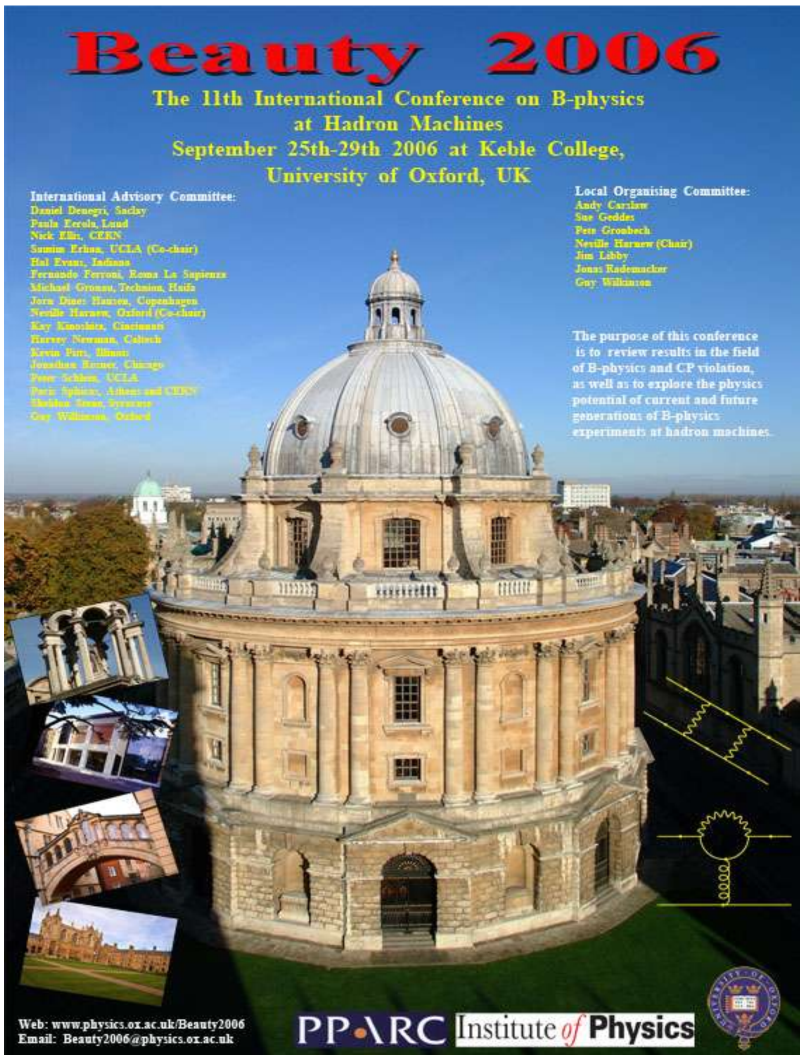
B-Physics & Trigger at the DØ experiment
- operational experience



Daniela Bauer
for the DØ collaboration

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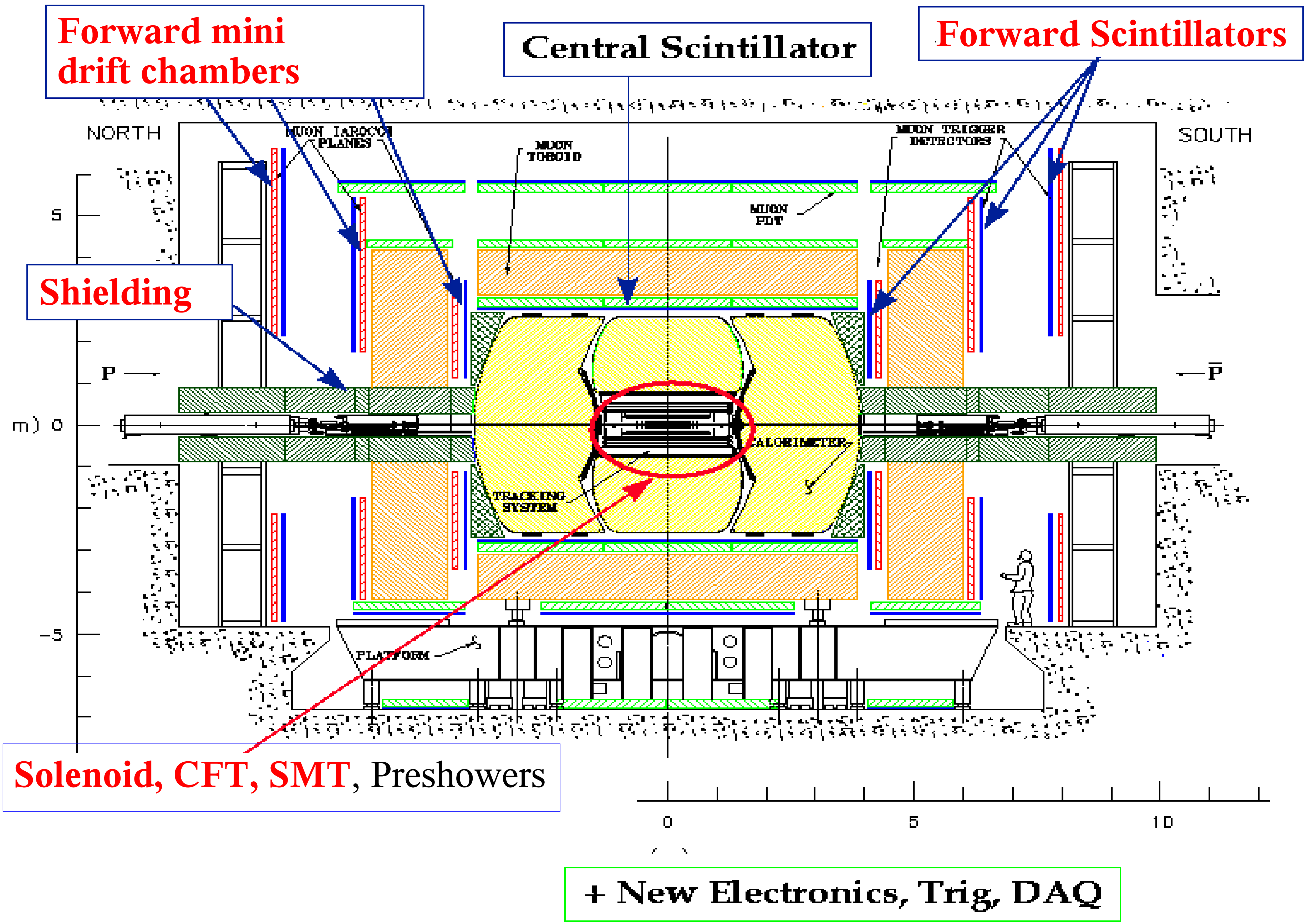
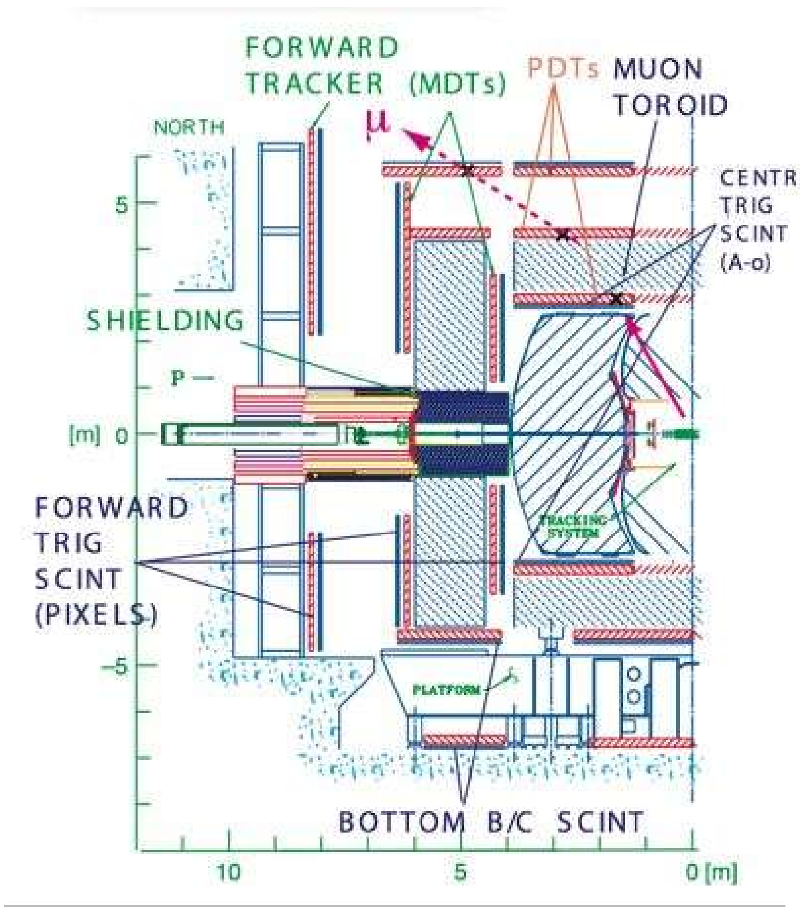
Overview

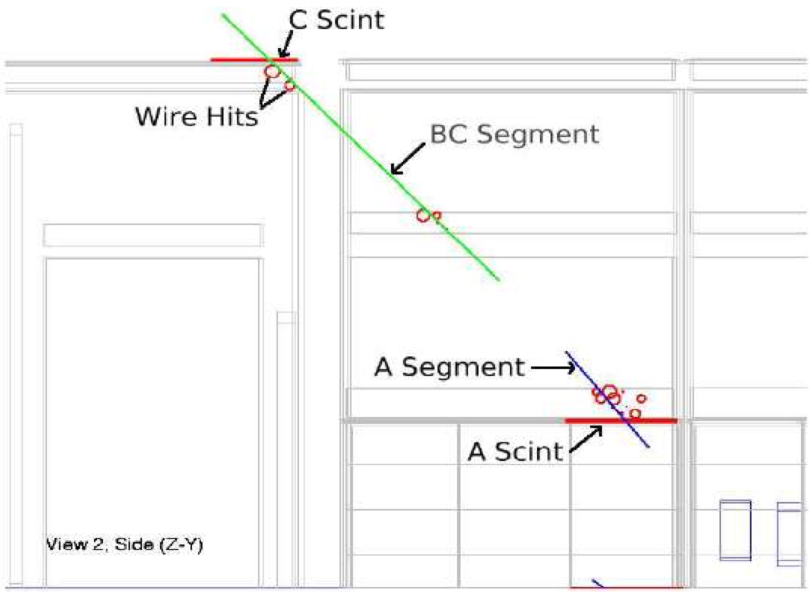
- Detector
  - RunIIa detector.
  - RunIIb: High luminosity challenges.
- Triggers
  - Strategy: Doing *b*-physics at a multi-purpose detector.
  - Trigger system.
  - *B*-Physics triggers.
- Summary

The upgraded DØ Detector



Muon system





Main features:

- 3 layers of drift tubes.
- 3 layers of scintillators: triggering, improved resolution in wire direction, rejection of cosmics
- Toroid magnet (1.8 T) after the first layer: local p_T measurement (trigger).
- Toroid and solenoid polarities reversed on regular basis.
- Track matched muons up to $|\eta| < 2.2$

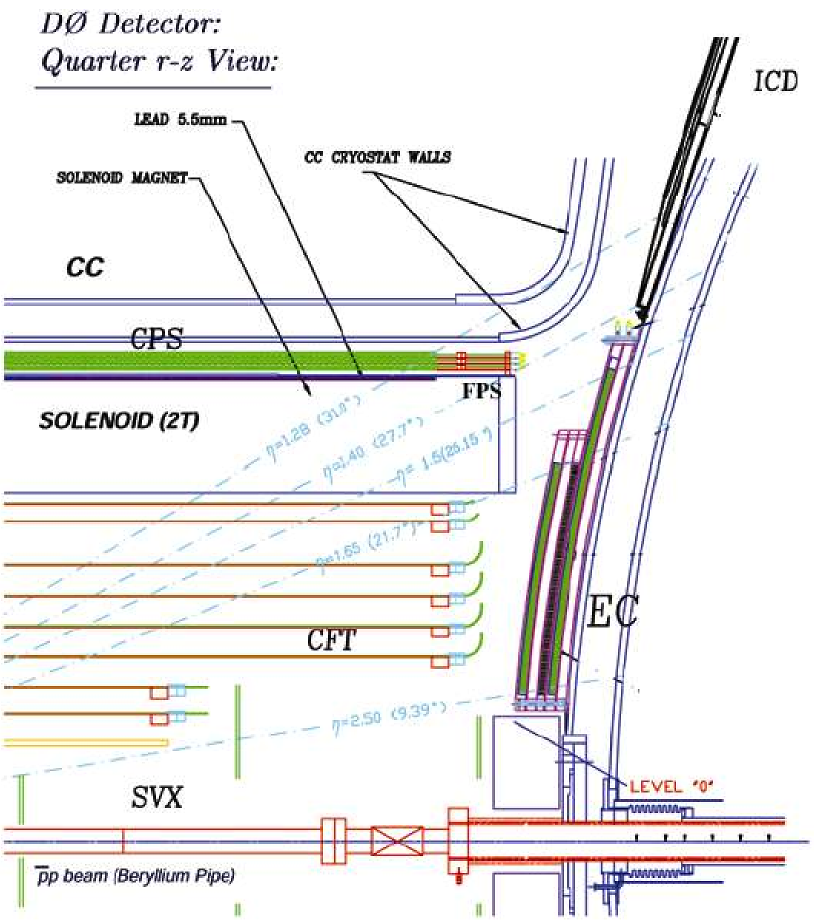
Central Fiber Tracker (CFT)

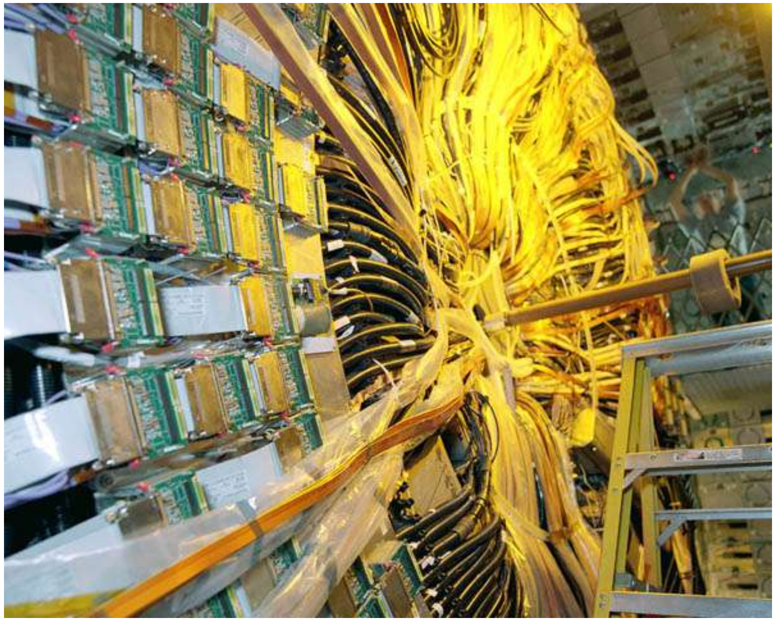
16 doublet layers of scintillating fibers, arranged in 8 superlayers

Radius 20 – 52 cm

Track reconstruction up to |η| < 2.0

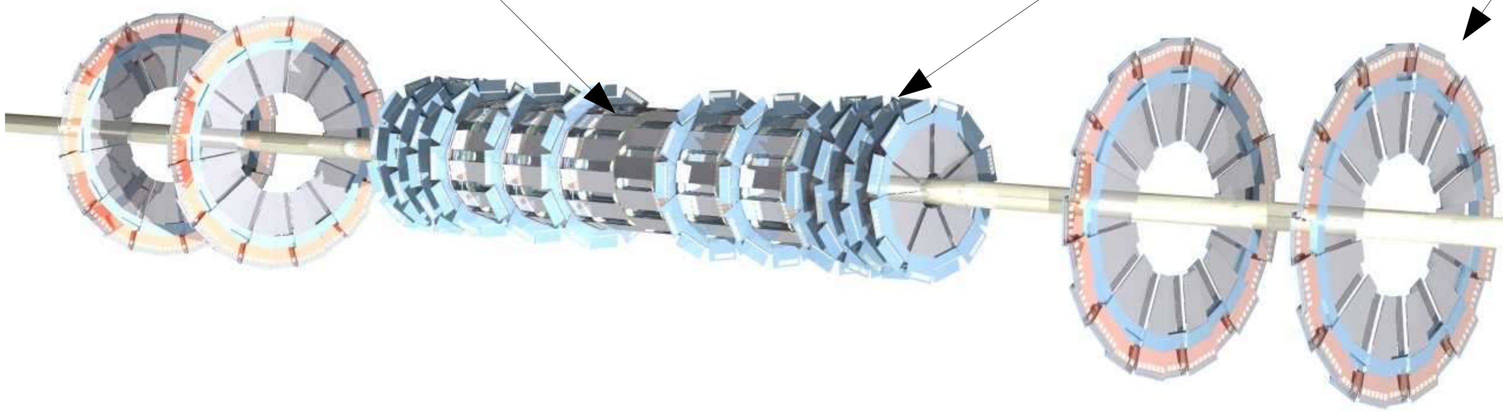
CFT standalone used for triggering at lowest trigger level.





Silicon Microstrip Tracker (SMT)

Hybrid design: 6 barrels with 8 layers (+ Layer 0), 12 F-Disks, 4(2) H-Disks



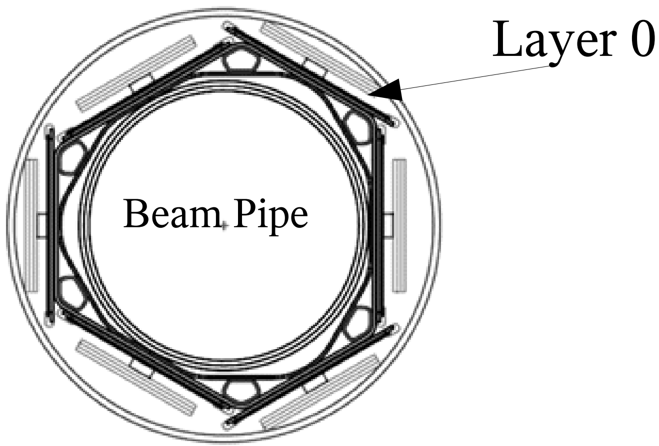
Essential for *b*-physics trigger *and* analysis:

Tracking, primary and secondary vertex reconstruction, impact parameter.

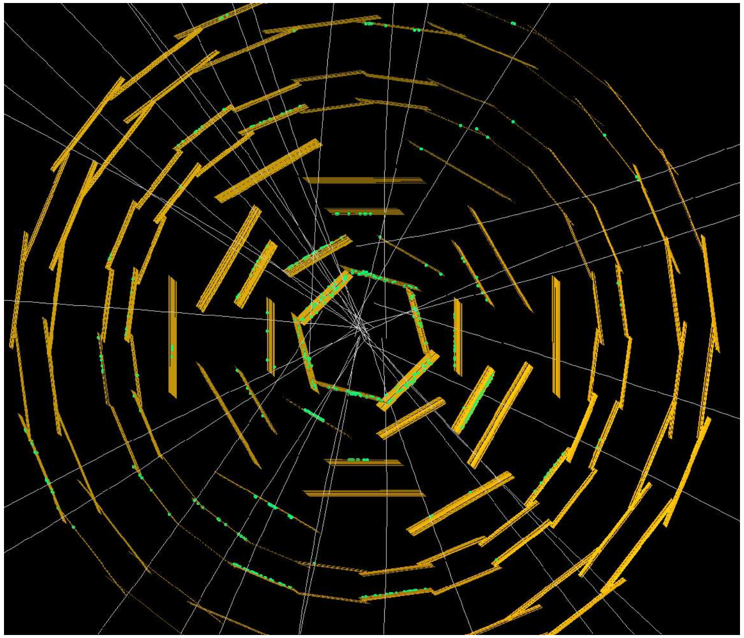
Design provides tracking up to $|\eta| < 3.0$, but

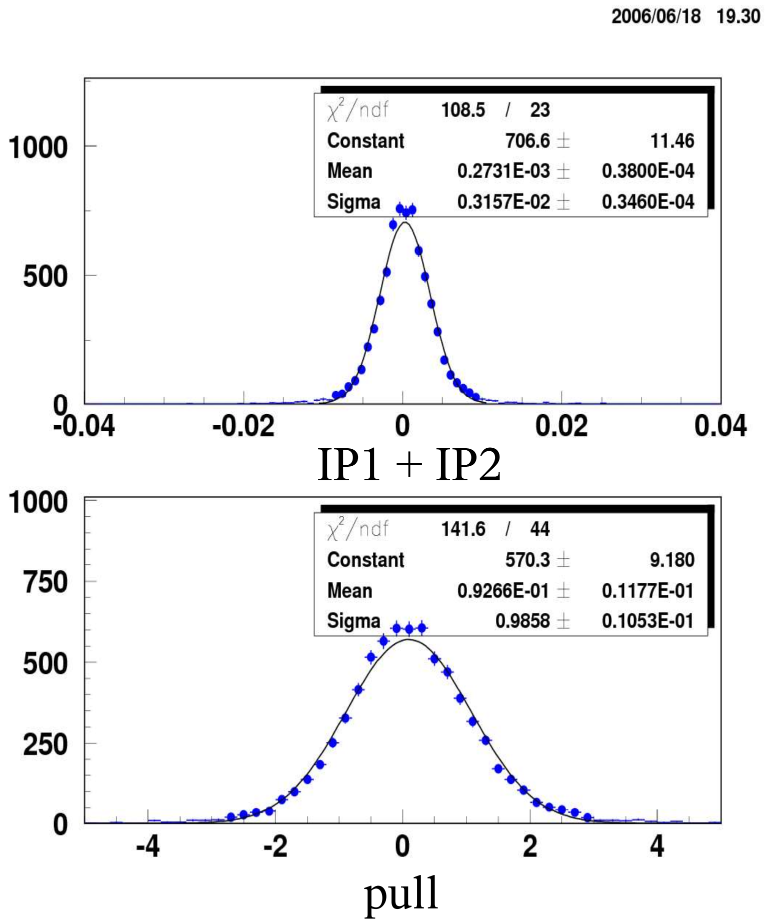
- Most analyses also require tracks to have hits in the CFT.
- H-disks had high rate of failure, most forward disks have now been decommisioned to make room for Layer 0 readout cables.

Silicon Microstrip Tracker Layer 0



30% improvement in impact parameter resolution vs RunIIa → great news for *b*-physics





Impact parameter resolution from cosmics: 21 μm

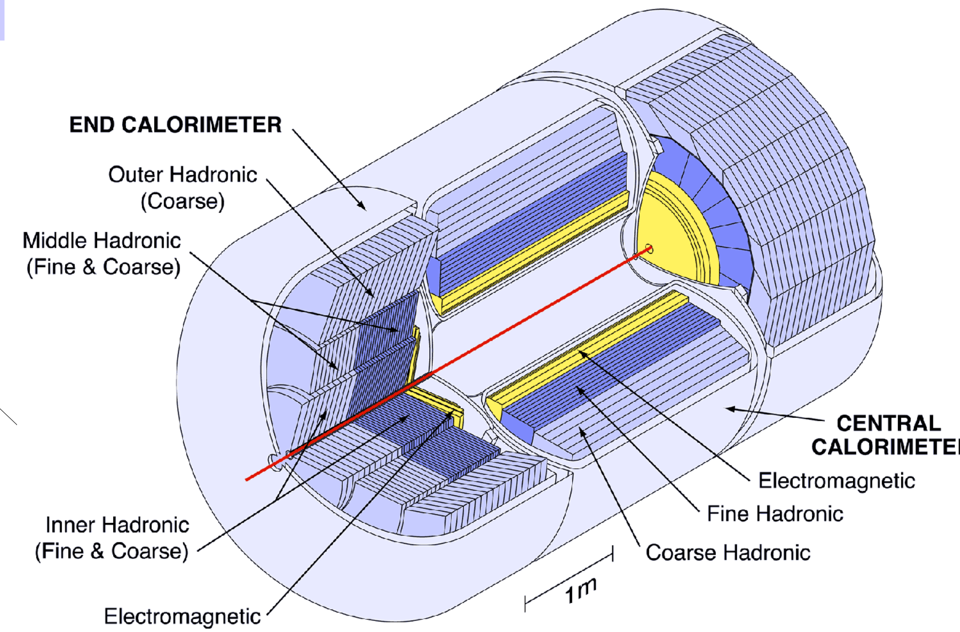
Commisioned and up and running.

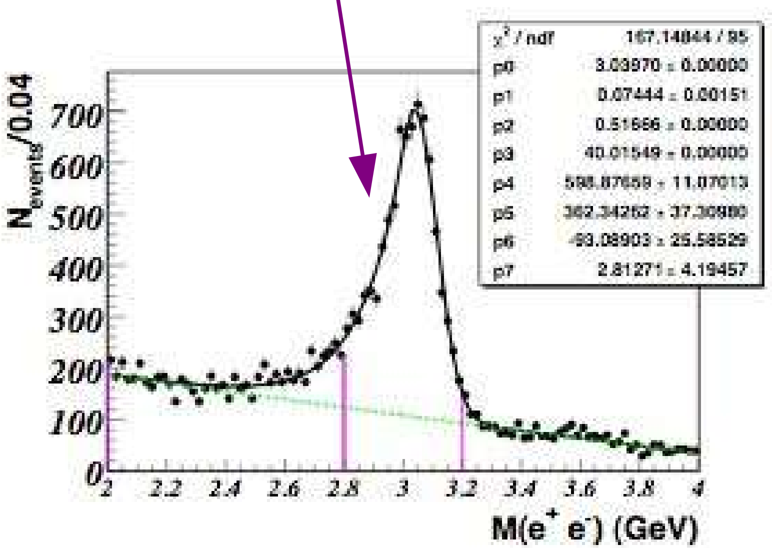
Calorimeter

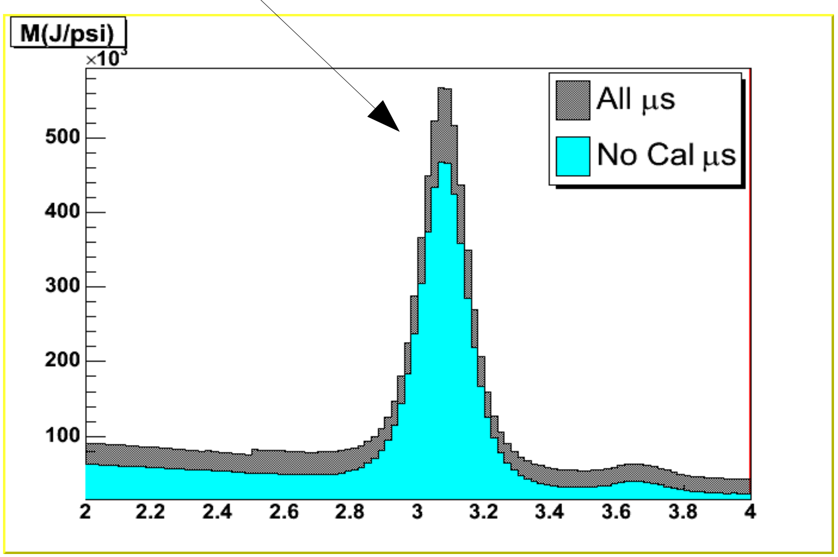
Designed for high p_T physics, but

- Muons reconstructed in calorimeter enhance J/ψ signal by 10%
- Low p_T electrons used in tagging

$$\varepsilon D^2(\mu) = 1.48\%$$
$$\varepsilon D^2(e^-) = 0.21\%$$

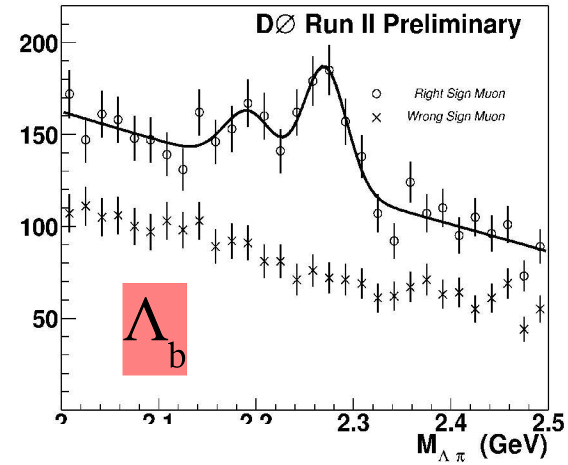


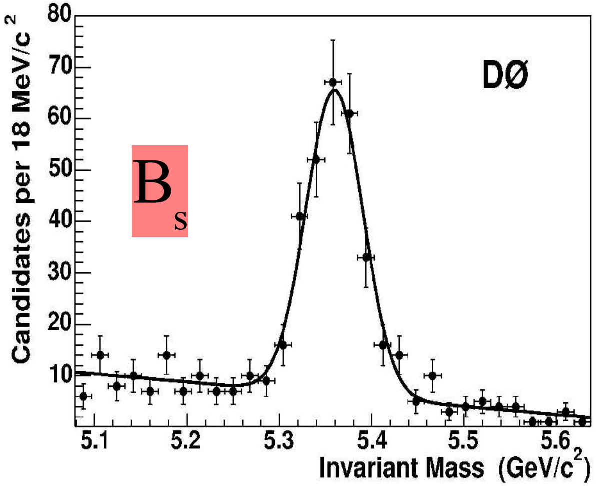


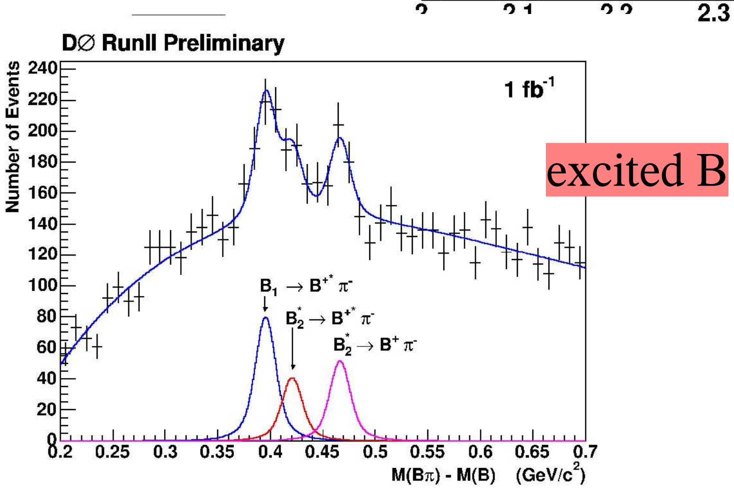


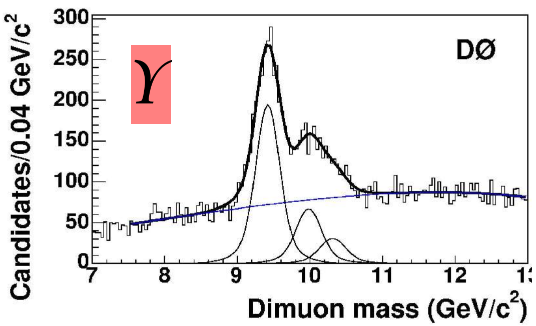
Results

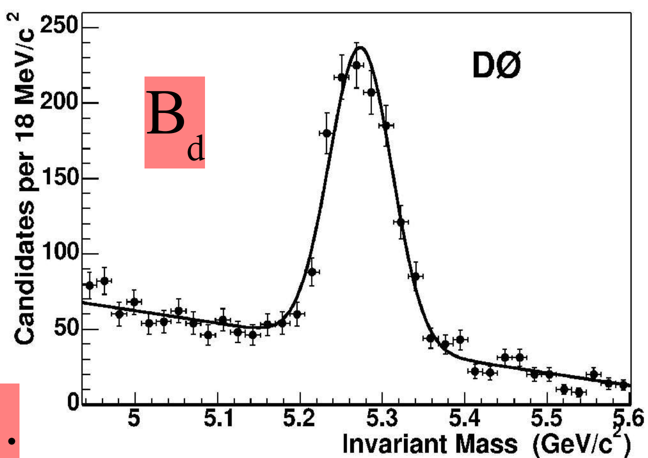
With this detector we have seen all sorts of *b*.....

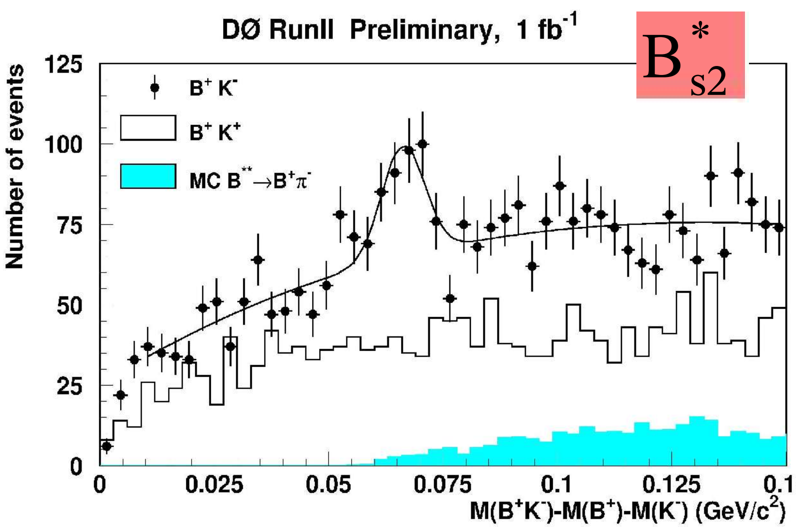












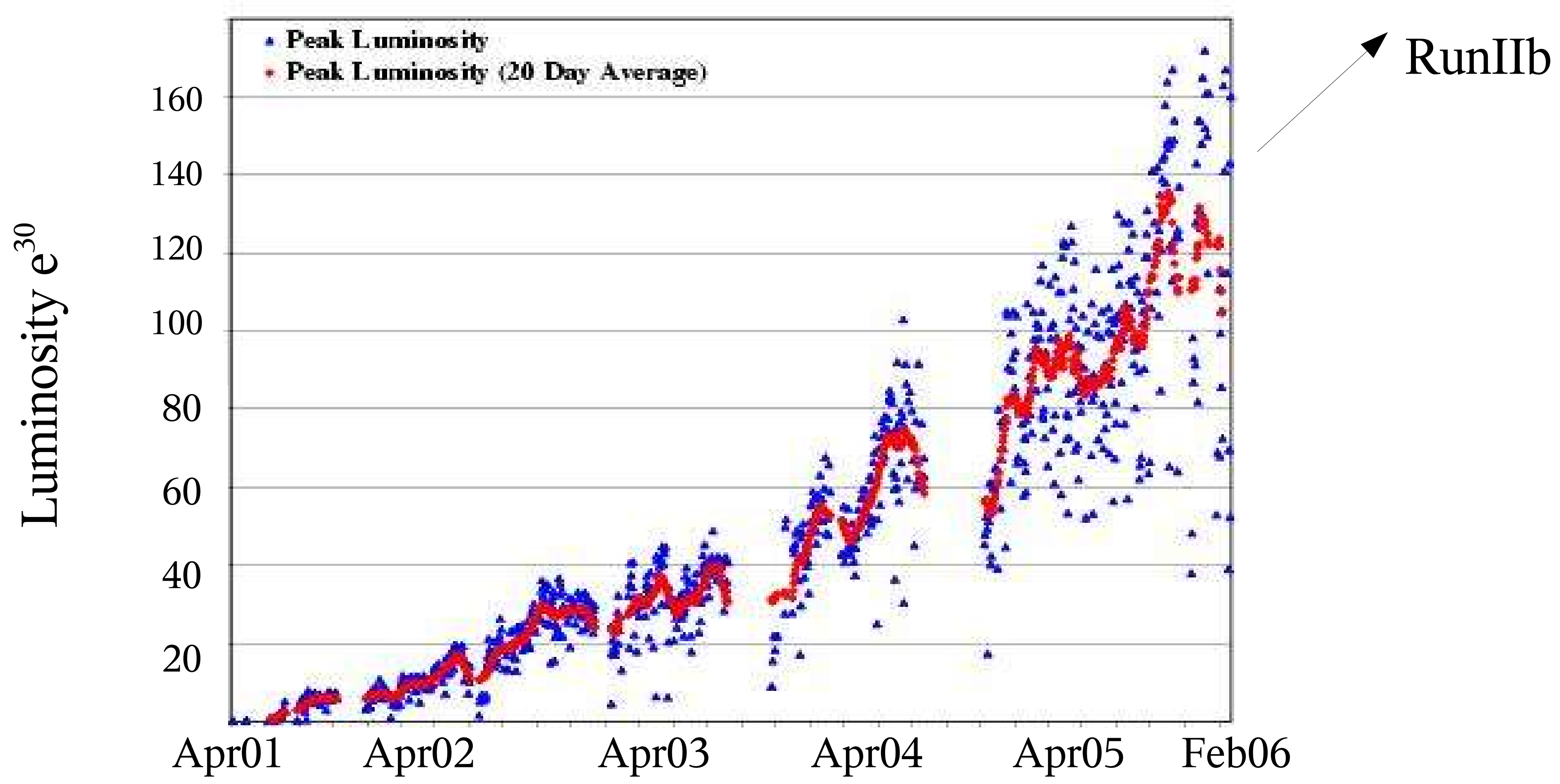
+ B^+, B_c, X(3872), ...

DØ *b*-physics publications

- Search for the Rare Decay $B_s \rightarrow \Phi\mu^+\mu^-$ with the DØ Detector, PRD 74, 031107 (2006)
- Direct Limits on the B_s Oscillation Frequency, PRL 97, 021802 (2006)
- Measurement of the Upsilon differential cross section..., PRL 94, 232001 (2005)
- Measurement of the ratio of B^+ and B^0 meson lifetimes, PRL 94, 182001 (2005)
- Measurement of the Λ_b lifetime in the decay $J/\psi\ \Lambda$ decays..., PRL 94, 102001 (2005)
- A search for the flavour-changing neutral current decay $B_s \rightarrow \mu^+\mu^-$, PRL 94, 071802 (2005)
- Measurement of the B_s lifetime in the exclusive decay channel $B_s \rightarrow J/\psi\ \Phi$, PRL, 94, 042001 (2005)
- Observation and Properties of the X(3872) Decaying to $J/\psi\ \pi^+\pi^-$..., PRL 93, 162002 (2004)
- Measurement of the lifetime difference in the B_s system, PRL 95, 171801 (2005)
- Measurement of semileptonic branching fractions of B mesons to narrow D** states, PRL 95, 171803 (2005)

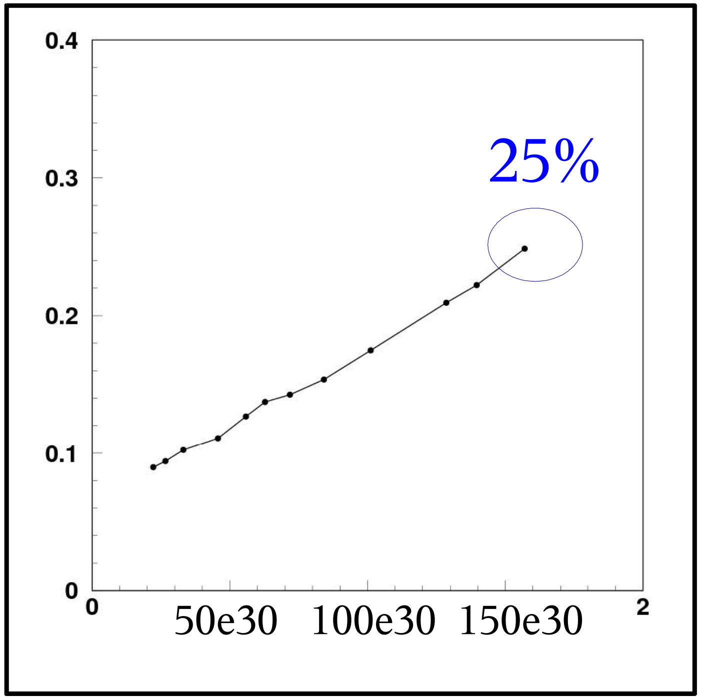
Challenges ahead: Increasing instantaneous luminosity

Peak Luminosities RunIIa



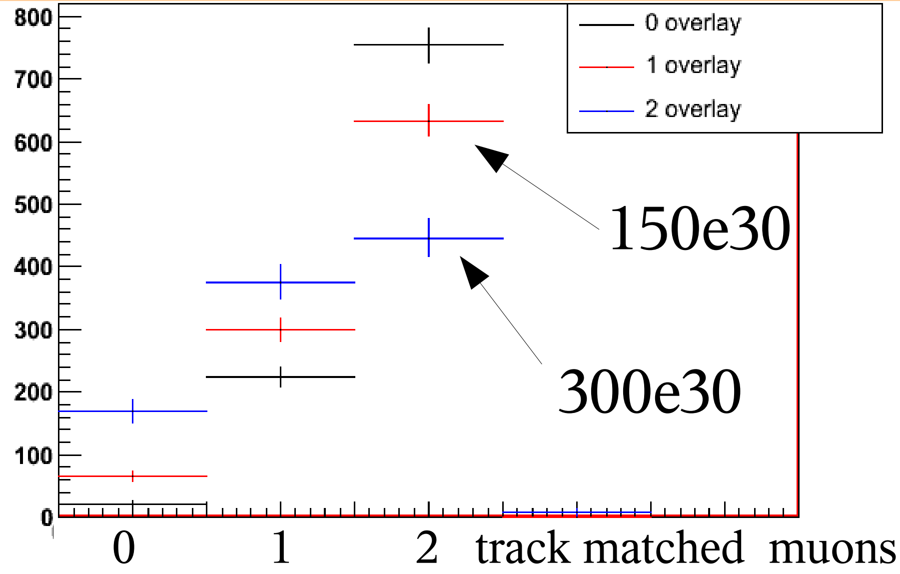
Challenges ahead: Increasing instantaneous luminosity

Occupancy of first Layer in CFT



Predicted effect of high lumi on muon-to-track matching efficiency

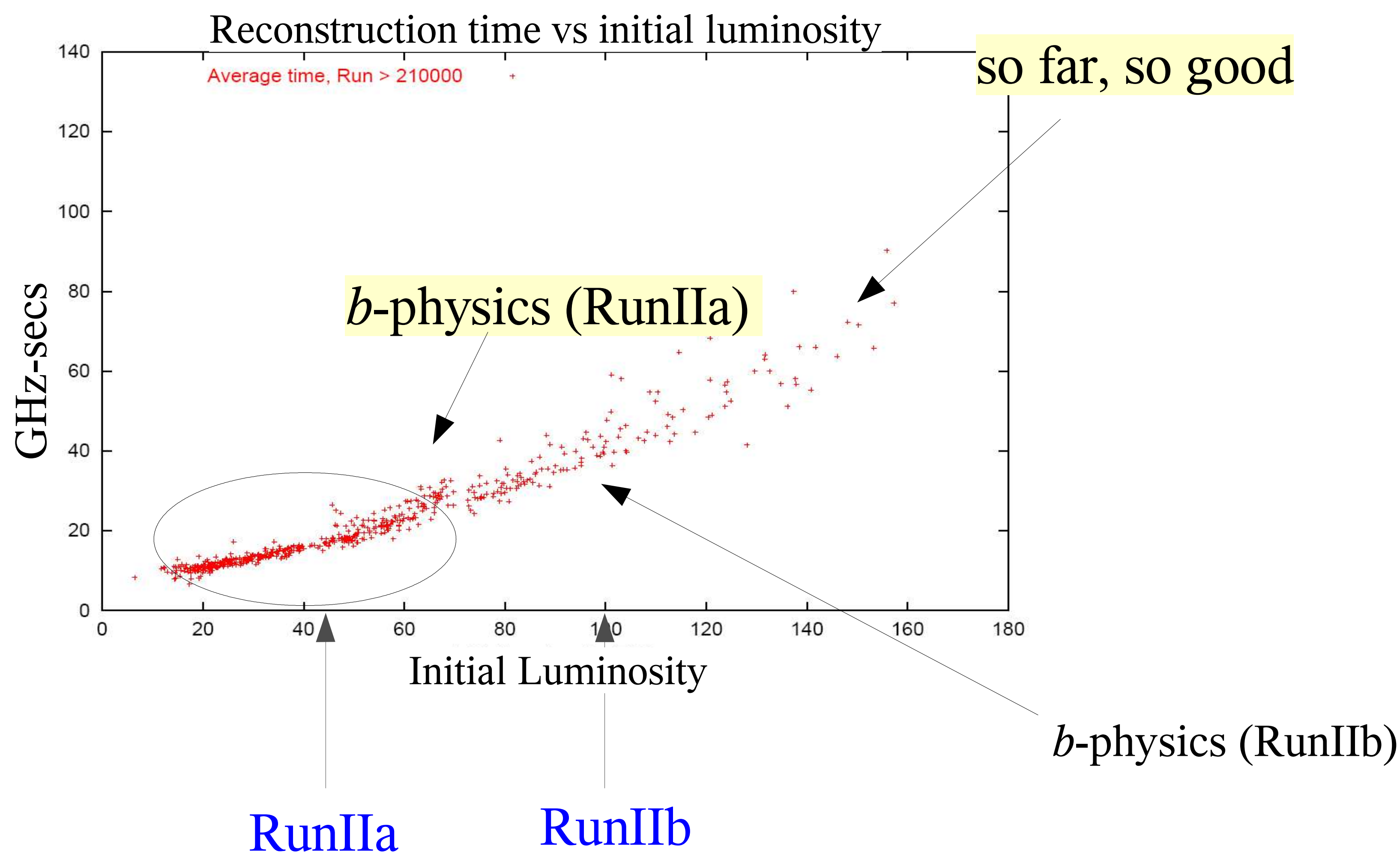
number of track matched muons in a di-muon sample



→ Keep the noise down !
→ AFEII boards

Challenges ahead: Increasing instantaneous luminosity

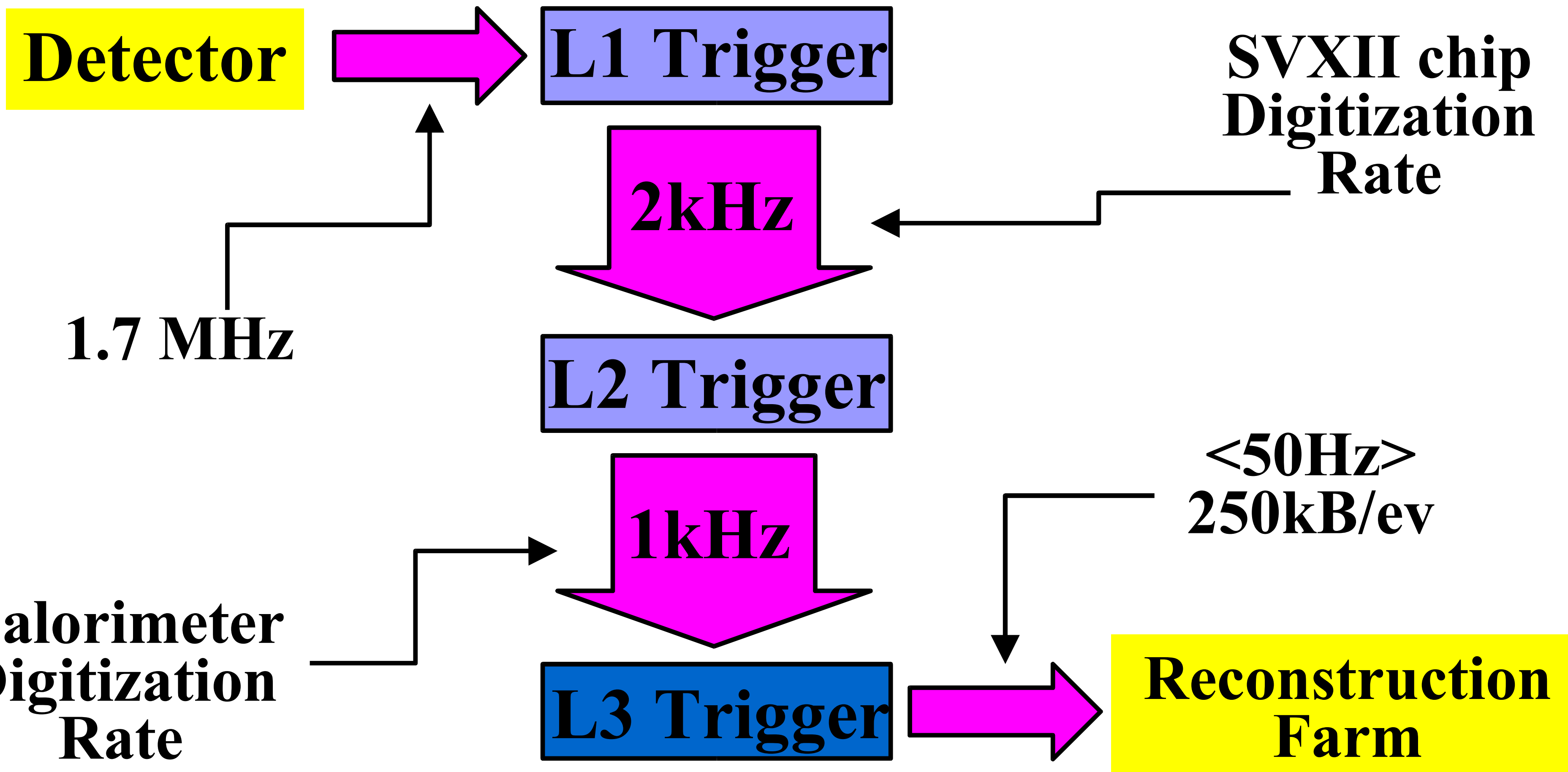
- Reconstruction of the events dominated by track finding.
- The same tracking algorithm has to run at all luminosities !



unbiased single muon triggers prescaled

Triggers

The DØ trigger system



Trigger System: Level 1 & Level 2

Level 1 triggers

Calorimeter: 0.2x0.2 η-φ triggers towers (+E_T)

Central Track Trigger (CTT): uses axial layers of the CFT to find tracks

4 p_T bins

Tracks can be confirmed by muon hits.

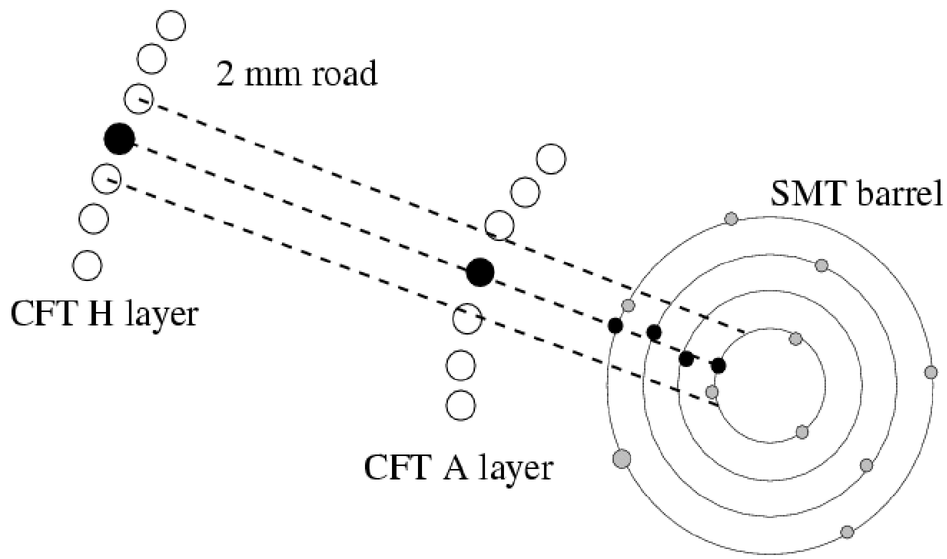
Muon: Looks for hits (wire & scintillator) consistent with muons.

Level 2 triggers

- Refine L1 trigger terms using added event information (e.g. wire and scintillator times for muons).
- Results are combined in a global L2 term.
- Silicon Track Trigger for displaced vertices, improved momentum measurement.

Silicon Track Trigger

- L1 CTT tracks are used to define roads into the SMT.
- SMT hits are clustered in these roads.
- Track is refit within the road.



→ Improved p_T measurement wrt L1.

→ Impact parameter measurement.

Under-used by *b*-physics in RunIIa:

- Impact parameter bias difficult to model/analyze.
- (Planned) late commissioning: Triggers already well established with sufficient rate reduction.
- No displaced track only trigger due to L1 bandwidth limitations.

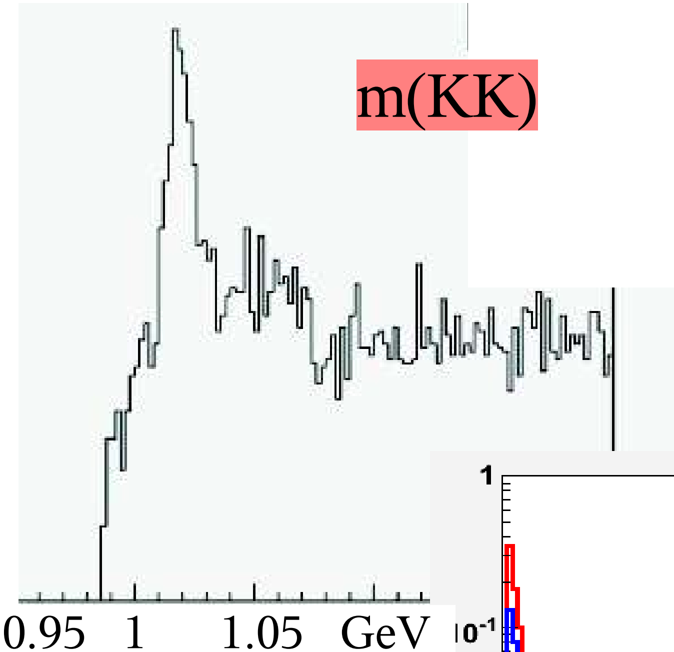
RunIIb: *b*-physics and Higgs group are the main users of the STT.

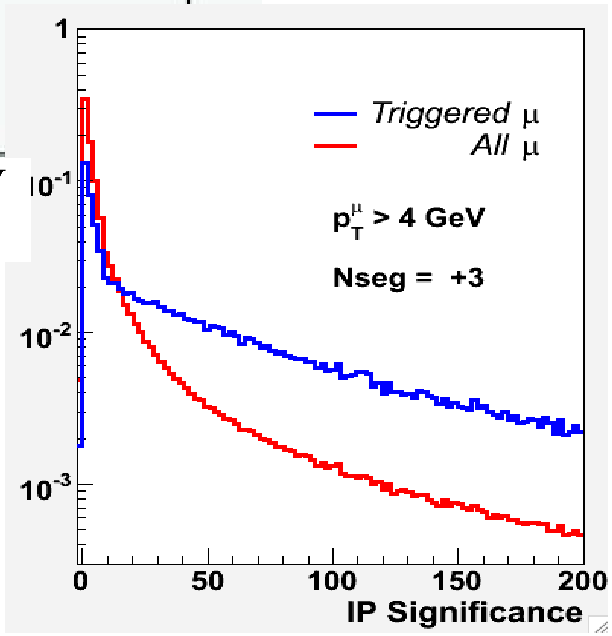
Trigger System: Level 3

• Software based.
• Goal: To perform a (partial) reconstruction of the event.

Tools of the trade:

- muons
- electrons
- tracking
- taus
- jets
- missing E_T
- primary & secondary vertexing
- isolation (muons, electrons)
- impact parameter (tracks, muons)
- invariant mass





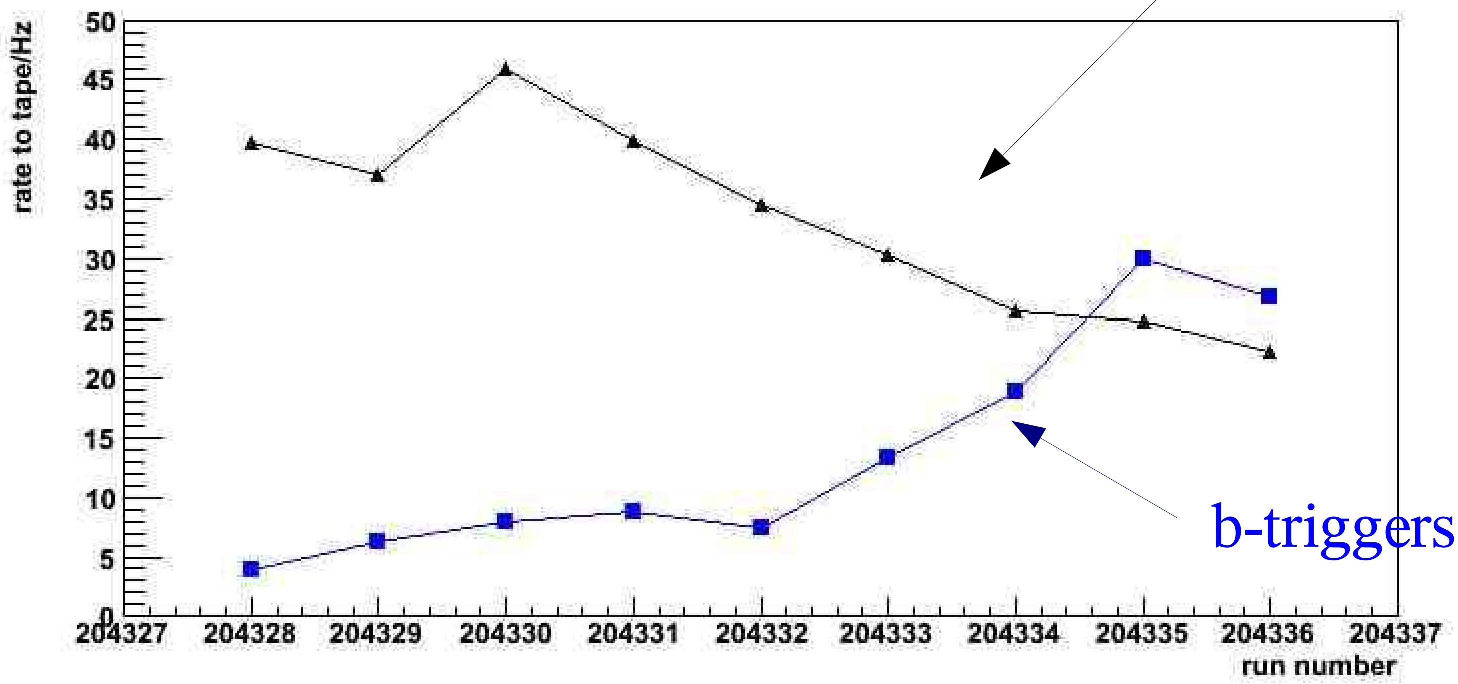
... and almost any combination thereof

Doing b-physics at a multi-purpose experiment

Trigger strategy:
- The trigger menu needs to accommodate all physics groups.
- Most physics aiming for maximum *luminosity* on a given trigger.
- Most *b*-physics needs the maximum of *b-events*.

non b-triggers

Store 4022 March 2005



b-triggers

$100e^{30}$ → $20e^{30}$

b-physics triggers at DØ

In RunIIa there were 3 major groups of *b*-physics triggers:

- single muons, impact parameter unbiased ('low' lumi)
- single muons with impact parameter requirement (all luminosities)
- di-muons (all luminosities)

additionally

- tri-lepton
- electron-muon
- muon+jets

Apart from requiring one or more muons, the *b*-physics triggers also use the following trigger requirements:

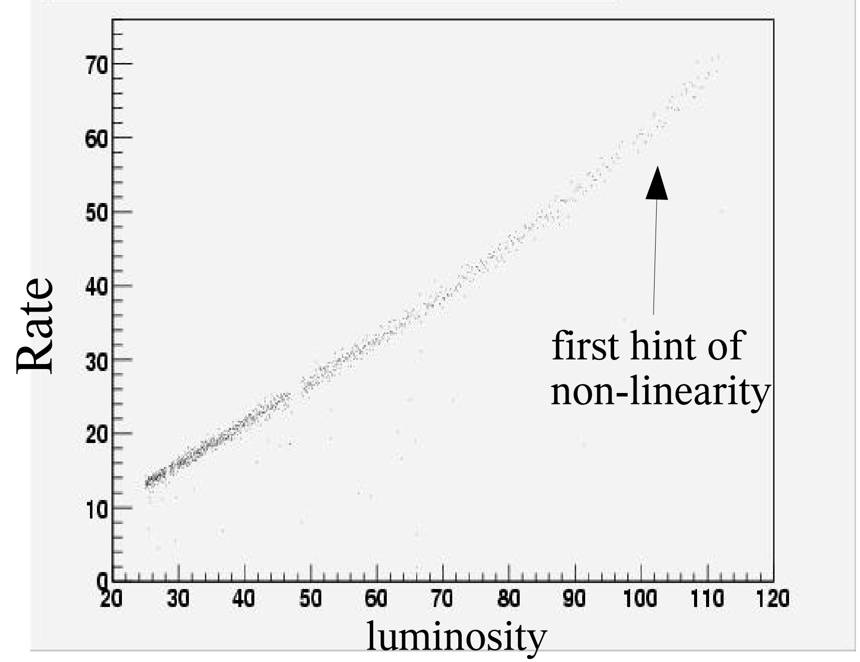
- track match for muons: tracks required to have SMT hits
- tracks (number of tracks, p_t)
- impact parameters (for muons and/or tracks)
- invariant mass filters: Φ, J/ψ, Υ
- charge (opposite sign)
- primary vertex: $\pm$ 35 cm

Triggers – timing is (almost) everything

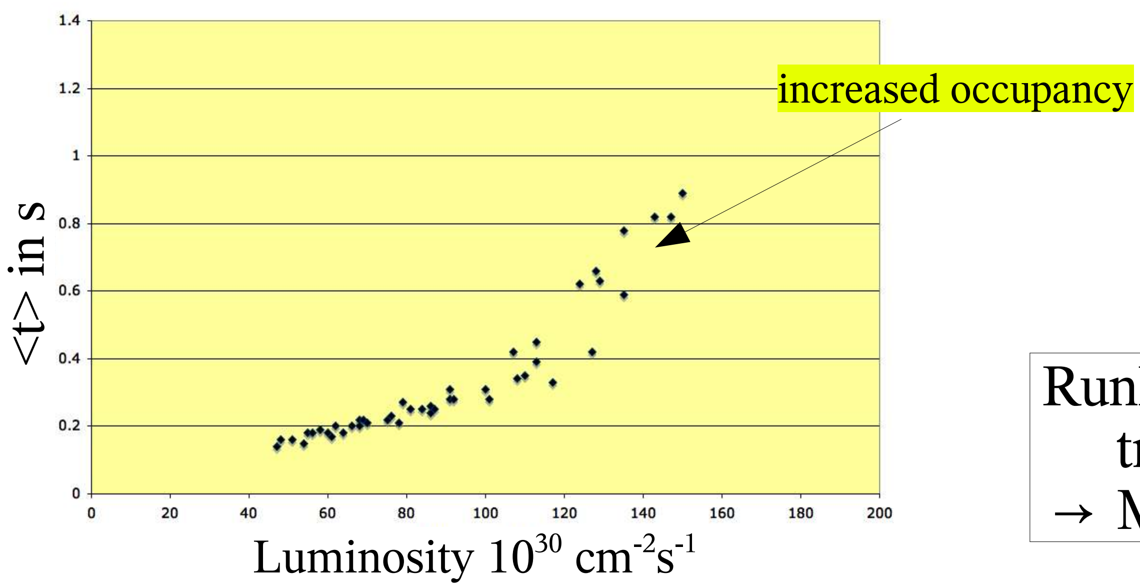
b-physics triggers often require low p_T tracks → triggers are intrinsically slow:

- optimize trigger ordering
- move rate reduction from L3 to L1/L2 (e.g. STT)

L1 track matched muon



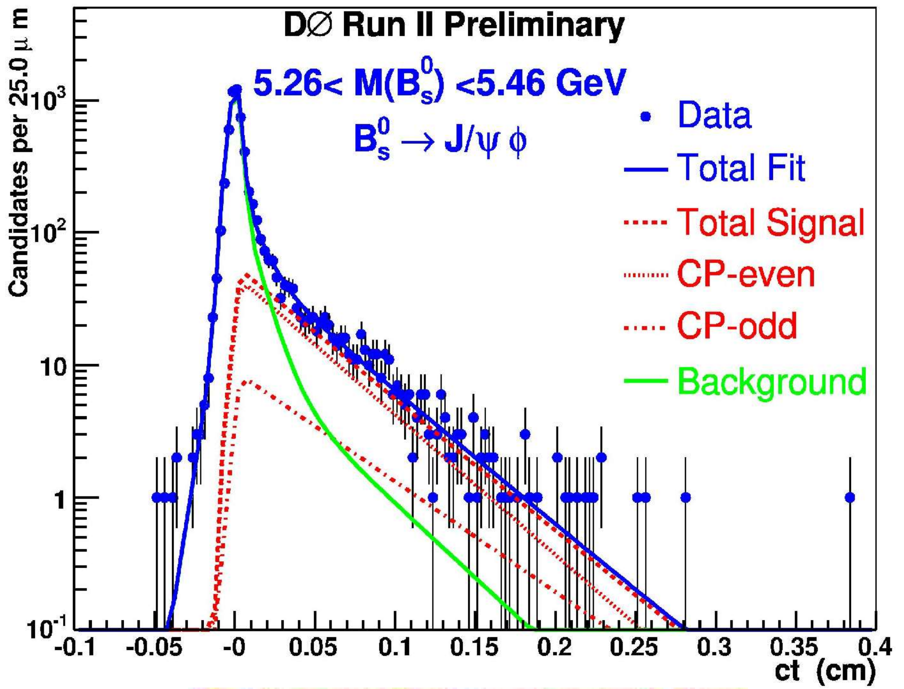
L3 Track CPU consumption vs lumi



RunIIb tracker 3 x faster than RunIIa tracking, but still not fast enough:
→ More CPUs.

The RunIIa *b*-physics programme has been a great success !

$$\bar{t}\left(B_s^0\right)=1.53\pm0.08^{+0.01}_{-0.04}\,ps$$

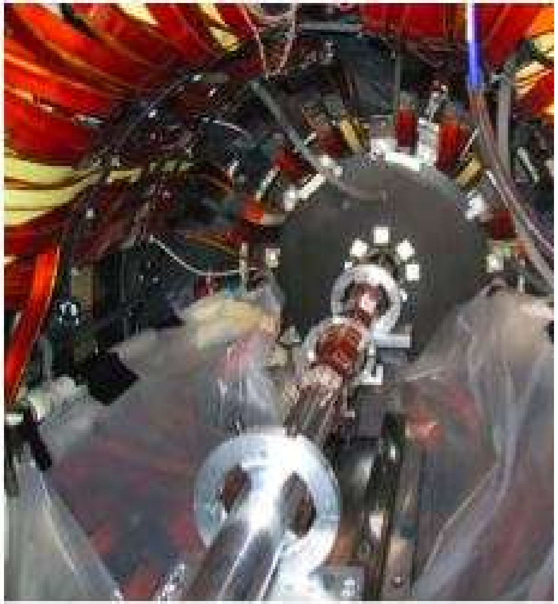


By playing to our strengths, i.e. making optimal use of our wide muon coverage and upgraded tracking system, DØ

- published 10 *b*-physics papers (out of 39 DØ publications), including the world's best measurement of the B_s lifetime.
- 3 papers currently submitted and 19 preliminary results, a lot of which have been presented during this conference.

- Results are also available on the web: http://www-d0.fnal.gov/Run2Physics/WWW/results/b.htm

- Increasing luminosity is a challenge and an opportunity.
- Layer 0 working as expected.
- High expectations for RunIIb.



Backup slide.....

Anatomy of three 'best-of' (late) RunIIa triggers

unbiased single muon trigger (up to $55e^{30}$, $100e^{30}$ RunIIb)

- semileptonic decays, mixing
- L1: tight scintillator, loose wire, pT > 3 GeV (from CTT), primary vertex
- L2: one medium muon (RunIIb: track match requirement)
- L3: track matched, 3-layer muon with pT > 3,4,5 GeV, $|z \text{ (primary vertex)}| < 35$ cm

single muon trigger with impact parameter (all luminosities)

- use muon for tagging to avoid IP bias in the signal (hadronic decays)
- L1: tight scintillator, loose wire, pT > 5 GeV (from CTT), primary vertex
- L2: one medium muon (RunIIb: track match requirement)
- L3: track matched 3-layer muons with IP significance > 3 and pT > 5 GeV $|z \text{ (primary vertex)}| < 35$ cm

di-muon trigger (all luminosities)

- J/ψ (e.g. $\Delta\Gamma/\Gamma$), Υ , $B_s \rightarrow \mu\mu$
- L1: 2 muons, no pT cut, (RunIIb: one match to a CTT track required)
- L2: one or two muons, depending on luminosity
- L3: 2 muon system only muons, pT > 2 GeV, one or two muons must have hits in all 3 layers.