Universität Zürich[UZH]

LHCb Silicon Tracker Performance and Forward Electroweak Physics

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LHCb-CONF-2010-004

Commissioning and performance of the LHCb Silicon Tracker

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[e] *National Academy of Sciences, Institute for Nuclear Research, Kiev*

Tracker Turicensis

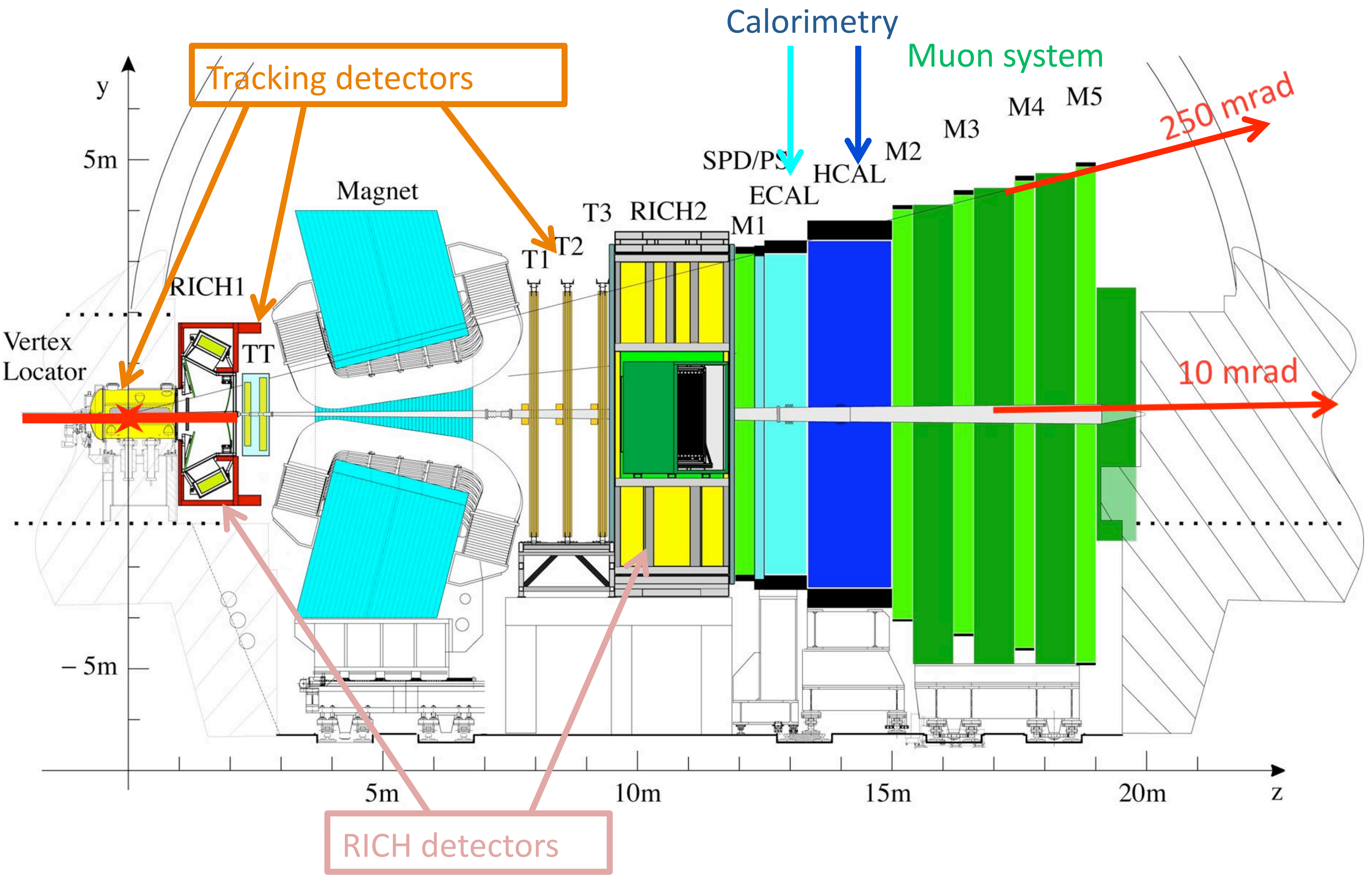
Performance of TT

Inner Tracker

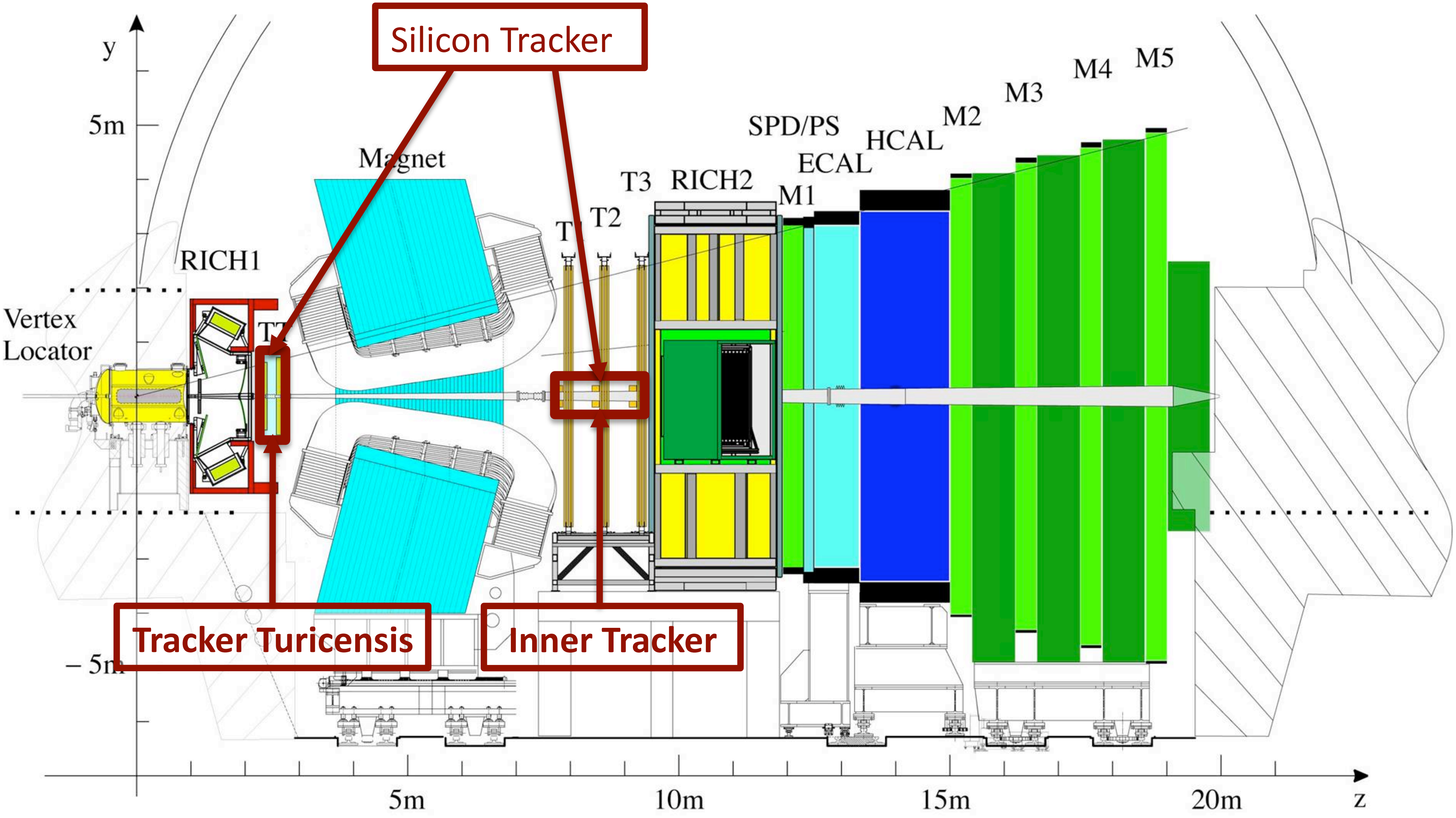
Performance of IT

LHCb SILICON TRACKER

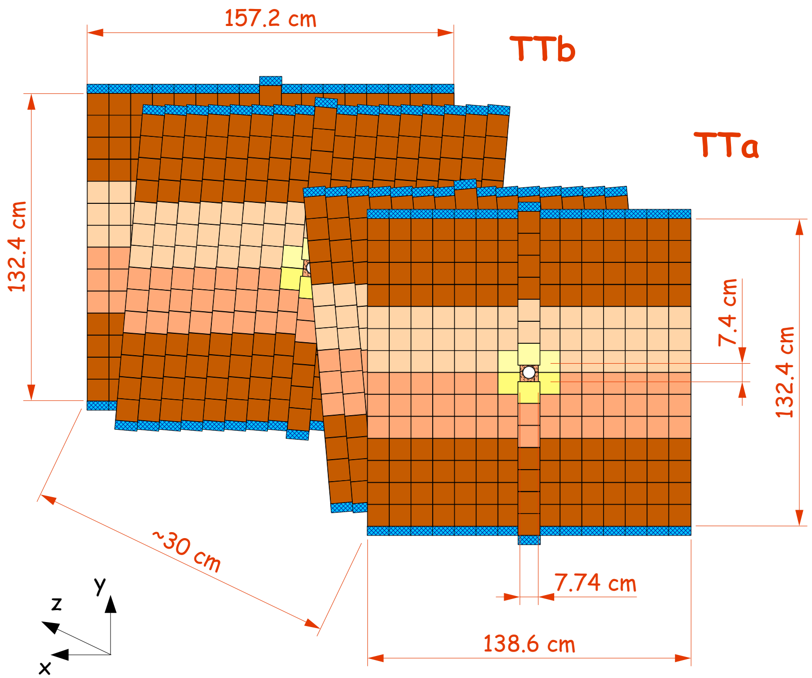
LHCb detector (again)

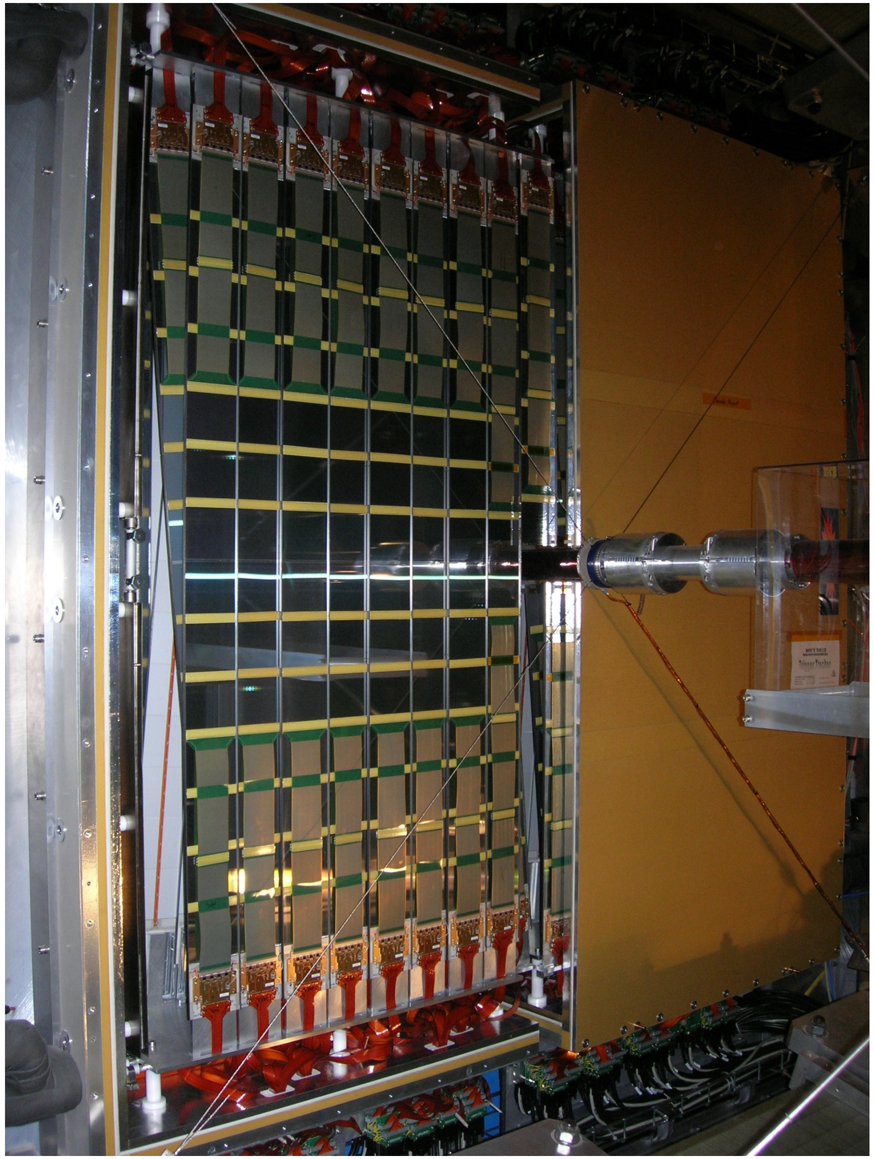


LHCb (the parts related to the first part of this talk)



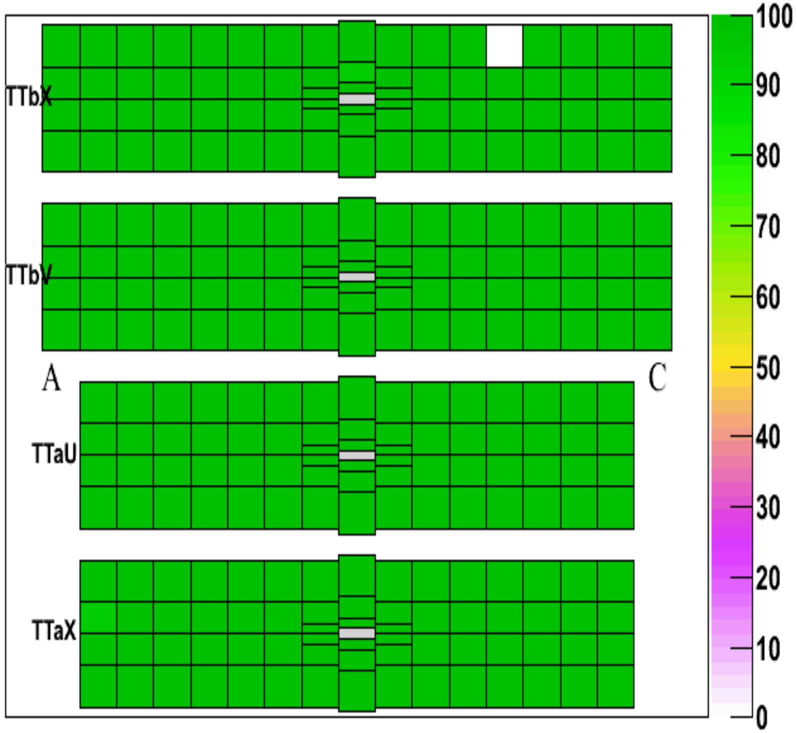
Tracker Turicensis (ZüriTracker)

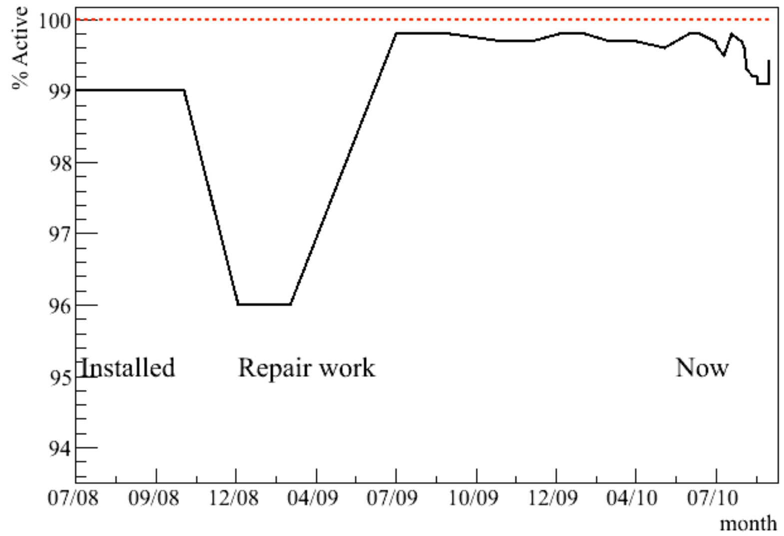




- Designed and built in Zürich.
- Silicon micro-strip detectors.
- Four planes (0°, +5°, -5°, 0°)
- Pitch: 183 μm; Thickness: 500 μm
- Different strip lengths (up to 37 cm)
- 143360 readout channels.
- Total Silicon area is 8 m^2.

TT Status





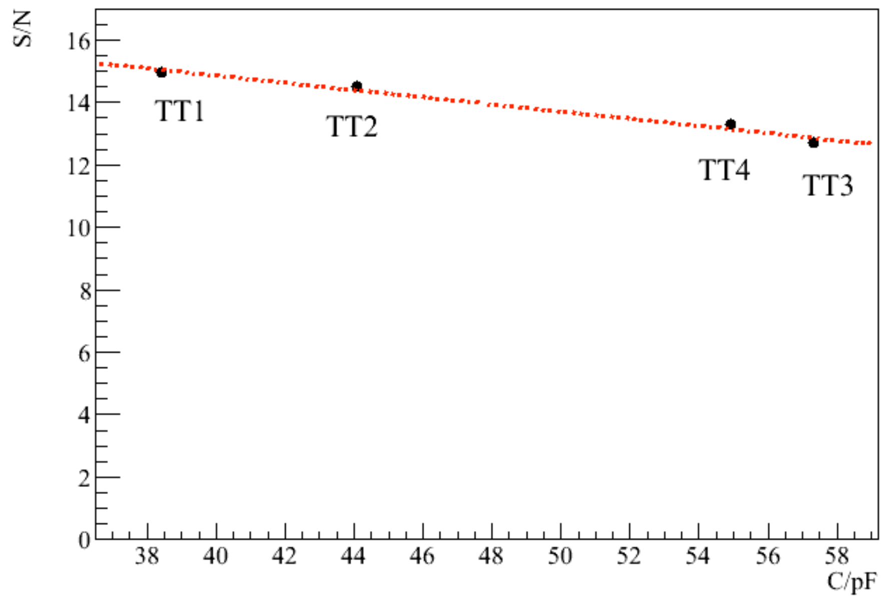
- 99.45% of the detector is fully functional.
  - 99.8% at start of running.
  - Repairs made yesterday.

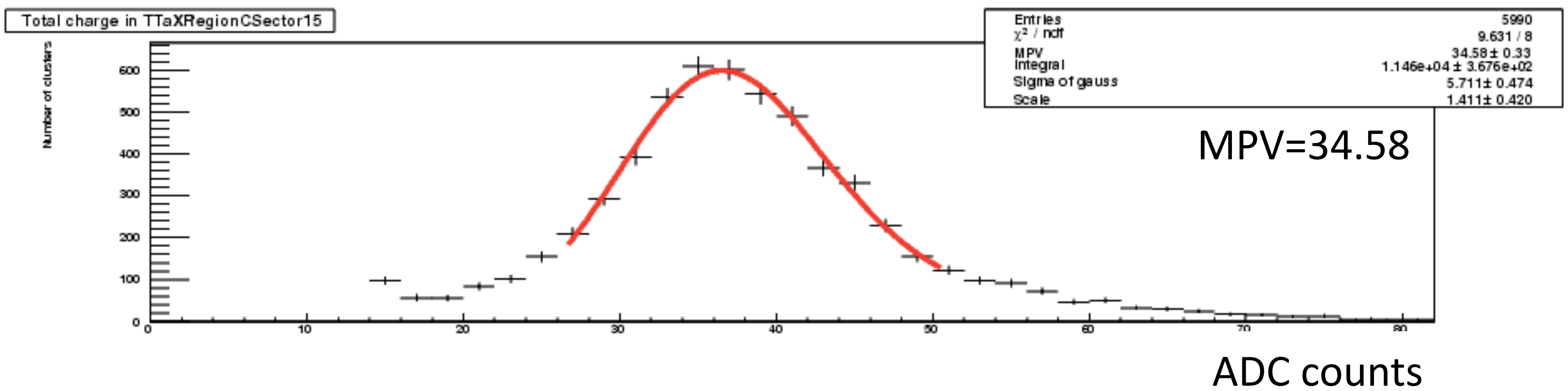
  (99.1, 99.8, 99.7, 99.8 to 99.45%)

- Constant battle against dying VCSEL diodes
  - Transmits optical data for processing.
- Have to replace around 3 per month.
- One sector with problem in box.

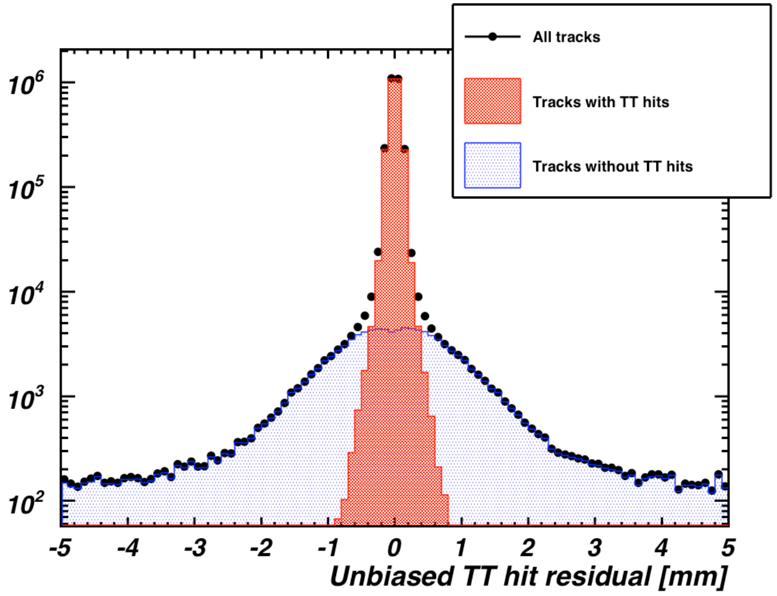
Signal/Noise Performance (TT)

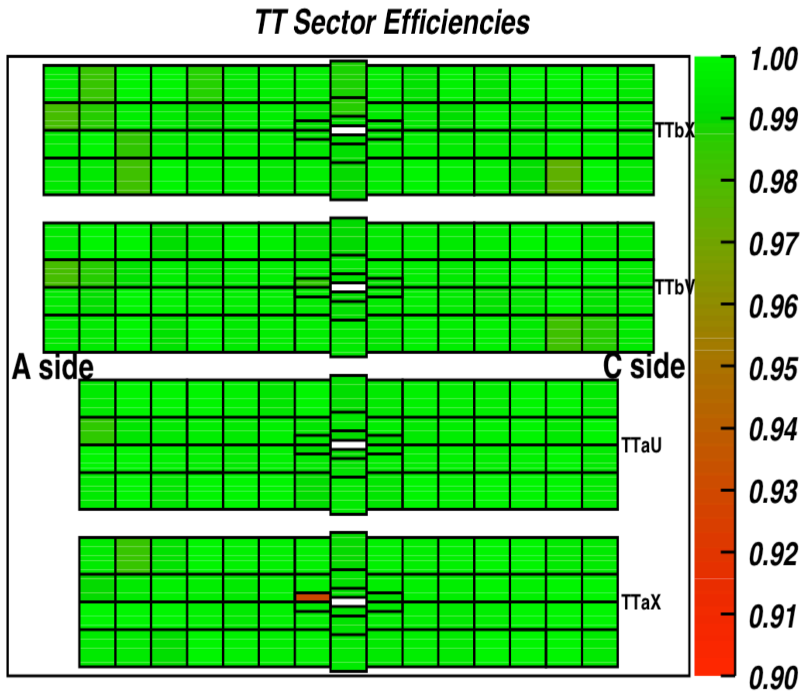
- Clusters assigned to tracks with p > 5 GeV:
  - S/N in range 12-15.
  - Different S/N for different capacitances.
  - 4 different strip lengths.





TT Efficiency

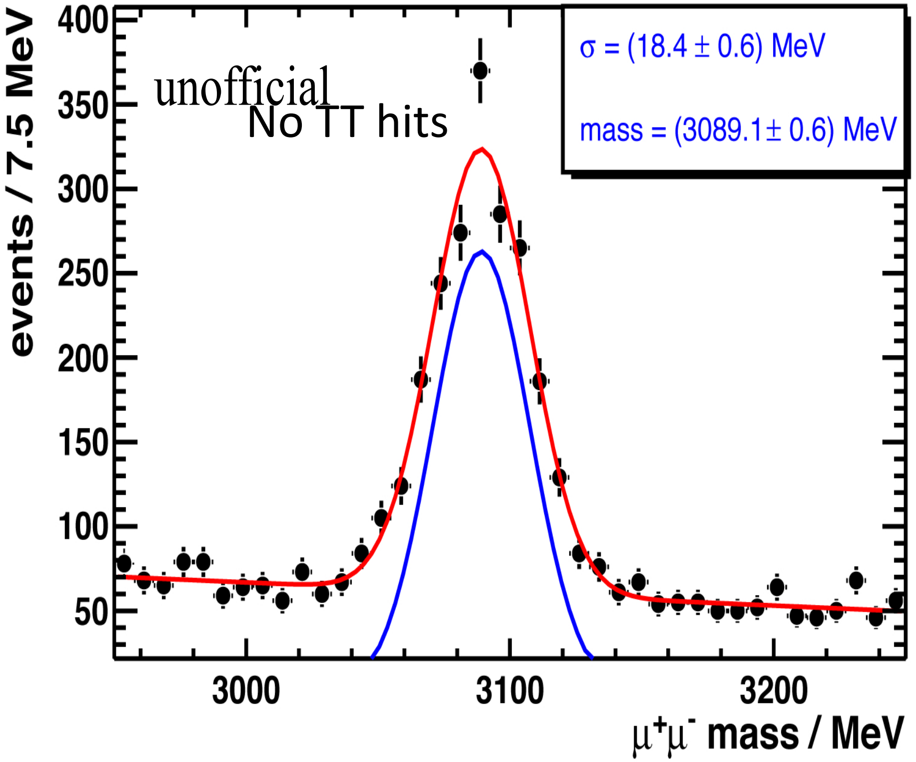


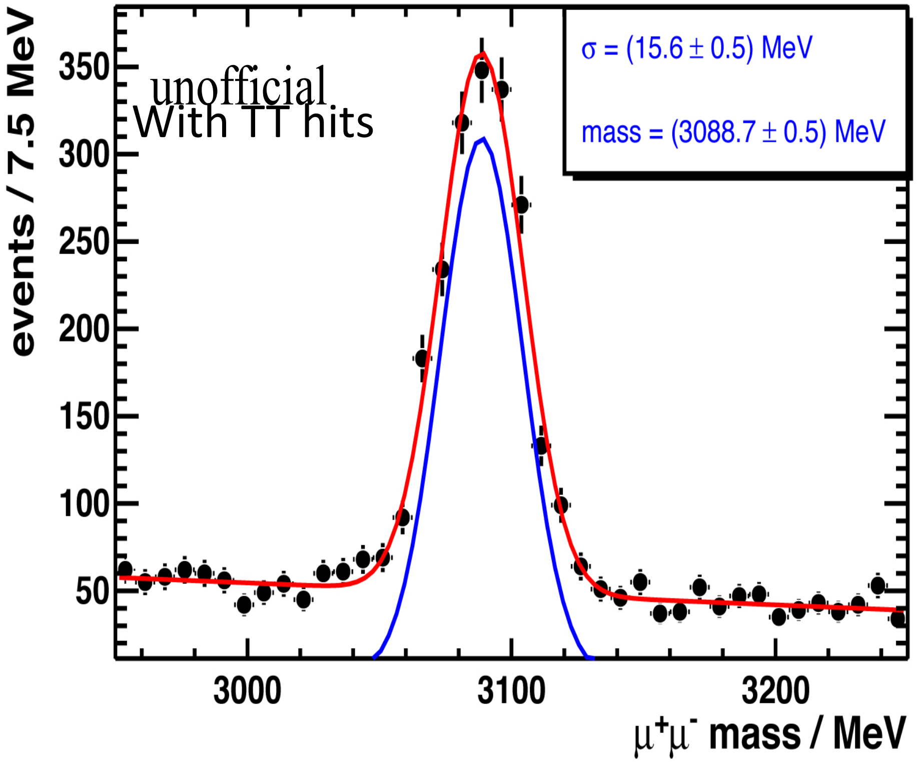


- Measure efficiency with tracks.
  - p > 10 GeV,
- Extrapolate tracks through TT
- Look for hits in 2.5 mm window around track

- eff = #found/#expected
- Overall efficiency is 99.3%
- Low efficiency sector has broken bonds

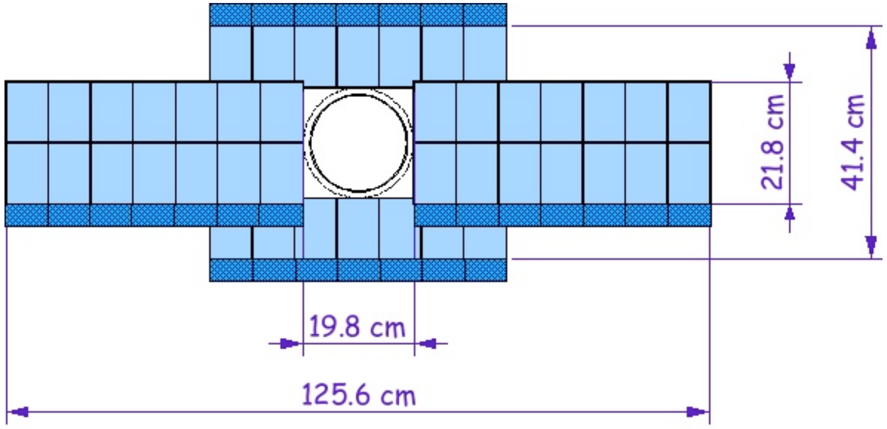
Why TT is great!

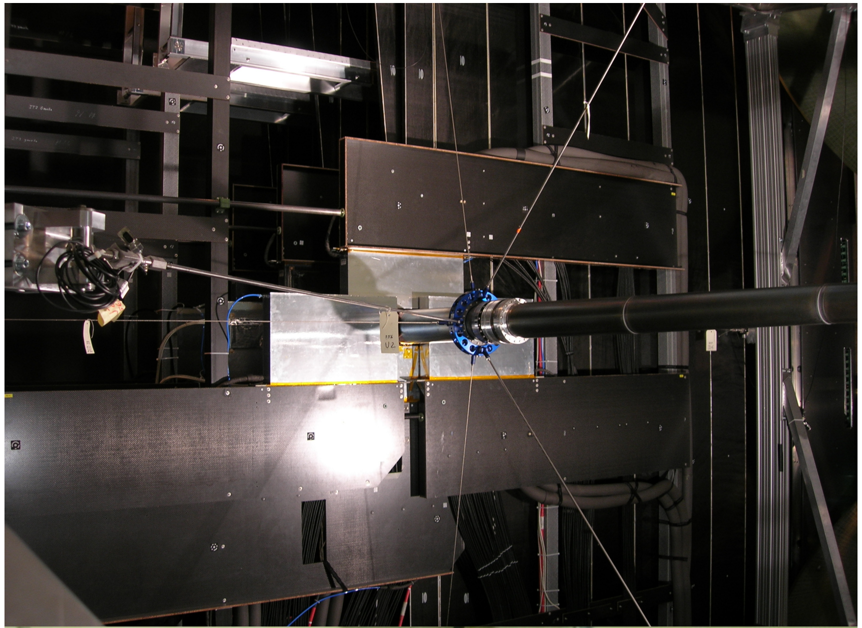


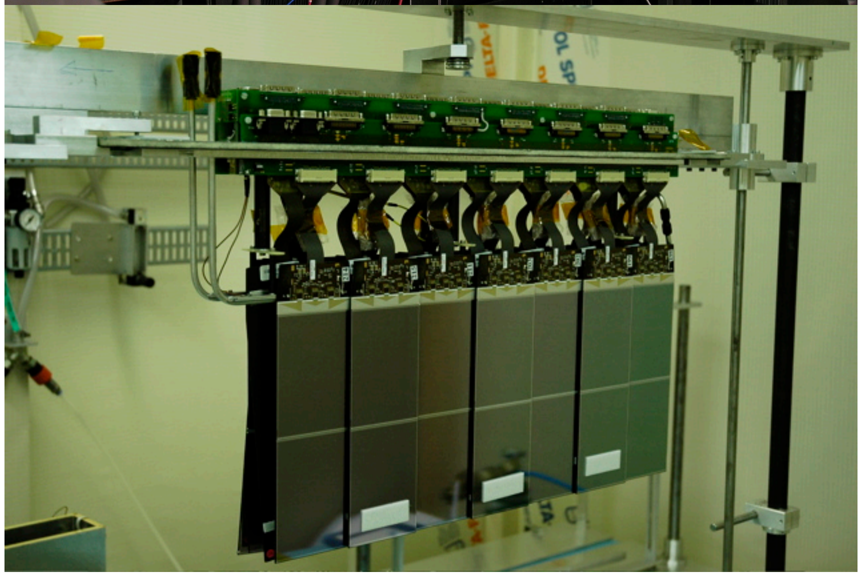


- Fit tracks with/without TT hits.
- Mass resolution is around 20% better with TT.

Inner Tracker

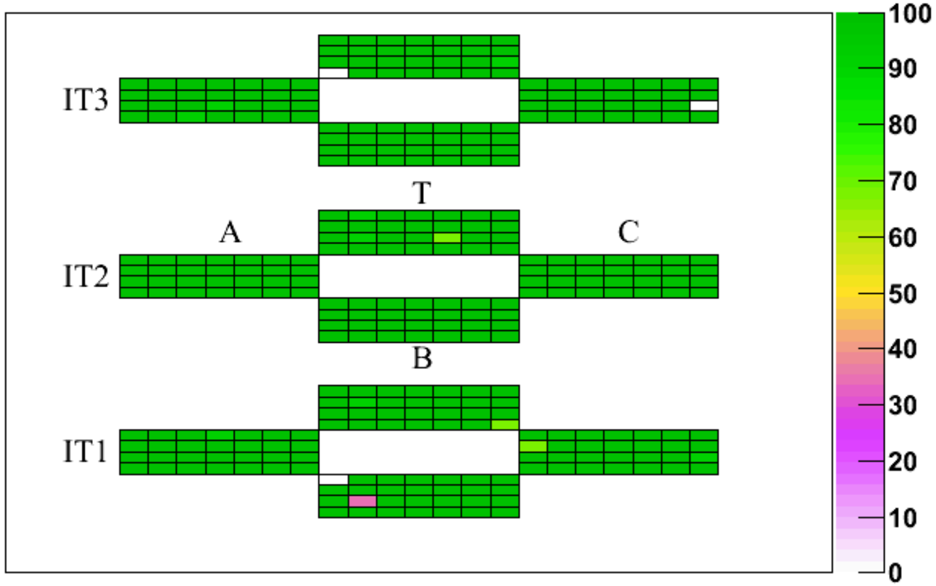


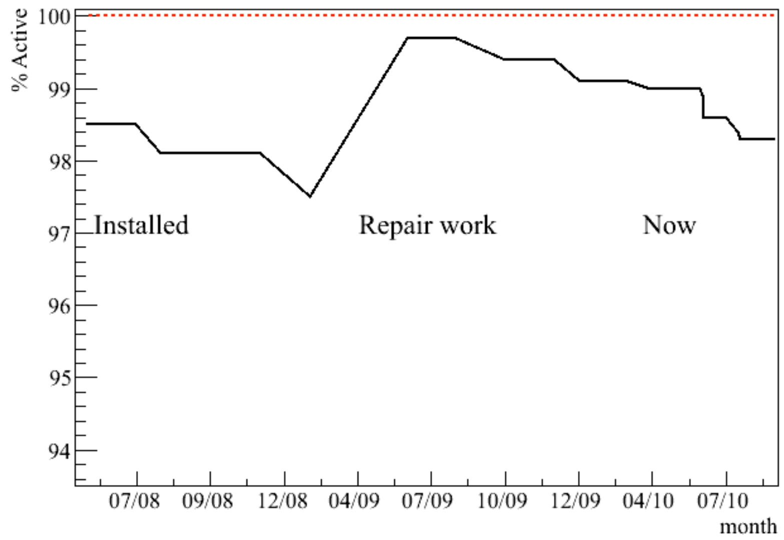




- Silicon micro-strip detectors.
- Four boxes in three stations
- Four planes (0°, +5°, -5°, 0°)
- Pitch: 198 µm
- Thickness:
  - 320 µm – 1 sensor ladders
  - 500 µm – 2 sensor ladders
- 129024 readout channels.
- Total Silicon area is 4.2 m^2.

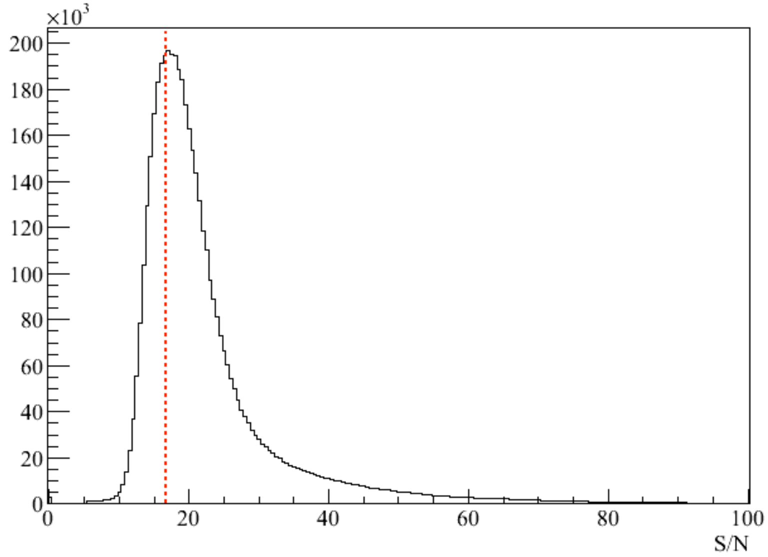
Inner Tracker Status

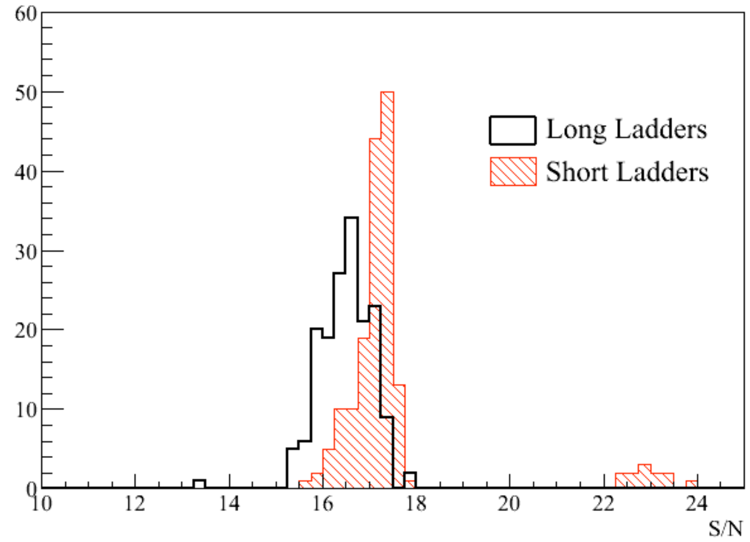




- 98.3% is fully functional.
- Three modules with problems inside detector:
  - HV faulty.
  - Two cannot be configured.
- Degradation in over time from failing optical links.
  - Same problem with as in TT
- Repair of IT difficult until long shutdown.
  - Requires access close to the beam pipe.

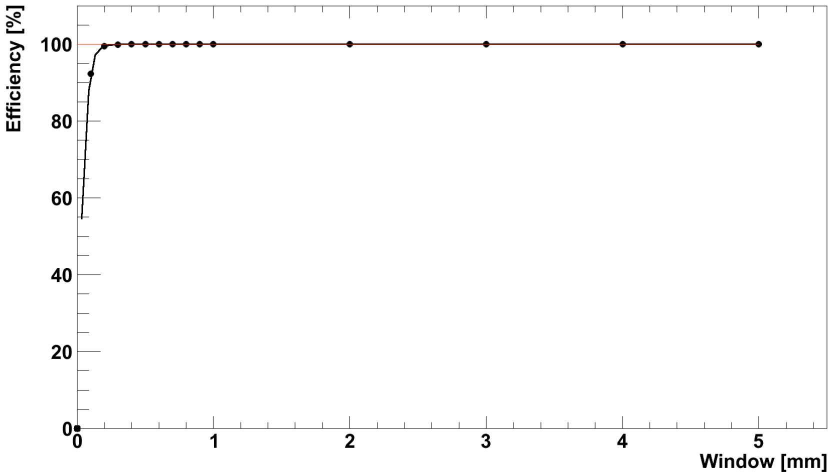
S/N Performance (IT)

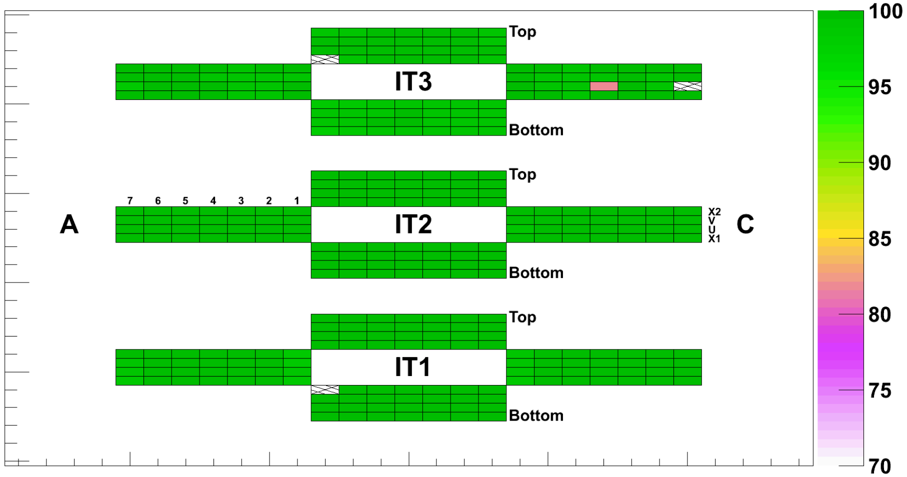




- Cluster from tracks with p > 5 GeV
- Signal to Noise:
  - 16.5 (Long)
  - 17.5 (Short)
- Within 10-20% of expectation.

IT Efficiency





- High momentum:
  - p > 10 GeV
- Isolated tracks.
- Two low efficiency modules.
- Overall efficiency is 99.65%

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Partons at LHC and LHCb

W, Z production

Low mass Drell-Yan production

Effect on PDF uncertainties

FORWARD ELECTROWEAK PHYSICS

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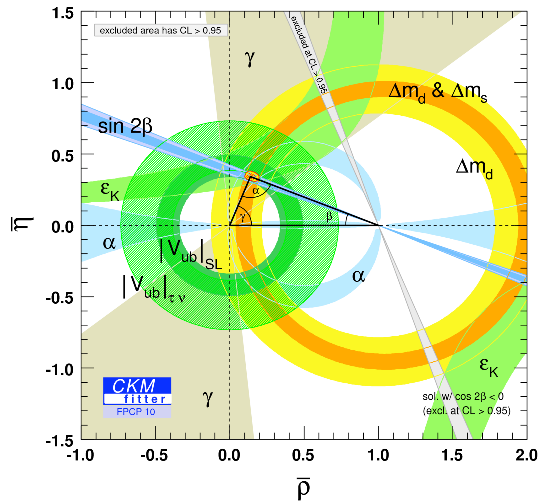
LHCb (b physics at LHCb)

- **Core program of LHCb:**
  - Searching for new physics in rare B decays.
    - $B_s \to \mu^+\mu^-$, $B_d \to K^*\mu^+\mu^-$.
  - Measuring CKM parameters in heavy quark decays
    - $B_s \to J/\psi\phi$.



- **Lots of non-B physics:**
  - Minimum bias physics (inclusive particle production, multiplicities)
  - Forward diffractive physics
  - Charm physics
  - Higgs and Exotics (SM Higgs, Super-symmetry, hidden valley, etc…)
  - Exclusive production
  - Electroweak boson production (study proton structure)
    - J. Anderson, Electroweak physics prospects at LHCb
    - R. McNulty, PDF sensitivity studies using electroweak processes at LHCb

LHC!b (Non b physics at LHCb)

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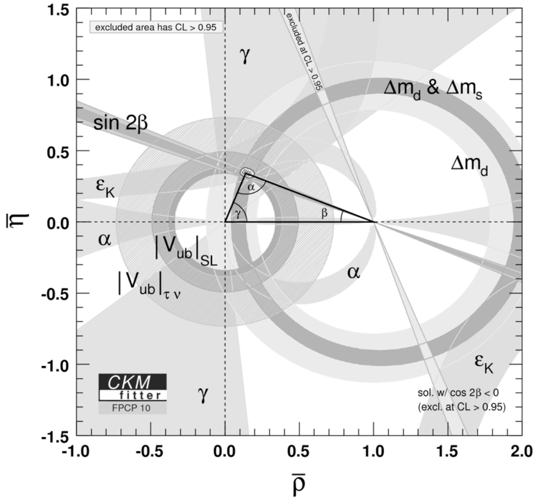

- **Lots of non-B physics:**
  - Minimum bias physics (inclusive particle production, multiplicities)
  - Forward diffractive physics
  - Charm physics
  - Higgs and Exotics (SM Higgs, Super-symmetry, hidden valley, etc…)
  - Exclusive production $((\gamma\gamma \to \mu\mu), (I\!P \to J/\psi))$
  - Electroweak boson production (study proton structure)
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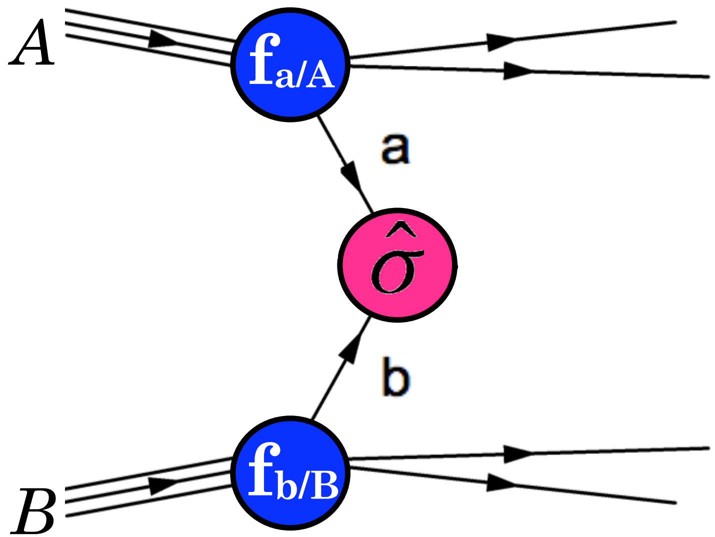
Calculations at LHC

- Primary parton interaction calculable
  - pQCD
- Parton distribution not calculable
  - PDF from data



$$\sigma_{AB\to X} = \int dx_a dx_b f_{a/A}(x_a, Q^2) f_{b/B}(x_b, Q^2) \hat{\sigma}_{ab\to X}$$

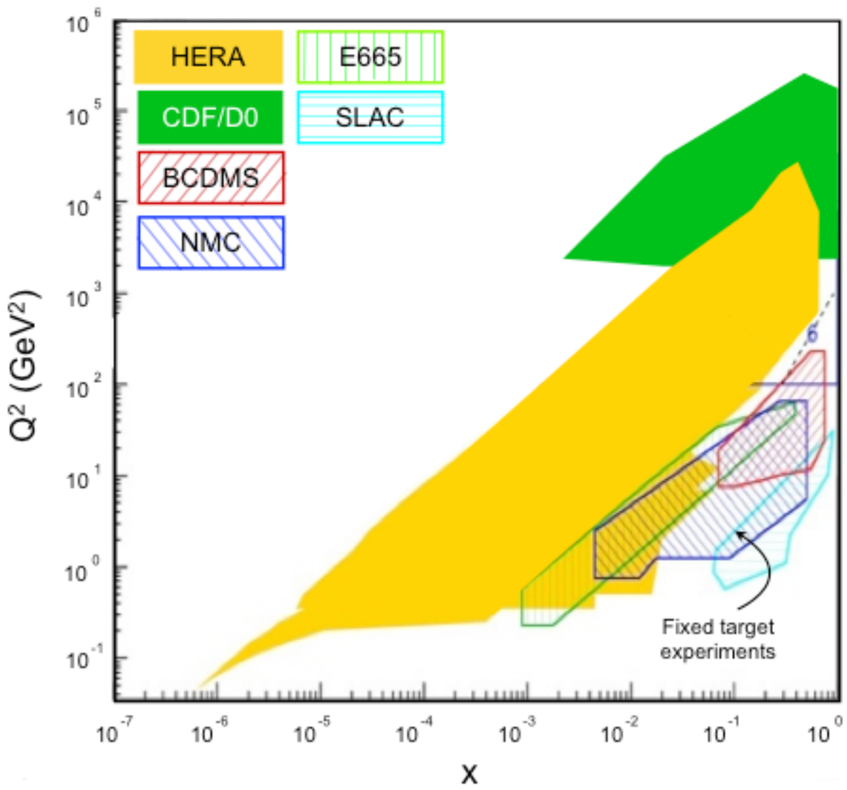
PDFs (from data)

Partonic interaction (pQCD)

W, Z: NNLO <1% uncertainty

Reminder:
- $x_{a,b}$ is fraction of hadron momentum carried by parton a, b.
- Q^2 is momentum scale which characterises the hard scatter.

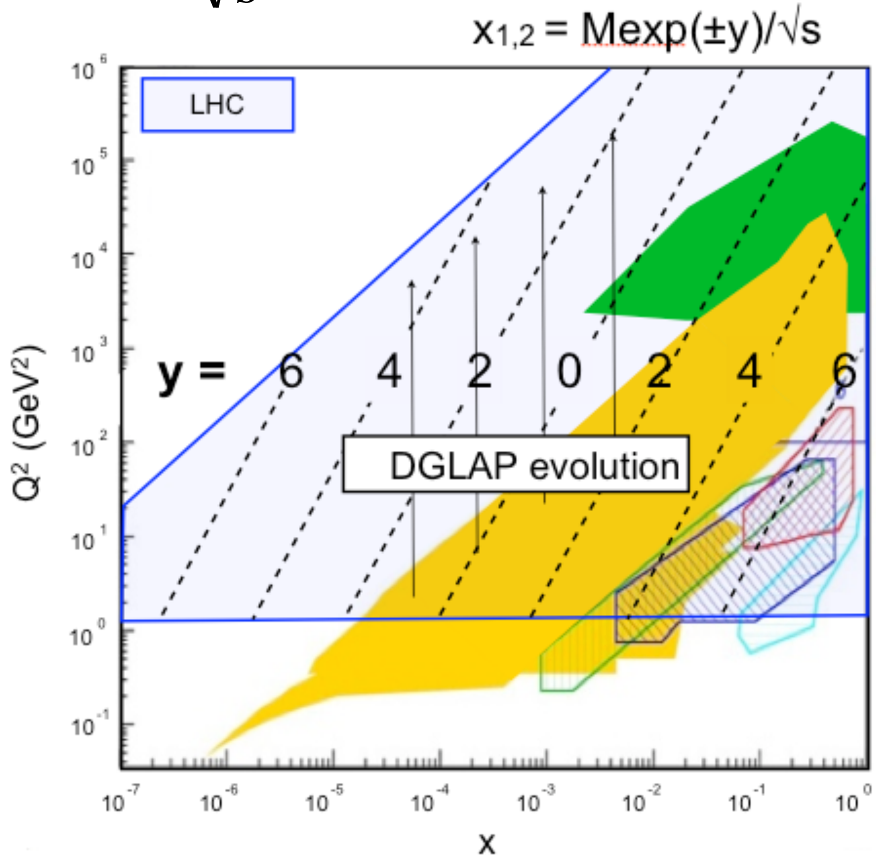
Current constraints



- Parton distributions are process independent
  - Evolution with scale can be calculated
- Measurement from one experiment
  - Predict other scattering processes.
- Many different measurements:
  - DIS at HERA.
  - DIS at fixed target.
  - Drell-Yan at E605, E866.
  - High p_T jets at the Tevatron.
  - W&Z production at the Tevatron.
- Data is fitted by a variety of groups
  - MSTW, CTEQ, NNPDF, Alekhin, ZEUS, H1…

Partons at the LHC

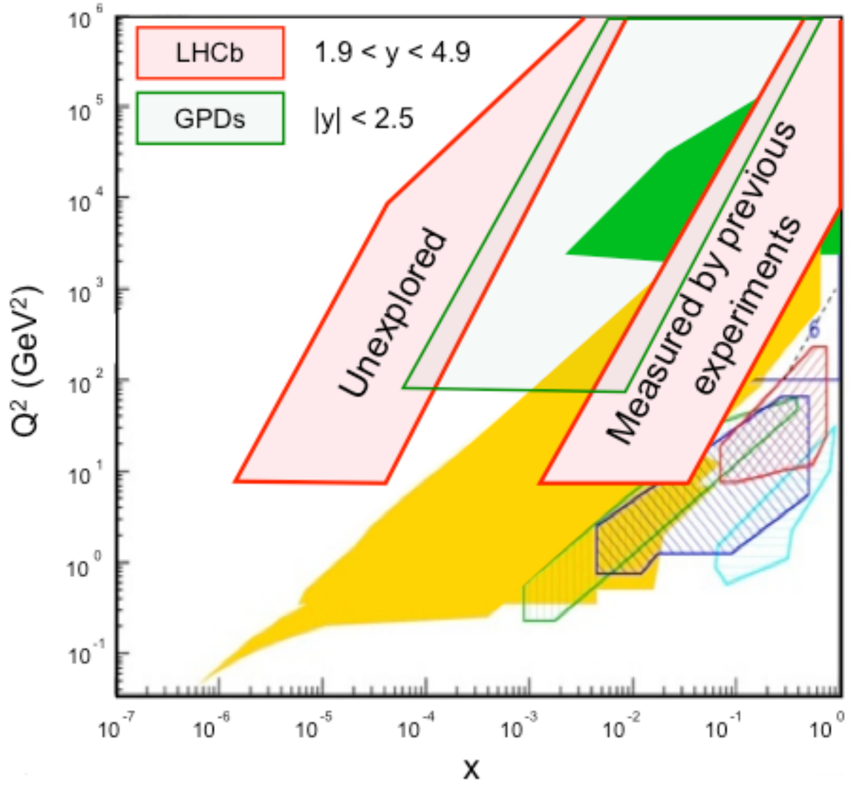
$$x_{1,2} = \frac{M}{\sqrt{s}} e^{\pm y}$$



- Partons must be evolved by DGLAP equations.
- Kinematic region extended at LHC:
  - higher Q^2.
  - lower x.

Partons at LHCb

$$x_{1,2} = \frac{M}{\sqrt{s}} e^{\pm y}$$

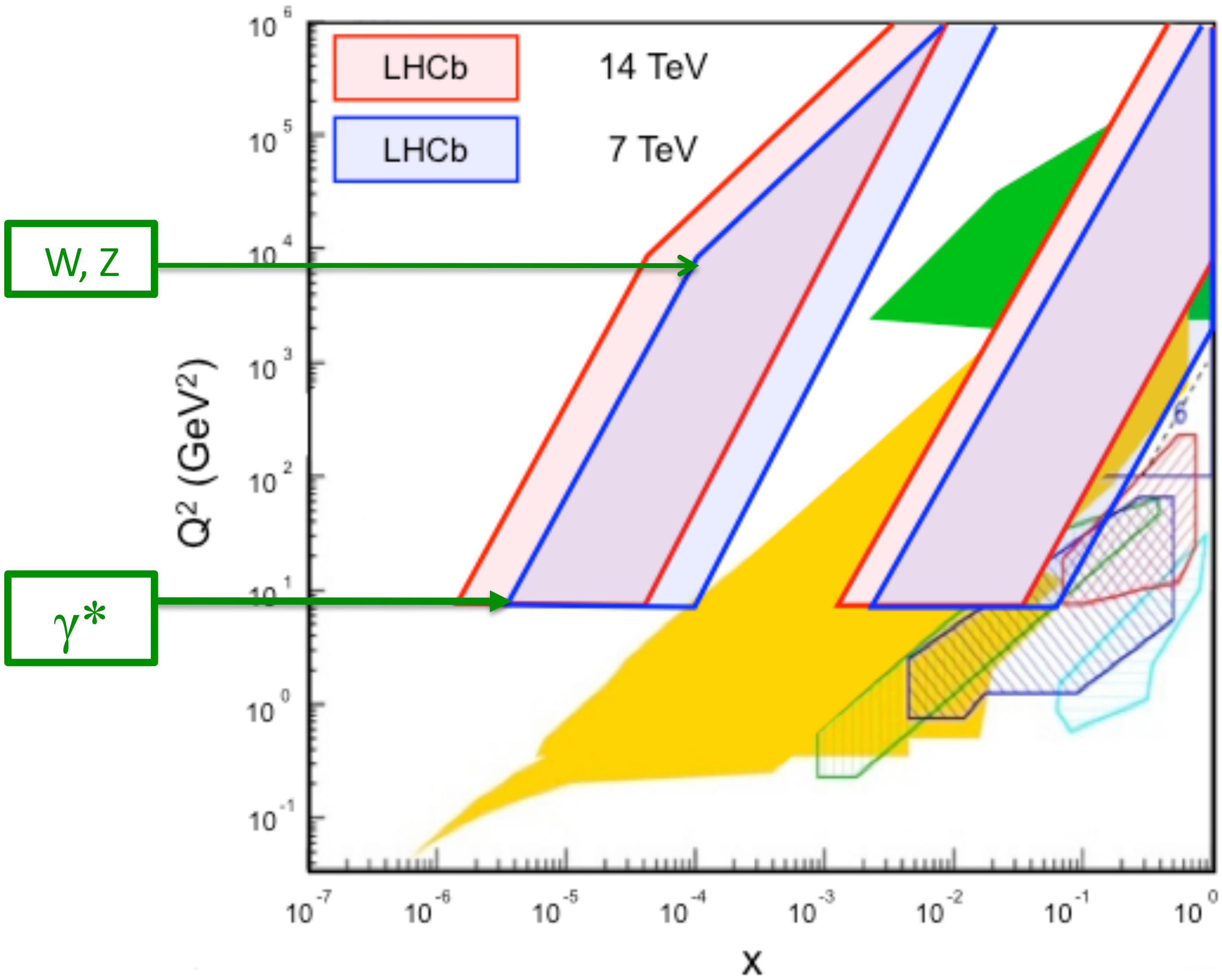


- Two distinct regions probed:
  - x1 >> x2
  - One parton well understood.
  - One parton from unexplored region.

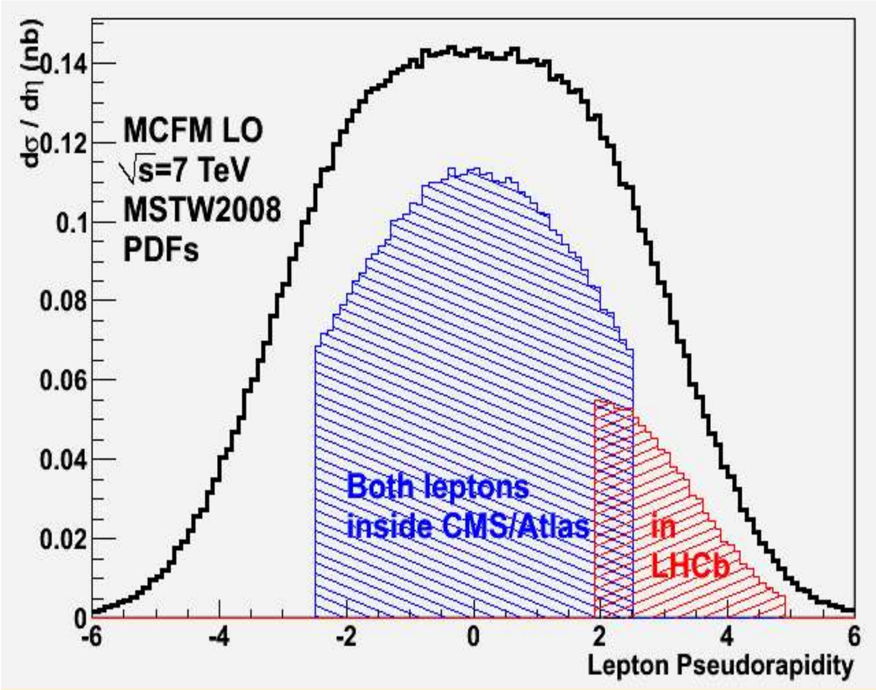
- LHCb detector:
  - Fully instrumented, $1.9 < \eta < 4.9$
    - $1.9 < \eta < 2.5$ LHCb&ATLAS&CMS
    - $2.5 < \eta < 4.9$ LHCb only
  - Trigger on low momentum muons
    - $p > 8$ GeV
    - $p_T > 1$ GeV

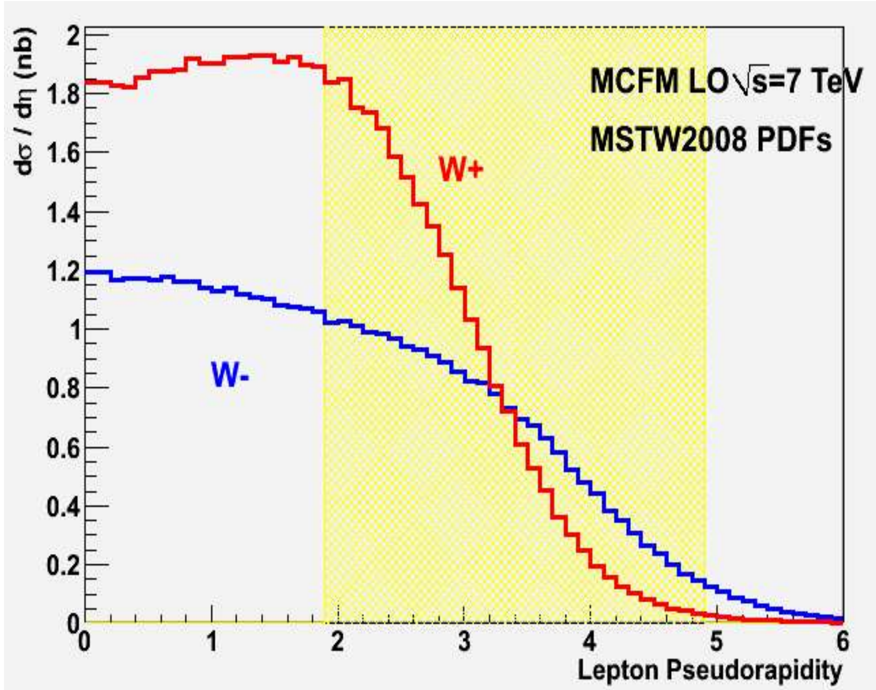
- LHCb can probe this totally unexplored region:
  - Access to unique range of (x, Q^2).
- Allows precision test of QCD.
- Determine PDFs.

Partons at 7 TeV



W, Z production





- Unique region with both leptons in LHCb
- Measure asymmetry in W decays.

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Electroweak boson cross-section measurements

LHCb

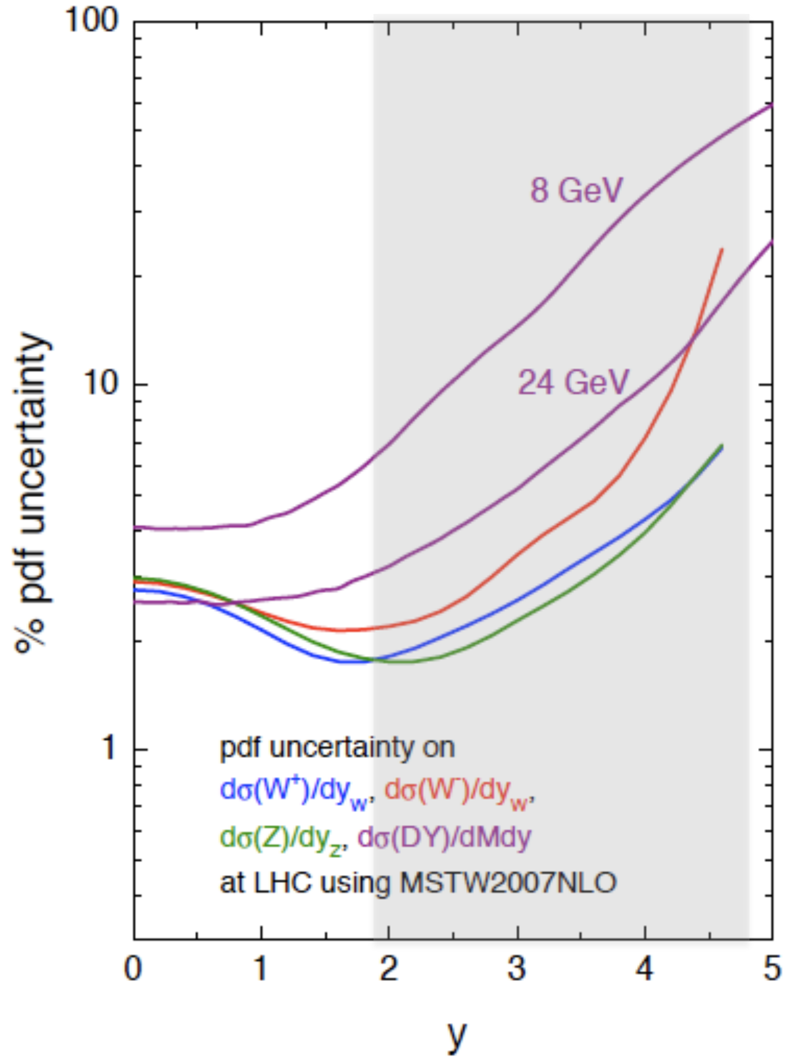
W, Z production:

- Clean experimental signature.
- Cross-section measurement can constrain PDFs.
- Dominant theoretical uncertainty comes from PDFs.
- Uncertainty grows at large rapidity.
- Uncertainty grows fastest for W-.
- Production rate can be used to measure luminosity.

Low mass Drell-Yan production:

- PDF uncertainty grows at low di-muon mass.
- Depends on low-x partons.
- Differential cross-section measurement at LHCb.

From R. Thorne



W production with 14.6 nb^{-1}

Z production with 37 nb^{-1}

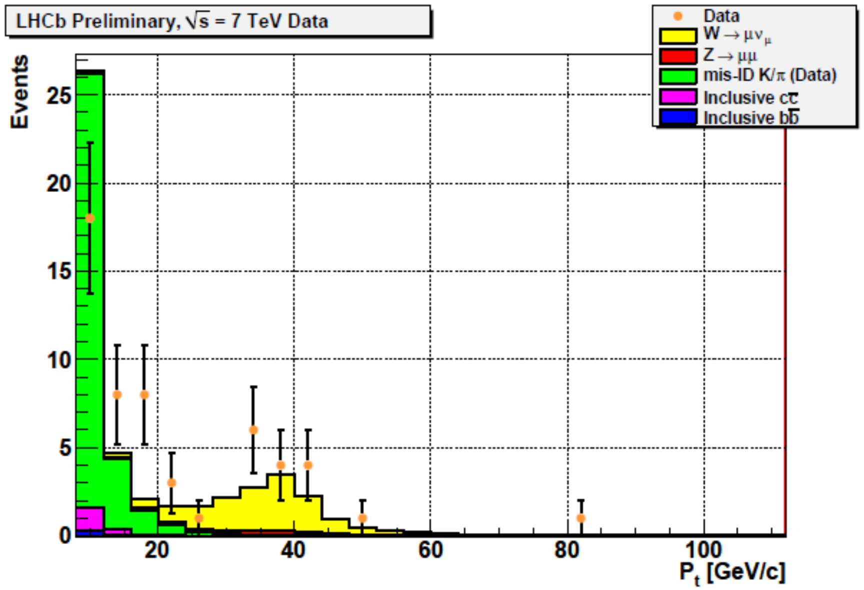
Drell-Yan production with 37 nb^{-1}

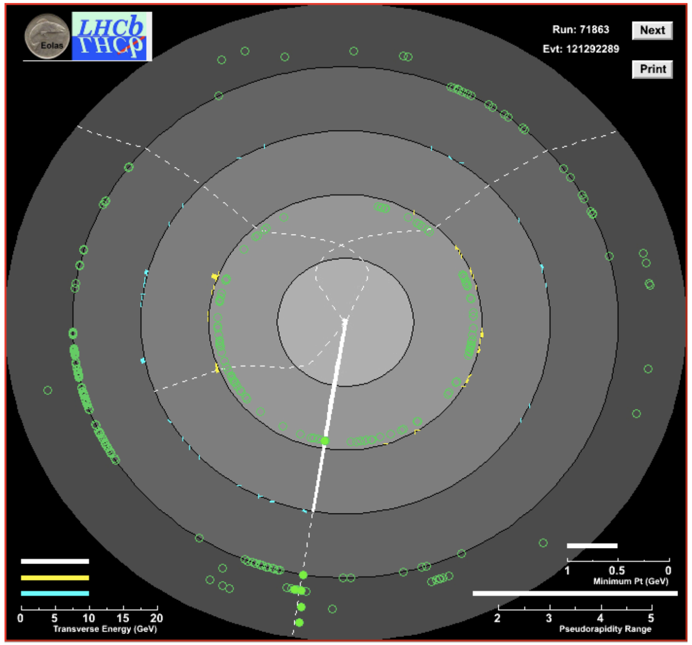
Impact on PDFs

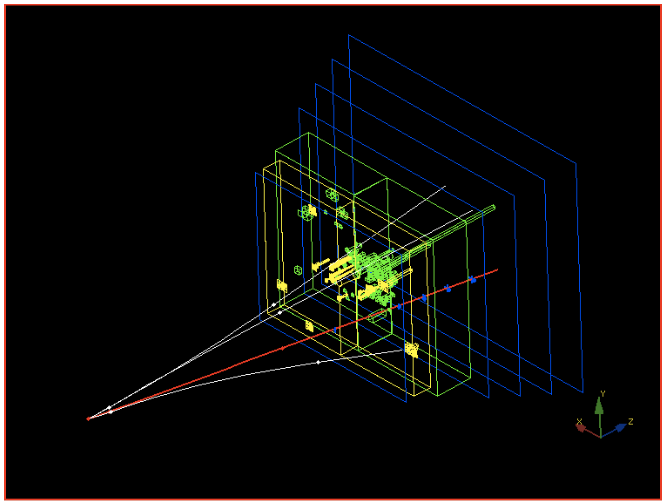
RESULTS

14.6 nb^{-1} for ICHEP

W->μν





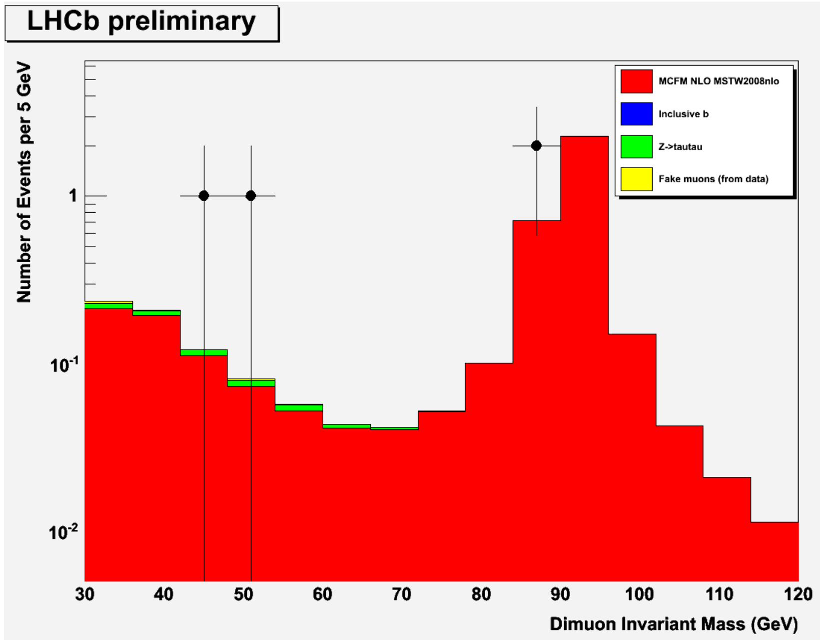


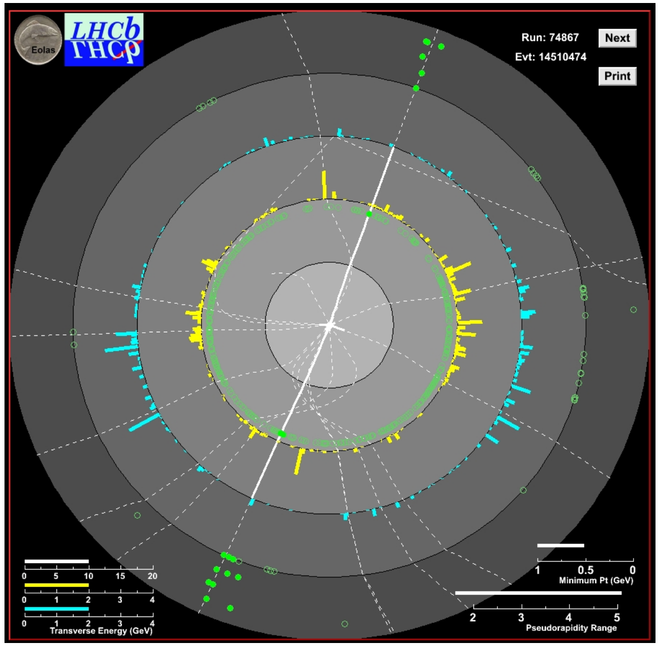
- Require high p_T muon.
- Little other activity in event.

- Around 20 candidates.
- Expect around 1000/pb^{-1}.

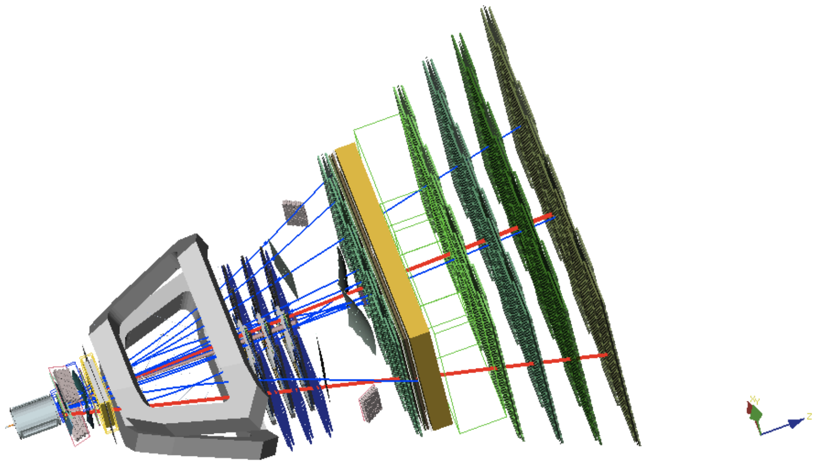
37 nb^{-1} for ICHEP

Z->μμ





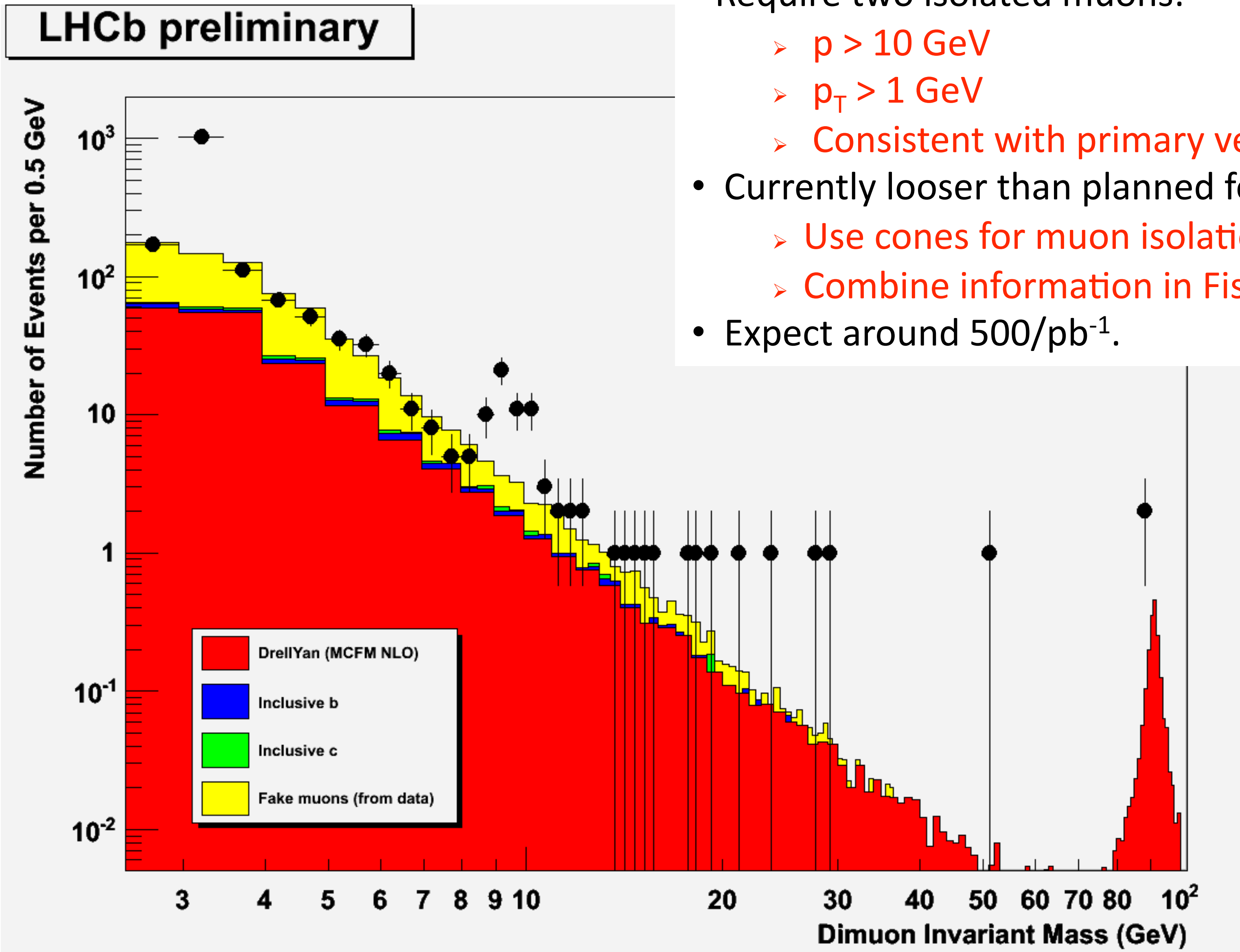
- Require two high p_T muons:
  - $p_T > 15$ GeV & $p_T > 20$ GeV
- Impact parameter, IPS < 5
- Hadronic energy < 50 GeV
- Mass window:
  - 71 GeV < $M_{\mu\mu}$ < 111 GeV



- Expect around 170/pb^{-1}.

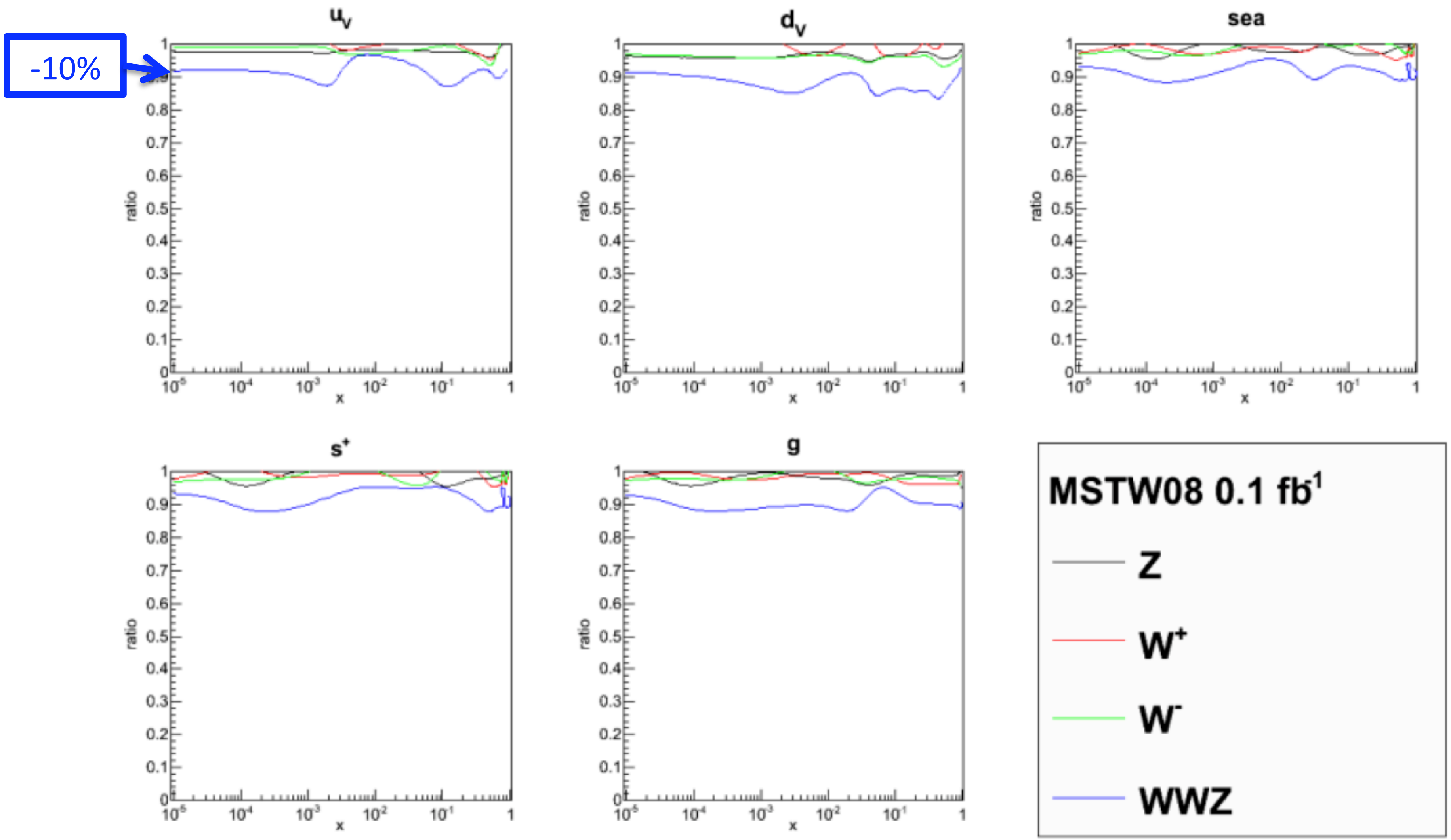
37 nb^{-1} for ICHEP

Drell-Yan Production



- Require two isolated muons:
  - p > 10 GeV
  - p_T > 1 GeV
  - Consistent with primary vertex.
- Currently looser than planned for future
  - Use cones for muon isolation.
  - Combine information in Fisher discriminant.
- Expect around 500/pb^{-1}.

Impact on PDFs of W and Z measurements



ratio = uncertainty with 0.1 fb^{-1} LHCb data : uncertainty without LHCb data

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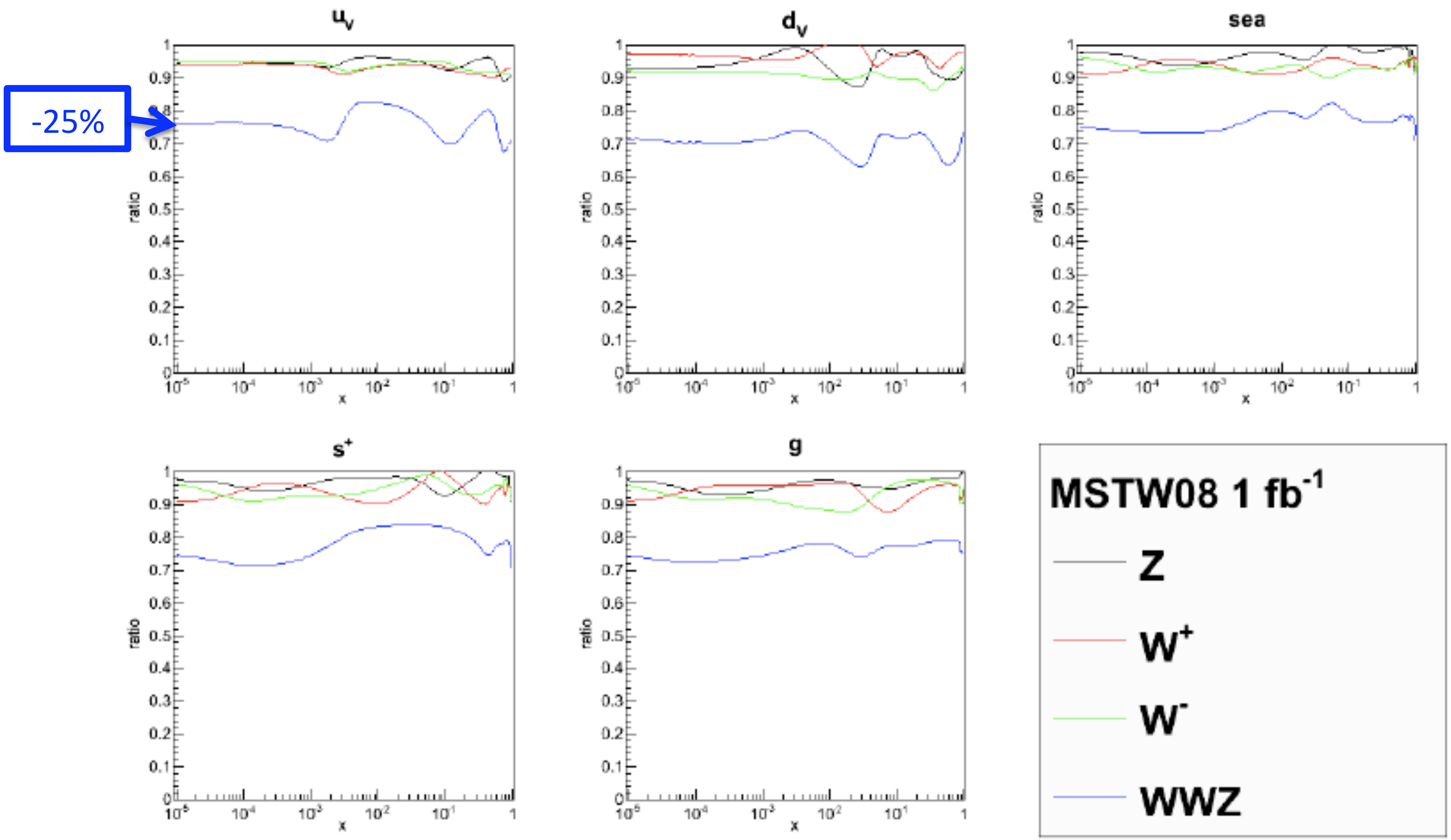
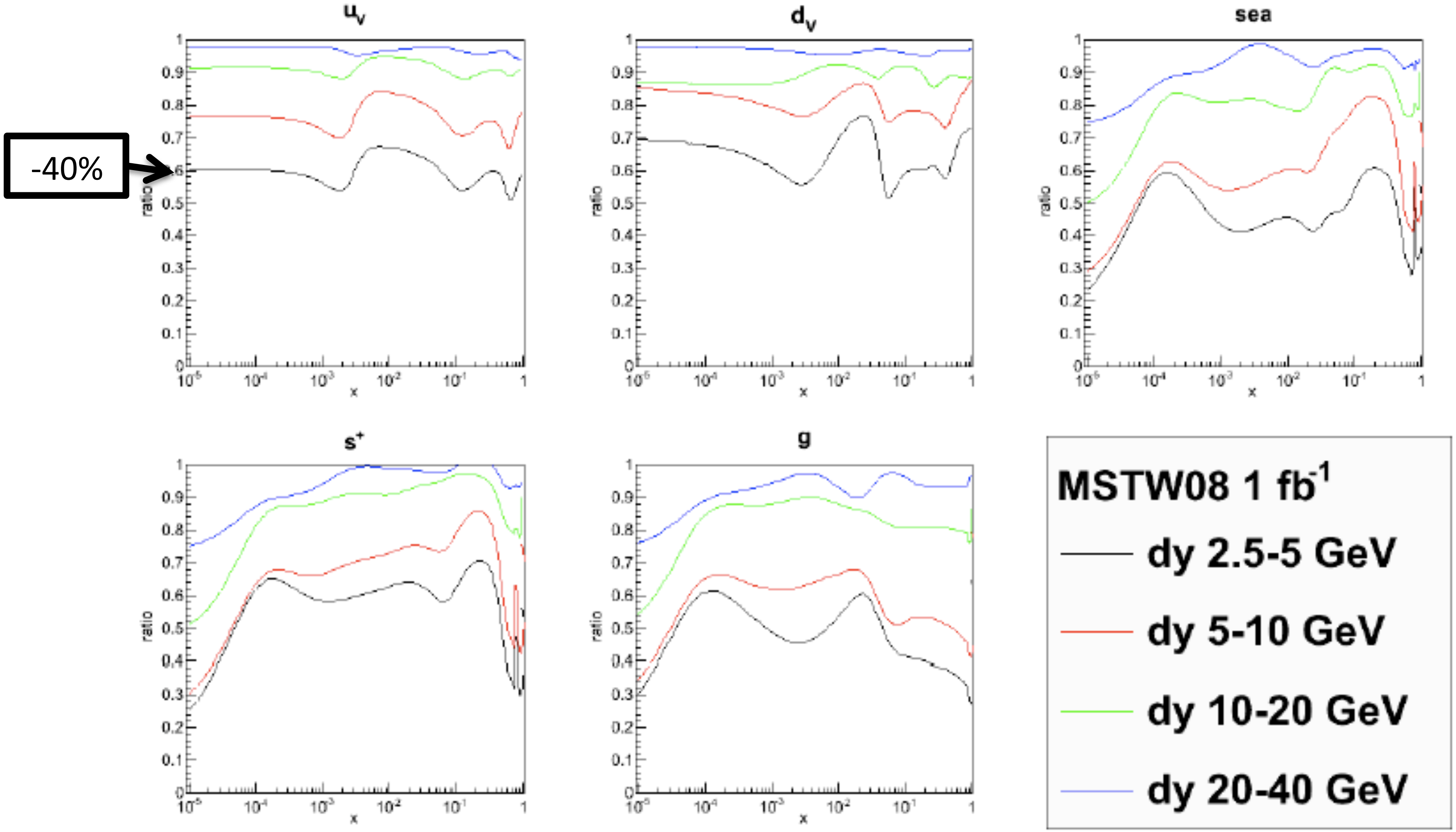
Impact on PDFs of W and Z measurements



ratio = uncertainty with 1 fb^{-1} LHCb data : uncertainty without LHCb data

Impact on PDFs of low mass Drell-Yan measurements



ratio = uncertainty with 1 fb^{-1} LHCb data : uncertainty without LHCb data

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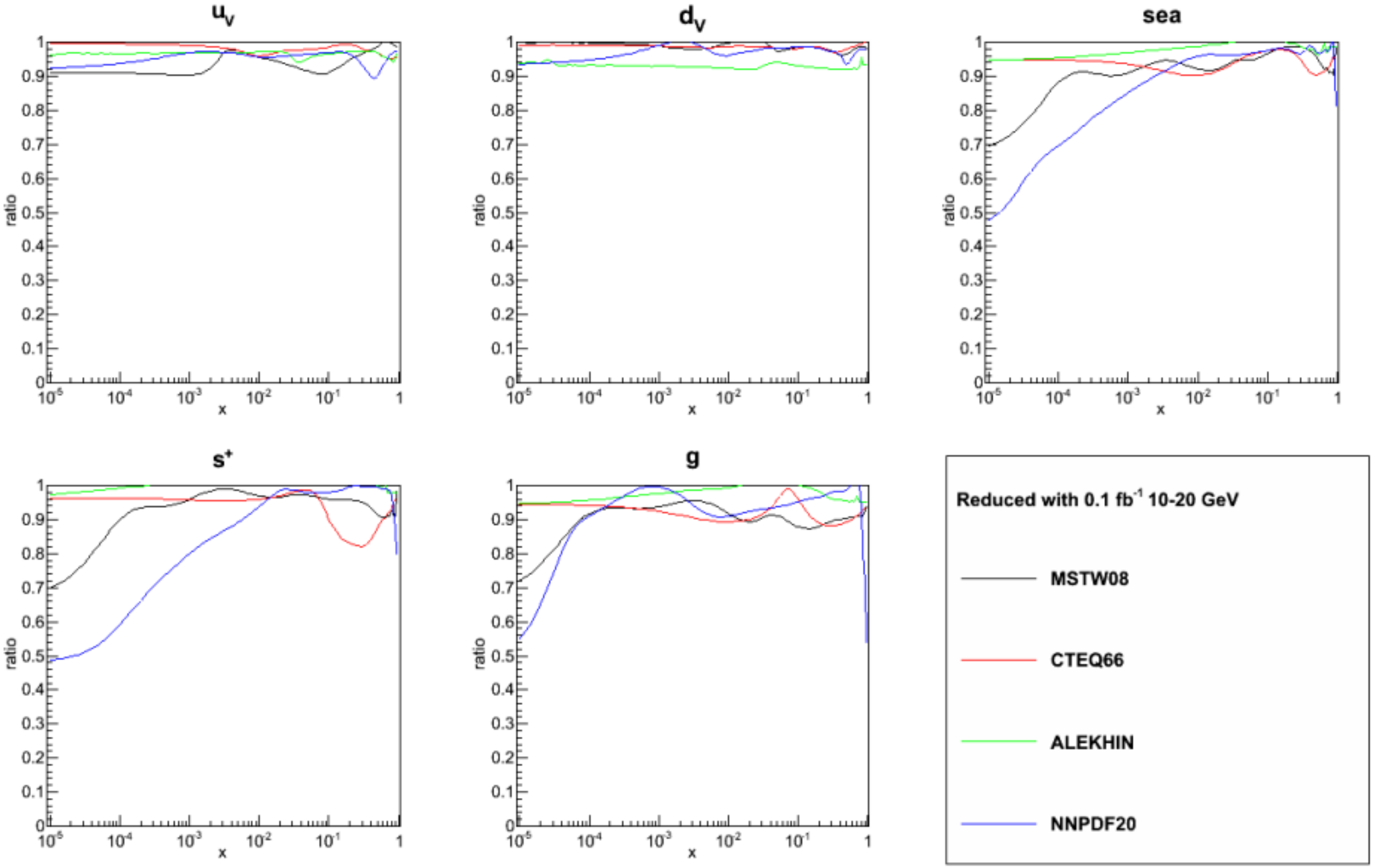
Impact on different PDF sets from low mass Drell-Yan production (10-20 GeV)



Possibility to distinguish between different models.

Conclusions

- **Silicon Tracker**
- Performance of the detectors is excellent
  - S/N 16-18 (IT), 13-15 (TT).
  - Efficiency measured to be > 99% with tracks.
- Lifetime of VCSEL diodes is a concern.
  - Repairs required during long shutdown.

- **Forward electroweak physics**
- LHCb can access a unique kinematic region
- Rapidly collecting large W, Z and low mass Drell-Yan samples with high purity.
  - 10^5 Zs, 10^6 Ws and 10^6 low mass Drell-Yan by end of 2011
- Large improvements in PDFs from 100 pb^{-1}.
  - Low mass Drell-Yan data provides strongest constraints at low x.

You want more?

Really?

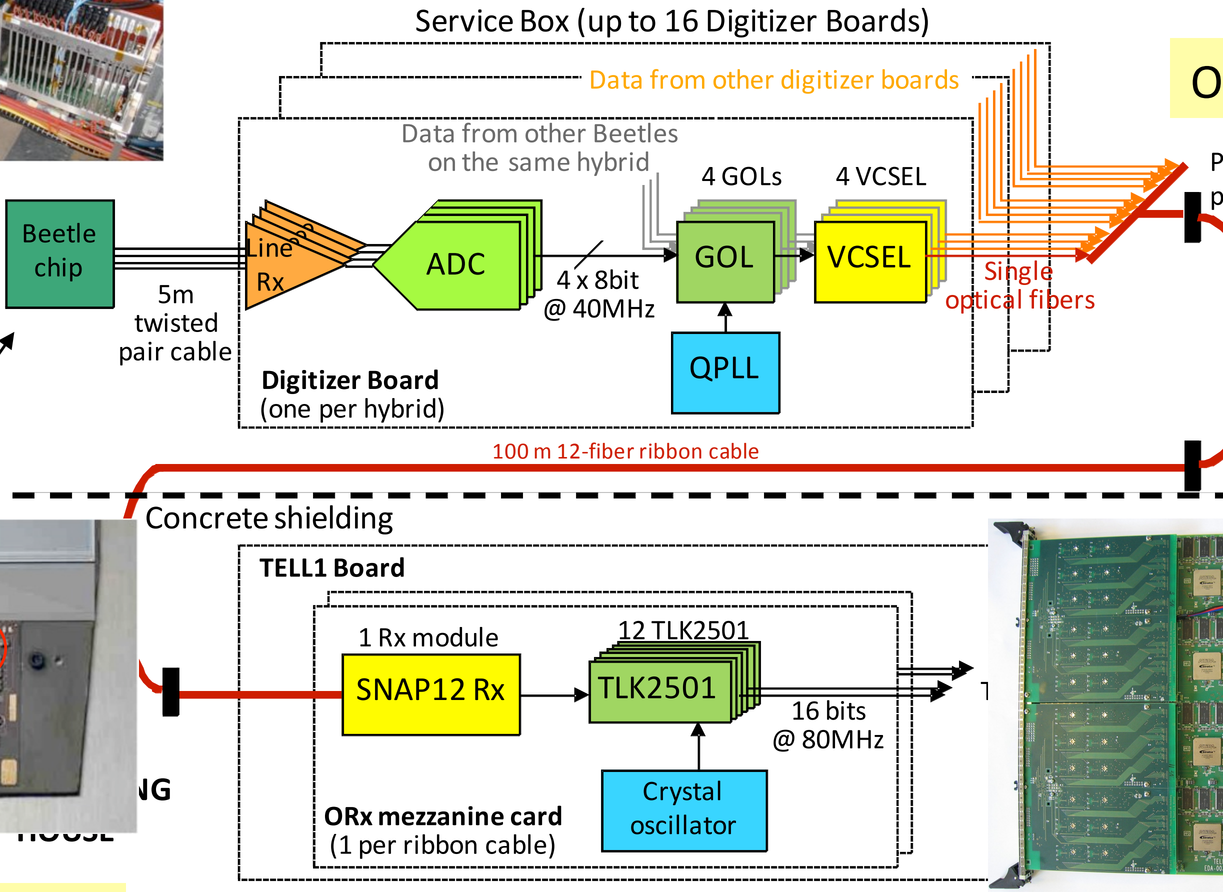
BACK UP

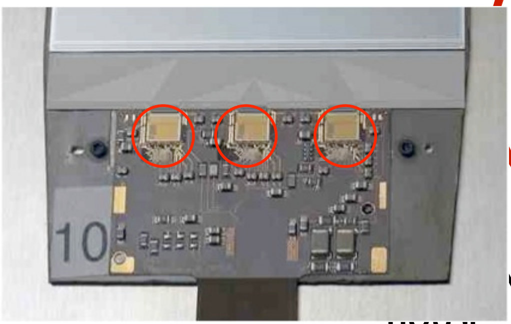
Readout chain

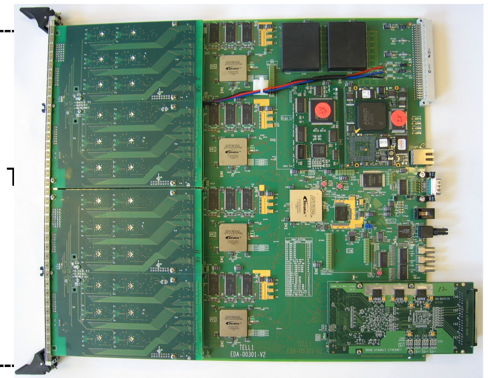
From Matt Needham talk at Vertex 2010

Digitization: Service box near detector 15 krad in 10 years

Optical link







Front end on detector
< 1 Mrad in 10 years

Tell1 readout boards in counting House: Zero Suppression

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Broken bonds in TT

- Problem seen on 9 hybrids:
  - Bonds break on innermost layer.
  - Effect not reproducible in lab.
  - Majority of problems after installation.
- Possible causes:
  - Cracks in initial bonding process.
  - Loop heights too low: should be > 25% of bond spacing.
  - Vibrations/Thermal cycling.

bond row	distance between bond pads	bond loop height above pitch adaptor
innermost	1.35 mm	0.48 mm
second	1.70 mm	0.66 mm
third	2.05 mm	0.84 mm
outermost	2.40 mm	1.02 mm

Bond heights for innermost bonds are tight, but if increased outermost bonds become too high

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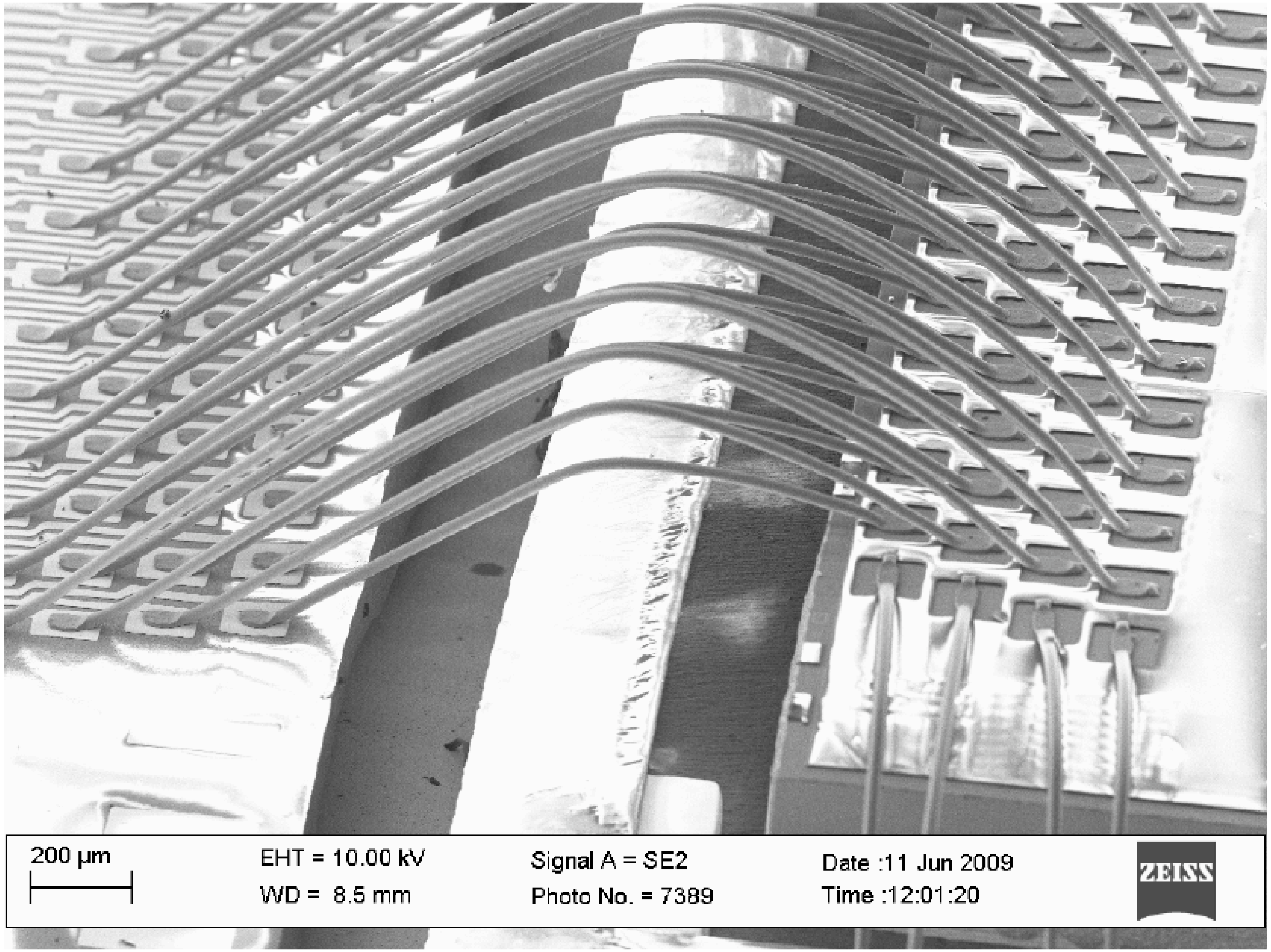
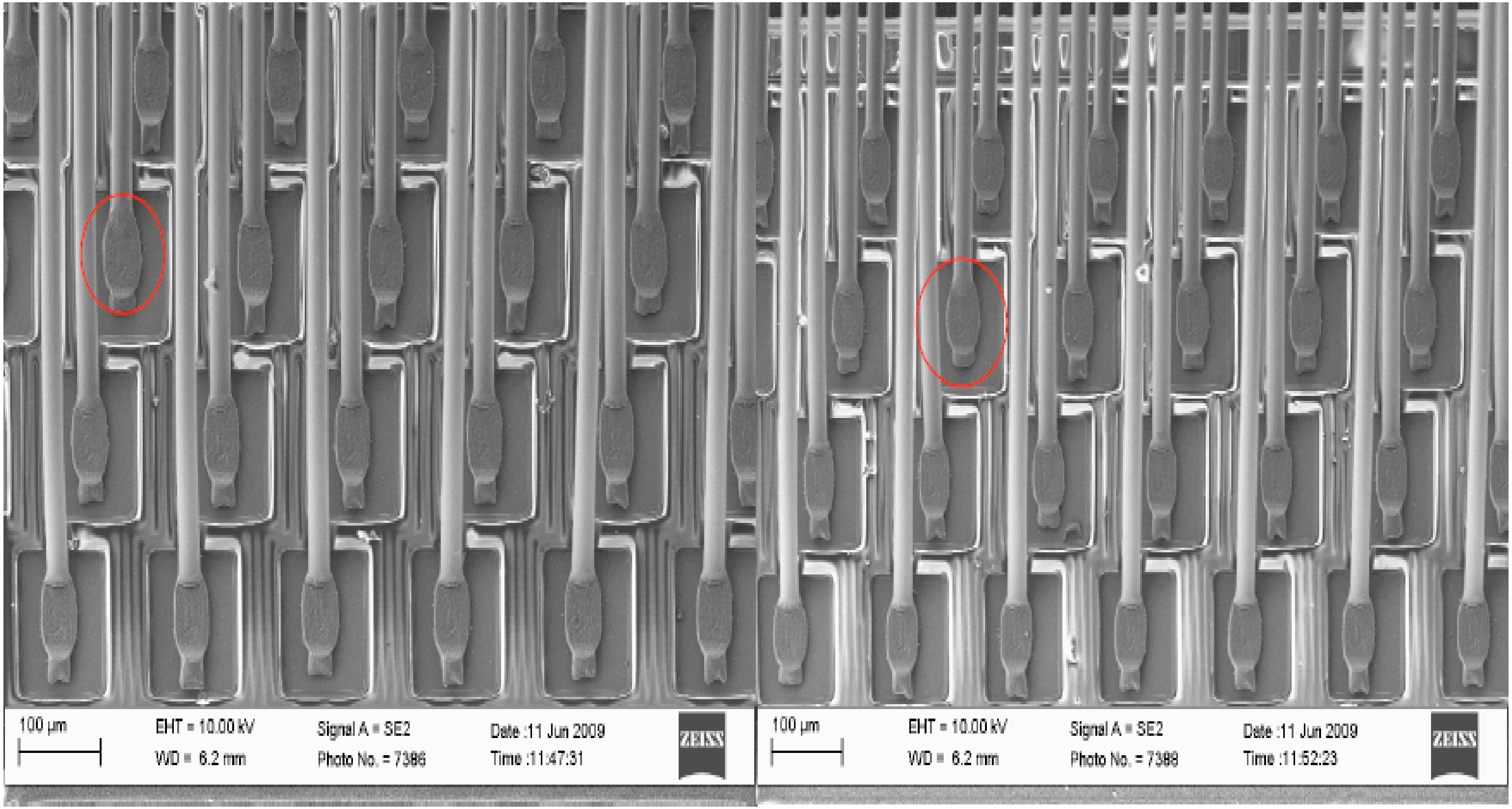
Broken bonds in TT



It was not possible to take a picture from a better angle because of collisions with the elektron gun.
So I can't quantify the loop height of the bonds.

Broken bonds in TT



A lot of cracks on the Beetle side. Only two proper bonds, marked with a circle.

SEM picture from Stefan Steiner