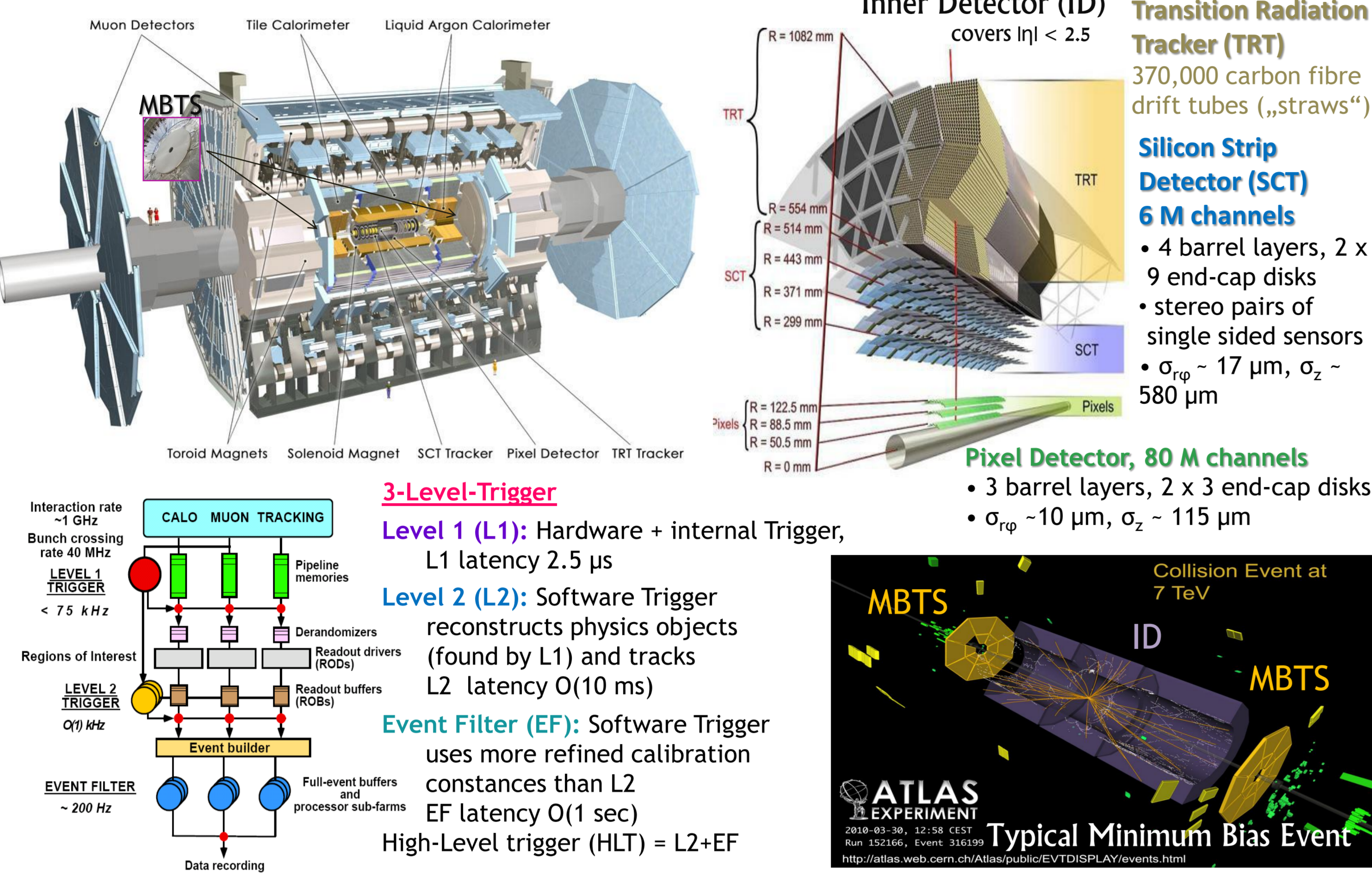# Minimum Bias InteractionTriggers in ATLAS

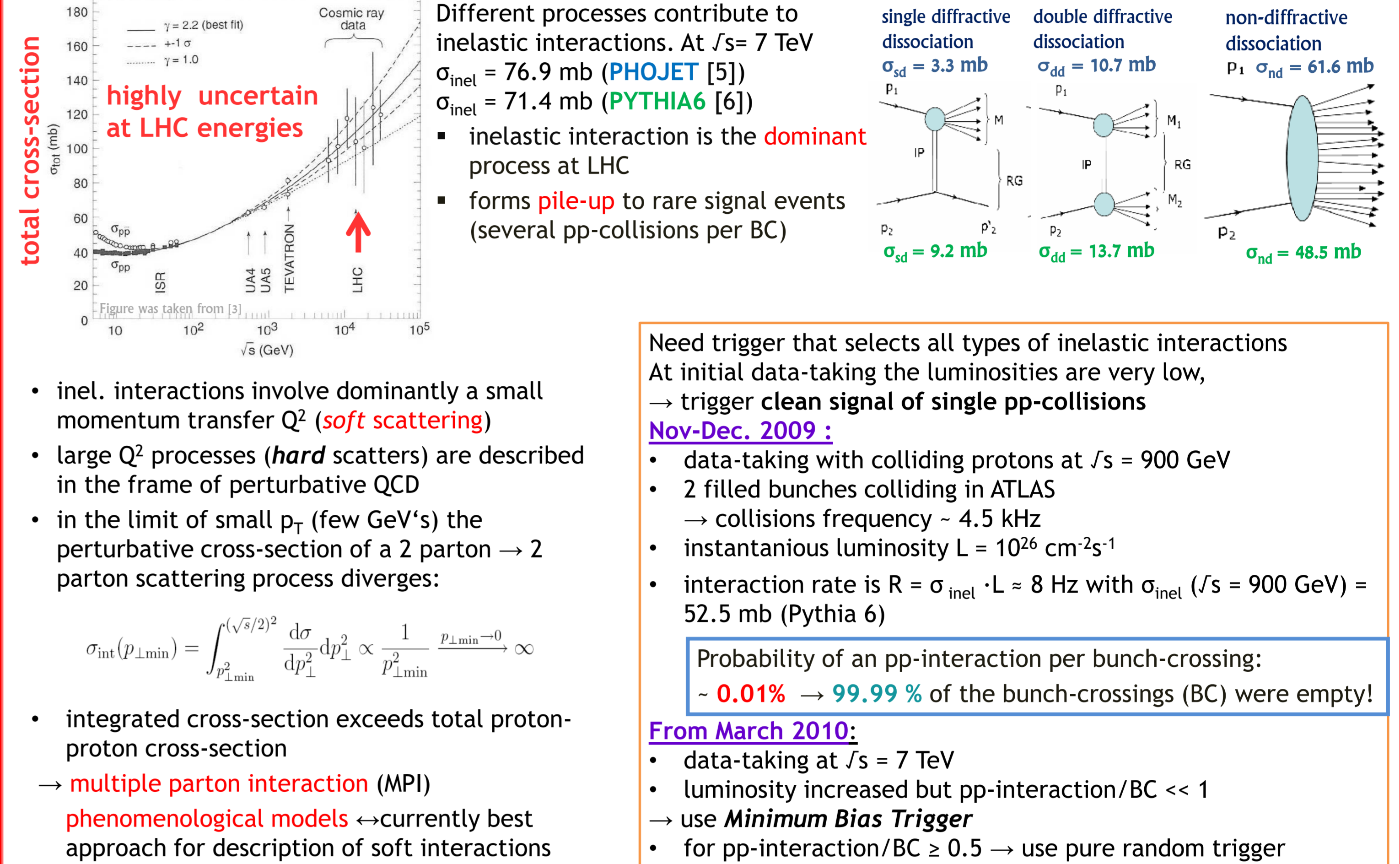Regina E. Kwee, CERN/Humboldt-University of Berlin
for the ATLAS-Collaboration

The Detector and Trigger System
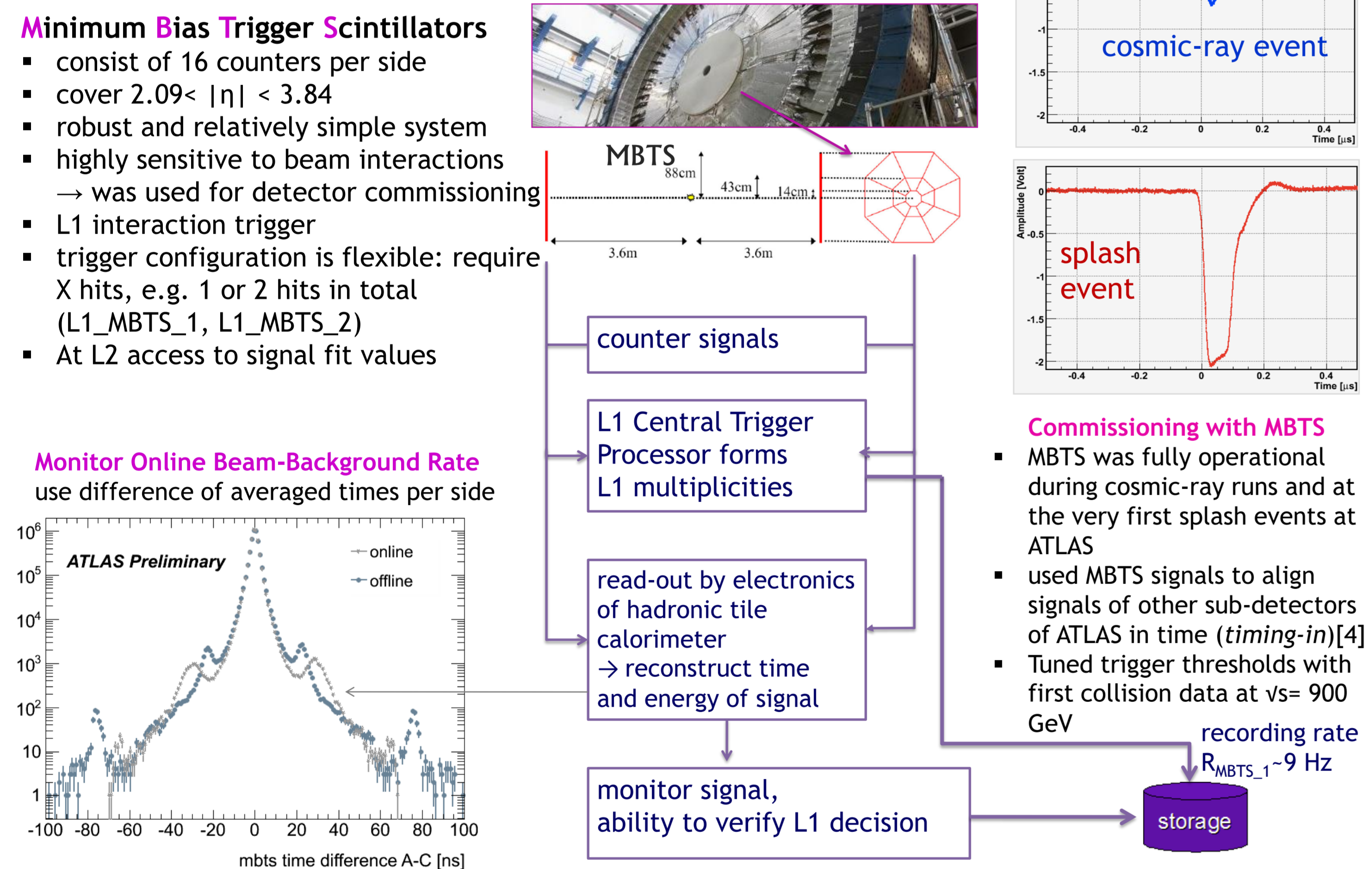
Inner Detector (ID) covers $|\eta| < 2.5$

Transition Radiation Tracker (TRT) 370,000 carbon fibre drift tubes („straws")

Silicon Strip Detector (SCT) 6 M channels
- 4 barrel layers, 2 x 9 end-cap disks
- stereo pairs of single sided sensors
- $\sigma_{r\phi} \sim 17$ μm, $\sigma_z \sim 580$ μm

Pixel Detector, 80 M channels
- 3 barrel layers, 2 x 3 end-cap disks
- $\sigma_{r\phi} \sim 10$ μm, $\sigma_z \sim 115$ μm

3-Level-Trigger

Level 1 (L1): Hardware + internal Trigger, L1 latency 2.5 μs

Level 2 (L2): Software Trigger reconstructs physics objects (found by L1) and tracks L2 latency O(10 ms)

Event Filter (EF): Software Trigger uses more refined calibration constances than L2 EF latency O(1 sec) High-Level trigger (HLT) = L2+EF

Typical Minimum Bias Event

see also talk by John Baines about *Performance of the ATLAS Trigger with Proton Collisions at the LHC*

Physics Motivation and Trigger Scenarios
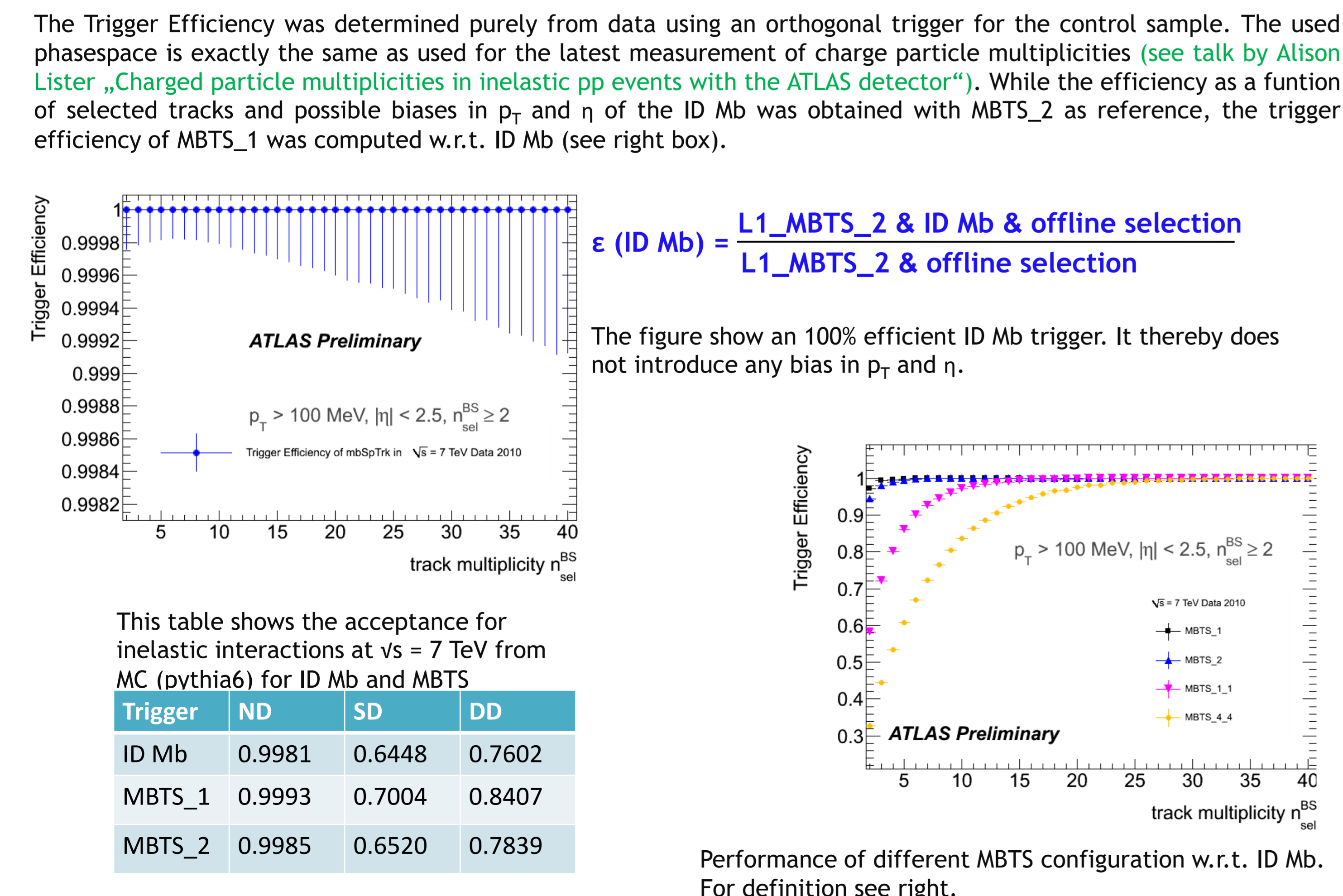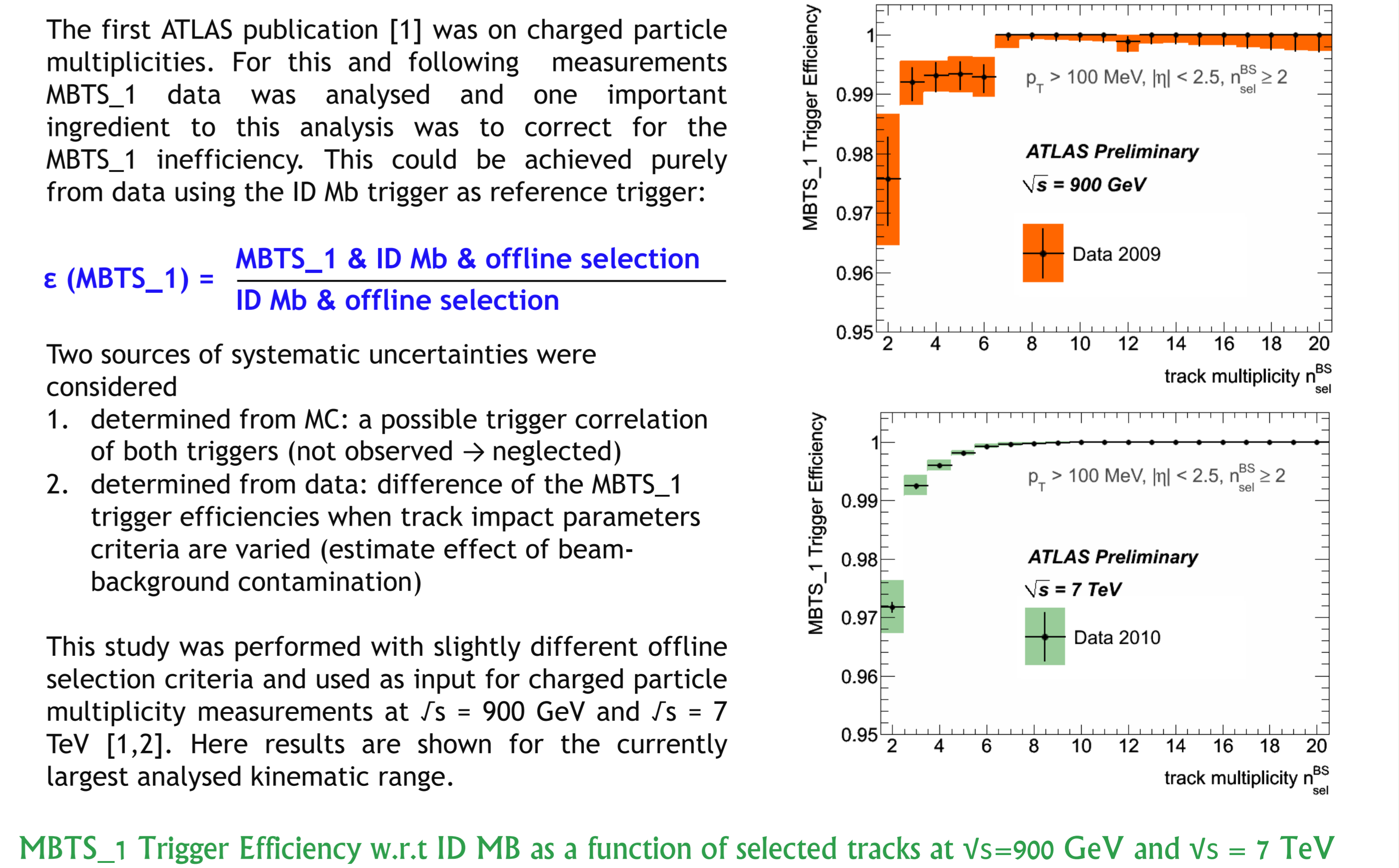
highly uncertain at LHC energies

Different processes contribute to inelastic interactions. At $\sqrt{s}$= 7 TeV
σ_{inel} = 76.9 mb (PHOJET [5])
σ_{inel} = 71.4 mb (PYTHIA6 [6])
- inelastic interaction is the **dominant** process at LHC
- forms pile-up to rare signal events (several pp-collisions per BC)

single diffractive dissociation σ_{sd} = 3.3 mb
double diffractive dissociation σ_{dd} = 10.7 mb
non-diffractive dissociation σ_{nd} = 61.6 mb

σ_{sd} = 9.2 mb σ_{dd} = 13.7 mb σ_{nd} = 48.5 mb

- inel. interactions involve dominantly a small momentum transfer Q^2 (*soft scattering*)
- large Q^2 processes (*hard* scatters) are described in the frame of perturbative QCD
- in the limit of small p_T (few GeV's) the perturbative cross-section of a 2 parton → 2 parton scattering process diverges:

$$\sigma_{int}(p_{\perp min}) = \int_{p_{\perp min}^2}^{(\sqrt{s}/2)^2} \frac{d\sigma}{dp_\perp^2} dp_\perp^2 \propto \frac{1}{p_{\perp min}^2} \xrightarrow{p_{\perp min}\to 0} \infty$$

- integrated cross-section exceeds total proton-proton cross-section
→ **multiple parton interaction** (MPI) phenomenological models ↔ currently best approach for description of soft interactions

Need trigger that selects all types of inelastic interactions At initial data-taking the luminosities are very low, → trigger **clean signal of single pp-collisions**

Nov-Dec. 2009 :
- data-taking with colliding protons at $\sqrt{s}$ = 900 GeV
- 2 filled bunches colliding in ATLAS → collisions frequency ~ 4.5 kHz
- instantanious luminosity L = 10^{26} cm^{-2}s^{-1}
- interaction rate is R = σ_{inel} ·L ≈ 8 Hz with σ_{inel} ($\sqrt{s}$ = 900 GeV) = 52.5 mb (Pythia 6)

Probability of an pp-interaction per bunch-crossing: ~ **0.01%** → **99.99 %** of the bunch-crossings (BC) were empty!

From March 2010:
- data-taking at $\sqrt{s}$ = 7 TeV
- luminosity increased but pp-interaction/BC << 1
→ use **Minimum Bias Trigger**
- for pp-interaction/BC ≥ 0.5 → use pure random trigger

Minimum Bias Trigger Scintillators

Minimum **B**ias **T**rigger **S**cintillators
- consist of 16 counters per side
- cover 2.09< $|\eta|$ < 3.84
- robust and relatively simple system
- highly sensitive to beam interactions → was used for detector commissioning
- L1 interaction trigger
- trigger configuration is flexible: require X hits, e.g. 1 or 2 hits in total (L1_MBTS_1, L1_MBTS_2)
- At L2 access to signal fit values

scope traces of an MBTS signal

cosmic-ray event

splash event

Commissioning with MBTS
- MBTS was fully operational during cosmic-ray runs and at the very first splash events at ATLAS
- used MBTS signals to align signals of other sub-detectors of ATLAS in time (*timing-in*)[4]
- Tuned trigger thresholds with first collision data at $\sqrt{s}$= 900 GeV

counter signals

L1 Central Trigger Processor forms L1 multiplicities

Monitor Online Beam-Background Rate use difference of averaged times per side

read-out by electronics of hadronic tile calorimeter → reconstruct time and energy of signal

monitor signal, ability to verify L1 decision

recording rate R_{MBTS_1} ~9 Hz

storage

ATLAS Preliminary

mbts time difference A-C [ns]

Inner Detector based Minimum Bias Trigger

HLT selection of inelastic events with Inner Detector based Minimum Bias Trigger ID Mb:
→ **L1: Random Trigger on colliding bunches**
→ **L2-Spacepoints (3D-hits)** at least 4 pixel clusters with enough deposited charge & 4 SCT spacepoints in whole ID range of $|\eta|$ < 2.5
→ **1 EF-track in silicon detector** switched off for this year runs due to low beam-background rates

bunch-crossings

L1 Random Trigger

SpacePoint Counter L2 rejects empty events

Track Counter EF rejects beam-gas events

storage

recording rate $R_{ID\ Mb}$ ~3 Hz

Commissioning of ID Mb Trigger
- deployment during cosmic ray data-taking
- development of validation, online- and offline monitoring tools and analysis frame for fast performance feedback

Robustness
- several fall-back configurations for different beam background conditions
- possibility to monitor noisy modules of pixel and SCT detector
- test of trigger in dedicated technical runs in „stress-scenarios":
→ running trigger at high input rates, reading out the **full** silicon detector
→ running trigger on very busy MC events

Noise occupancy in Pixel Detector
Pixel Detector occupancy in randomly triggered events with empty bunches. Noise rate is dominated by few pixels (300-1500 out of 80M) which are detected on a run-by-run basis by offline prompt calibration and masked during the bulk processing. For the bulk processing, the remaining noise occupancy is <10-9 hit/ pixel/BC, corresponding to <0.2 noise hits per event when reading out 5 BC. The runs shown correspond to the data taking period 18th April – 9th May 2010

ATLAS Preliminary

- Raw hits
- First pass reconstruction
- Bulk reconstruction

Run number

Trigger Efficiency Measurements

The Trigger Efficiency was determined purely from data using an orthogonal trigger for the control sample. The used phasespace is exactly the same as used for the latest measurement of charge particle multiplicities (see talk by Alison Lister „Charged particle multiplicities in inelastic pp events with the ATLAS detector"). While the efficiency as a funtion of selected tracks and possible biases in p_T and η of the ID Mb was obtained with MBTS_2 as reference, the trigger efficiency of MBTS_1 was computed w.r.t. ID Mb (see right box).

$$\epsilon\ (ID\ Mb) = \frac{L1\_MBTS\_2\ \&\ ID\ Mb\ \&\ offline\ selection}{L1\_MBTS\_2\ \&\ offline\ selection}$$

The figure show an 100% efficient ID Mb trigger. It thereby does not introduce any bias in p_T and η.

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p_T > 100 MeV, $|\eta|$ < 2.5, $n_{sel}^{BS} \geq 2$

Trigger Efficiency of mbSpTrk in $\sqrt{s}$ = 7 TeV Data 2010

This table shows the acceptance for inelastic interactions at $\sqrt{s}$ = 7 TeV from MC (pythia6) for ID Mb and MBTS

Trigger	ND	SD	DD
ID Mb	0.9981	0.6448	0.7602
MBTS_1	0.9993	0.7004	0.8407
MBTS_2	0.9985	0.6520	0.7839

p_T > 100 MeV, $|\eta|$ < 2.5, $n_{sel}^{BS} \geq 2$

$\sqrt{s}$ = 7 TeV Data 2010
- MBTS_1
- MBTS_2
- MBTS_1_1
- MBTS_4_4

ATLAS Preliminary

Performance of different MBTS configuration w.r.t. ID Mb. For definition see right.

Use of Interaction Triggers: Measurements of Charged Particle Properties

The first ATLAS publication [1] was on charged particle multiplicities. For this and following measurements MBTS_1 data was analysed and one important ingredient to this analysis was to correct for the MBTS_1 inefficiency. This could be achieved purely from data using the ID Mb trigger as reference trigger:

$$\epsilon\ (MBTS\_1) = \frac{MBTS\_1\ \&\ ID\ Mb\ \&\ offline\ selection}{ID\ Mb\ \&\ offline\ selection}$$

Two sources of systematic uncertainties were considered
1. determined from MC: a possible trigger correlation of both triggers (not observed → neglected)
2. determined from data: difference of the MBTS_1 trigger efficiencies when track impact parameters criteria are varied (estimate effect of beam-background contamination

This study was performed with slightly different offline selection criteria and used as input for charged particle multiplicity measurements at $\sqrt{s}$ = 900 GeV and $\sqrt{s}$ = 7 TeV [1,2]. Here results are shown for the currently largest analysed kinematic range.

p_T > 100 MeV, $|\eta|$ < 2.5, $n_{sel}^{BS} \geq 2$

ATLAS Preliminary $\sqrt{s}$ = 900 GeV Data 2009

ATLAS Preliminary $\sqrt{s}$ = 7 TeV Data 2010

MBTS_1 Trigger Efficiency w.r.t ID MB as a function of selected tracks at $\sqrt{s}$=900 GeV and $\sqrt{s}$ = 7 TeV

References:
[1] arXiv:1003.3124; CERN-PH-EP-2010-004; Phys Lett B 688, Issue 1, 21-42 [2] ATLAS-CONF-2010-024 [3] V. Barone and E.Predazzi, High-Energy Paricle Diraction, Springer-Verlag Berlin Heidelberg, 2002 [4] A. Messina, Commissioning of the ATLAS Level-1 Central Trigger, TWEPP 2008 [5] R. Engel, http: //lepton.bartol.udel.edu/~eng/phojet.html, Phojet source code and write-up [6] T. Sjostrand, S. Mrenna, P. Skands, PYTHIA 6.4 physics and manual, JHEP 05 (2006) 026