 capacitors to pipeline calorimeter signals

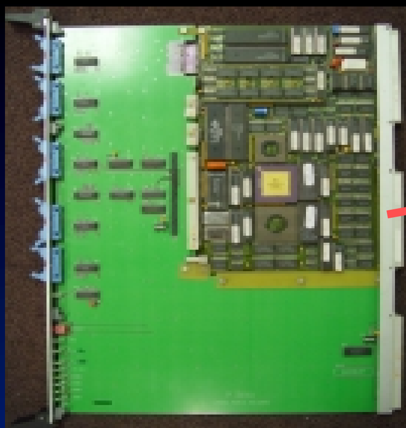
Shaper

Trigger Summers

Trigger Drivers

- ADCs have 12-bit dynamic range. To achieve 15-bit dynamic range, SCAs have low and high gain path for each readout channel ($\times 8/\times 1$).
- SCAs are not designed for simultaneous read/write operations. Two banks of SCAs, upper and lower, for alternate read/write operations.
- No dead time for L1 trigger rate of 2-5 kHz.
- Readout tower of 0.1×0.1 in $\Delta\eta\times\Delta\phi$, trigger tower formation 0.2×0.2 in $\Delta\eta\times\Delta\phi$ for Level 1.

Electronics Calibration System



Pulser Interface: configuration management

PIB

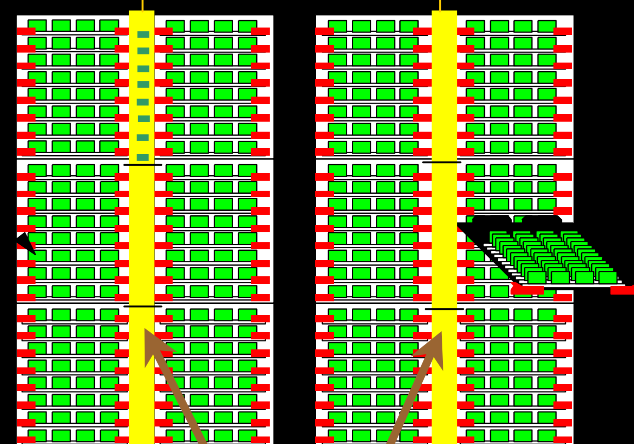
Trigger

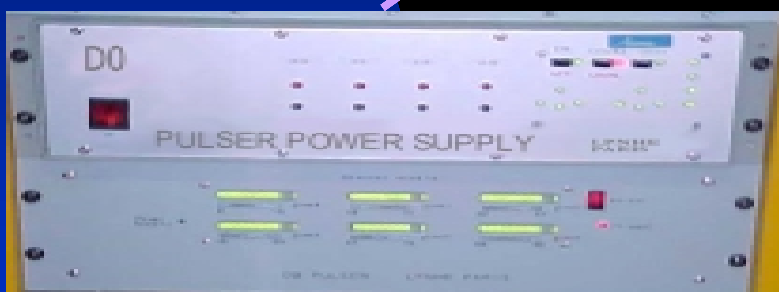
Pulse controller (Pulser)

6 commands (3×2)
96 currents

Preamp box

Preamp board



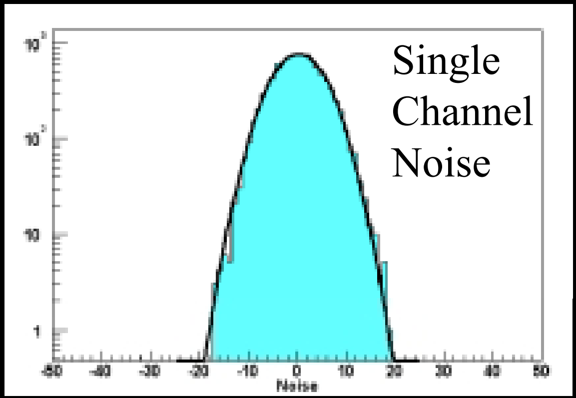


12 Pulsers deliver:
continuous current ∝ pulse height
command determines pulse start

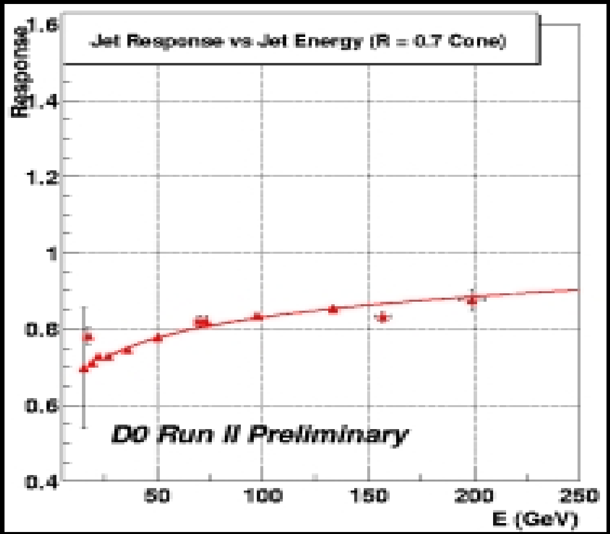
6 active Fanouts with 16 switches: inductances form the pulse shape

Calorimeter Calibration (1)

- Online calibration
  - Pulse shape measurements
  - Liquid argon purity
  - Reflection (impedance) measurements
  - Timing corrections
  - Debugging and noise studies
  - Linearity measurements and corrections
- Offline calibration
  - Data quality control
  - Trigger performance
  - ϕ inter-calibration
  - Absolute EM scale from W/Z, J/ψ and Υ events
  - Electron ID, Jet ID and missing E_T
  - Energy flow jet algorithm – track-calorimeter combination
  - Jet Energy Scale

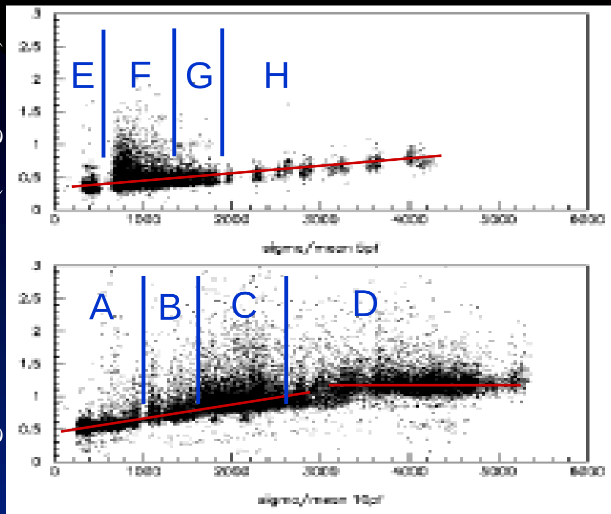


Noise of a single channel fitted with Gaus.



Calorimeter Calibration (2)

Sigma × 100 / Mean (for gain ×8)



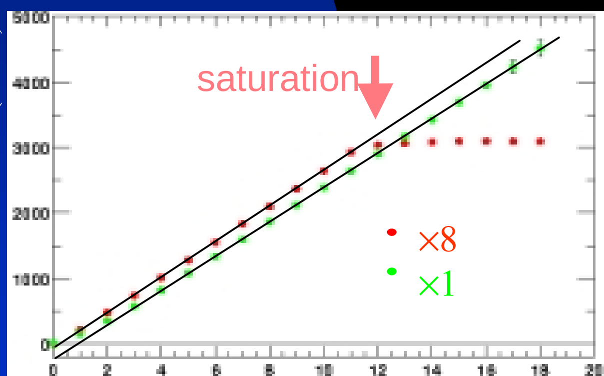
Calorimeter cell capacitance (pF)

Noise w.r.t. cell capacitance (for different Preamp species)

Preamp types E-H (5 pF feedback cap.)

Preamp types A-D (10 pF feedback cap.)

Electronics readout (ADC)

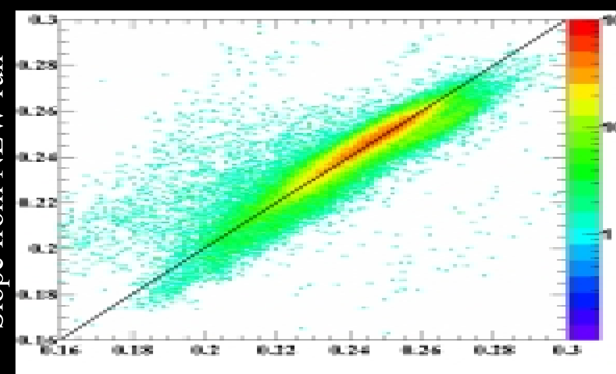


Pulse height (DAC/1000)

Linearity measurement

Slope

Slope from NEW run

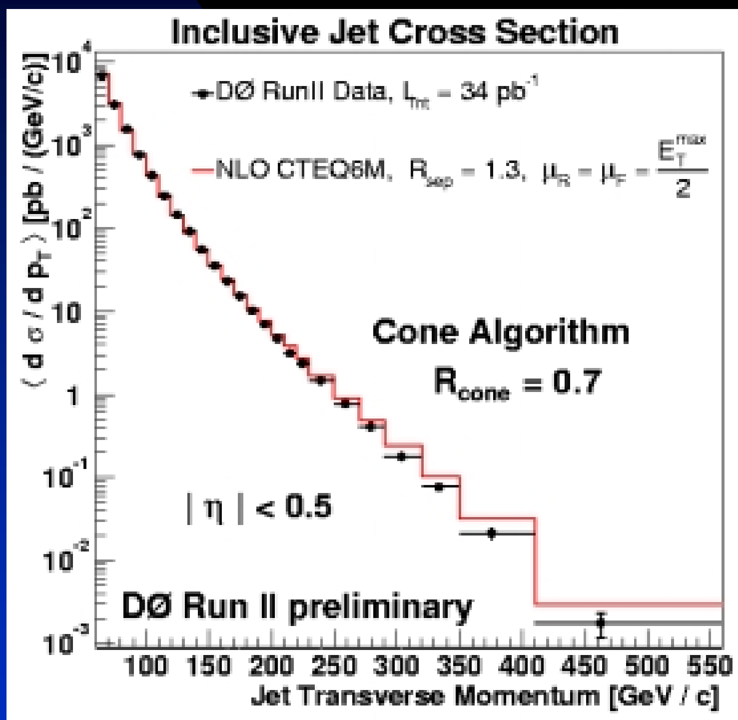


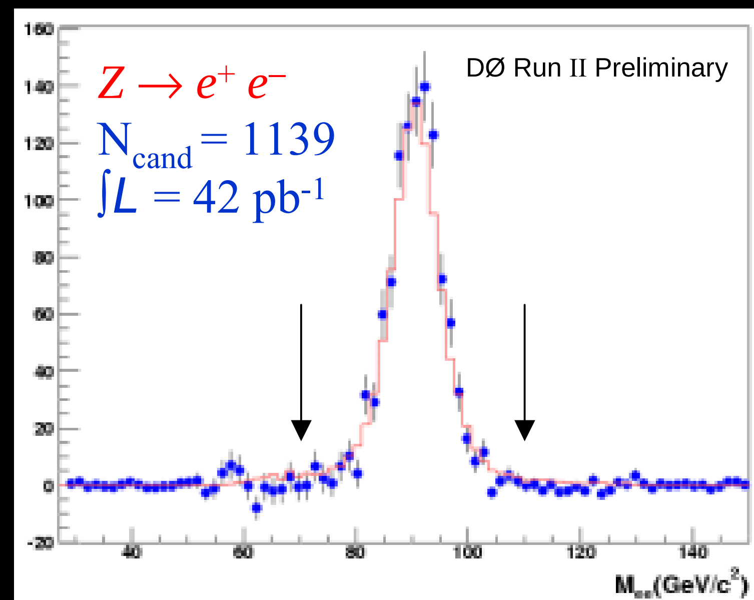
Slope of gain ×1 from OLD calibration run

Compare two runs taken 1 year apart ⇒ Linearity is stable.

Physics Results

- Preliminary results using Run II DØ calorimeter data have been shown at conferences, including QCD, Electroweak, B, Higgs, Top and New Phenomena physics.





$\sigma_Z \times Br(Z \to e^+e^-) = 275$
± 9 (stat) ± 9 (syst) ± 28 (lumi) pb

- Upgraded calorimeter performs well. We have about 200 pb^{-1} data.

There are a lot more to come!

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