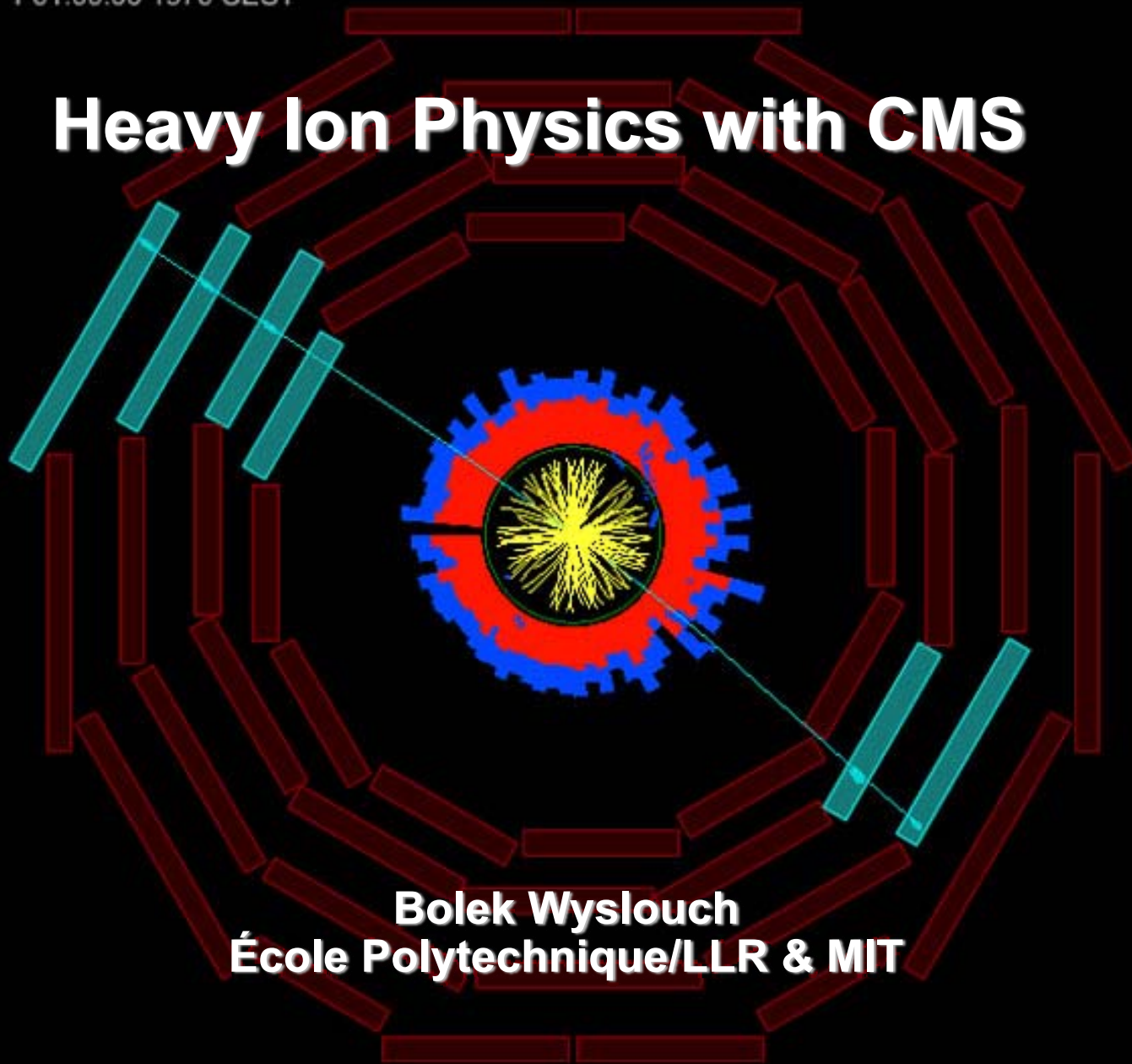


CMS Experiment at LHC, CERN
Data recorded: Thu Jan 1 01:00:00 1970 CEST
Run/Event: 1 / 39
Lumi section: 666685

Heavy Ion Physics with CMS

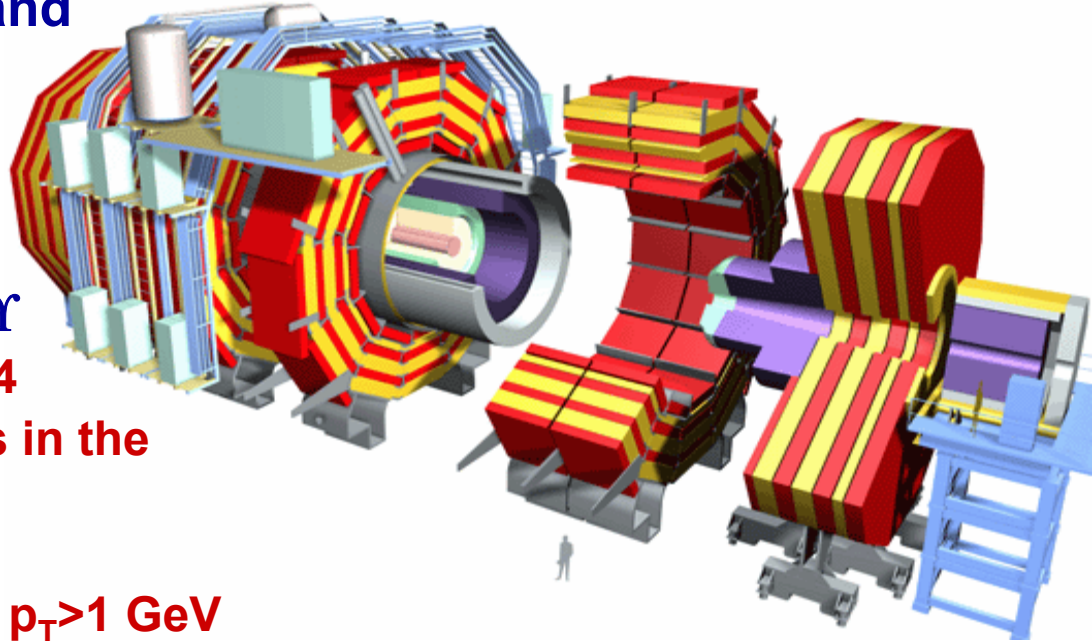


Bolek Wyslouch
École Polytechnique/LLR & MIT



CMS as a heavy ion experiment

- **Calorimeters: high resolution and segmentation**
 - Hermetic coverage up to $|\eta| < 5$
 - $-5.2 < \eta < -6.6$ with CASTOR
 - Zero Degree Calorimeter
- **Muon tracking: μ from Z^0 , J/ψ , Υ**
 - Wide rapidity coverage: $|\eta| < 2.4$
 - $\sigma_m \approx O(100)$ MeV at the Υ mass in the barrel
- **Silicon Tracker**
 - Good efficiency and purity for $p_T > 1$ GeV
 - Pixel occupancy: $< 2\%$ at $dN_{ch}/d\eta \approx 3500$
 - $\Delta p/p \approx 1-2\%$ for $p_T < 100$ GeV
 - Good low- p_T acceptance using pixels
- **DAQ and Trigger**
 - High rate capability for A+A, p+A, p+p
 - High Level Trigger: real time HI event reconstruction



Hermeticity, Resolution, Flexible Trigger and DAQ

CMS Heavy Ion Multi-Year Physics Plan

CMS



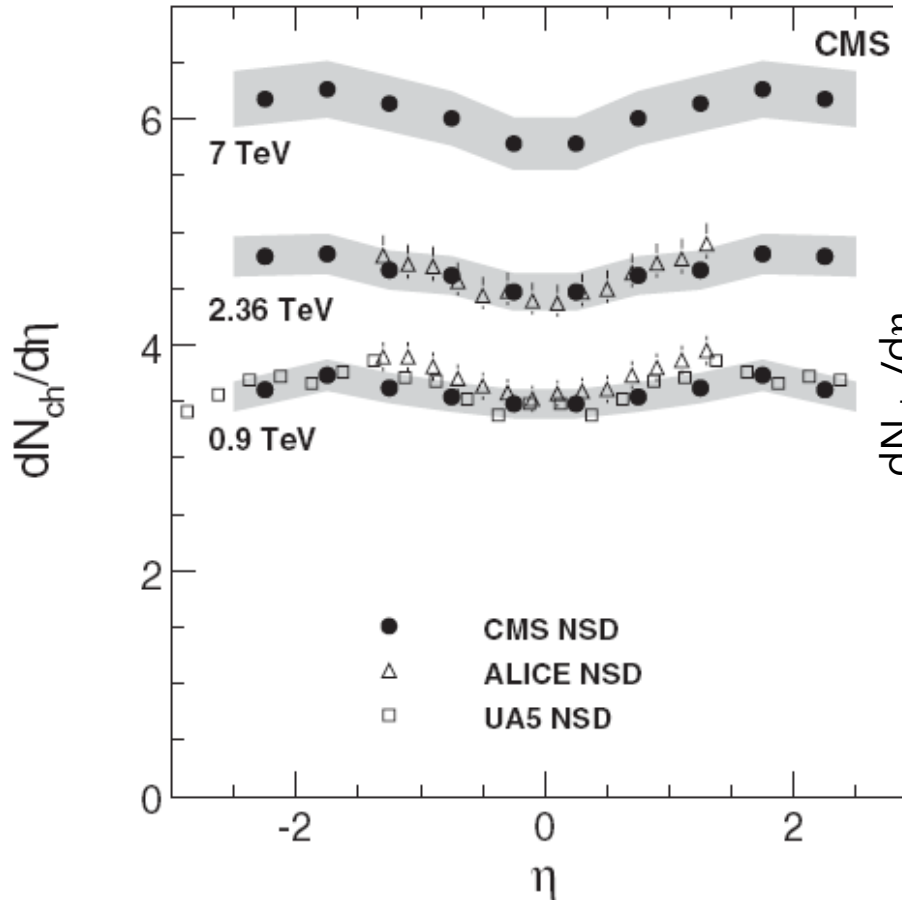
High Density QCD
with Heavy Ions

- Particle production: multiplicity, azimuthal asymmetry, particle spectra, photons
- Two particle correlations
- Jet physics: fragmentation, flavor dependence, jet+ γ , jet+ Z^0
- Quarkonia physics: J/ψ , Υ family
- Vector bosons: Z^0 production
- Forward Energy Flow
- Ultra Peripheral Collisions
- and more...

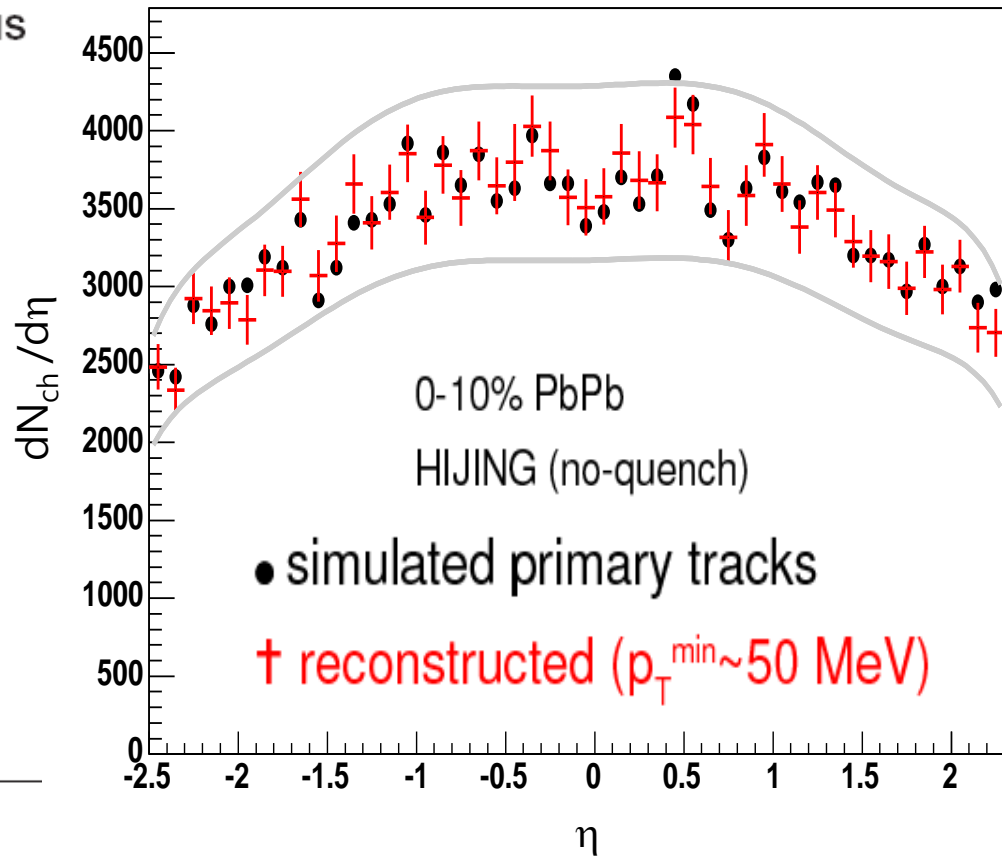
- Many simulations will be updated with better knowledge of multiplicity as soon as we get data. PTDR was at 5.5 TeV/A



Charged Particle Multiplicity



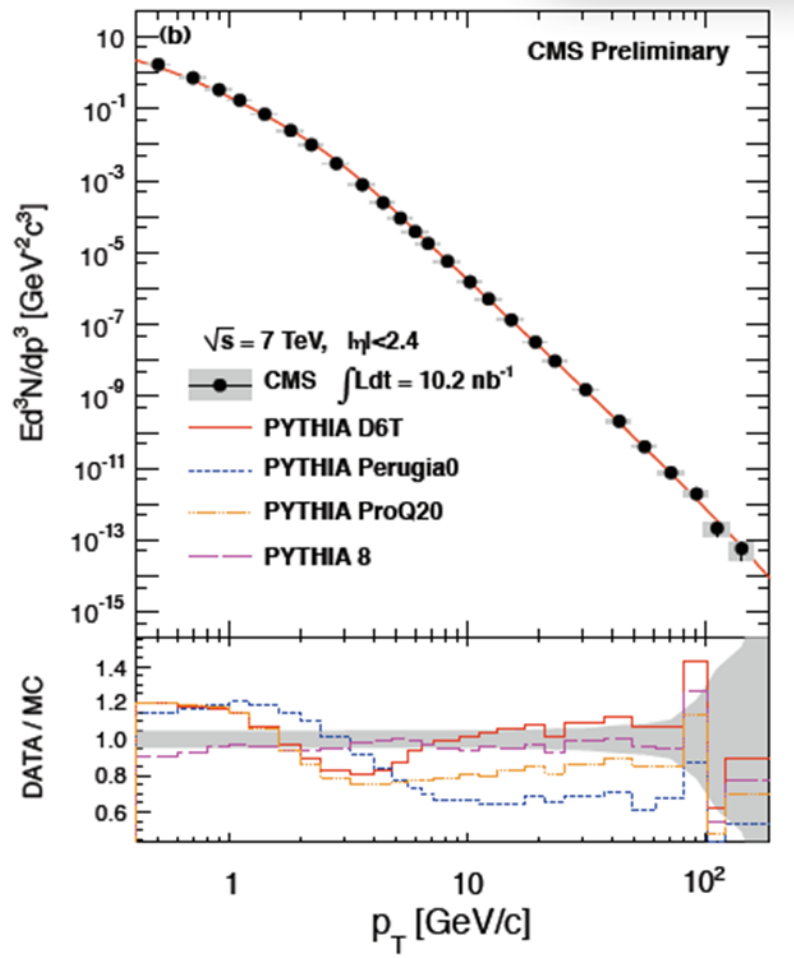
proton-proton data



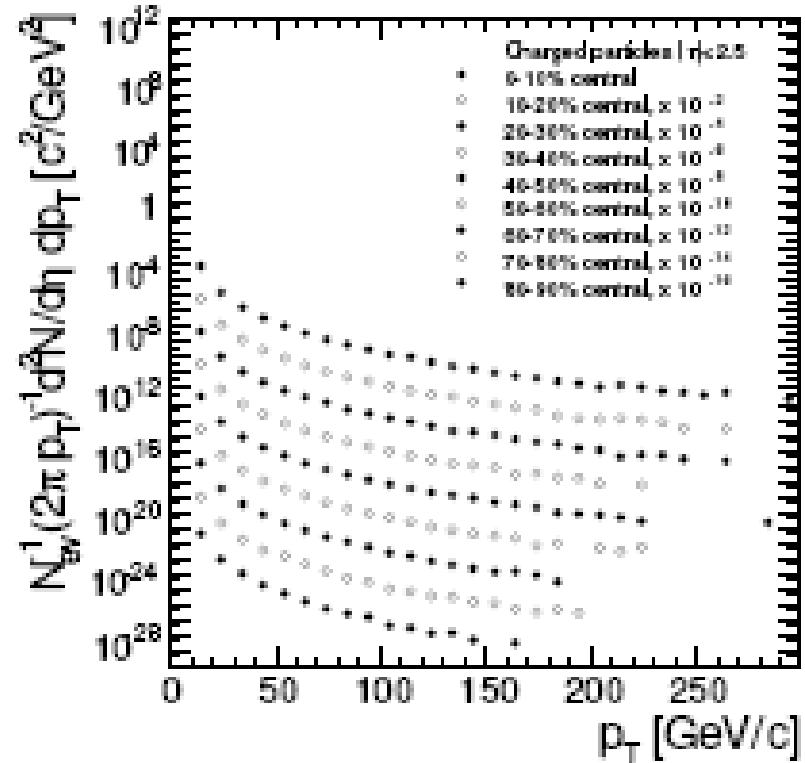
Pb-Pb simulation, PTDR



Charged Hadron Spectra p_T



CMS proton-proton data



Pb-Pb simulation



Two particle correlations

MinBias

(b) MinBias, $1.0\text{GeV}/c < p_T < 3.0\text{GeV}/c$

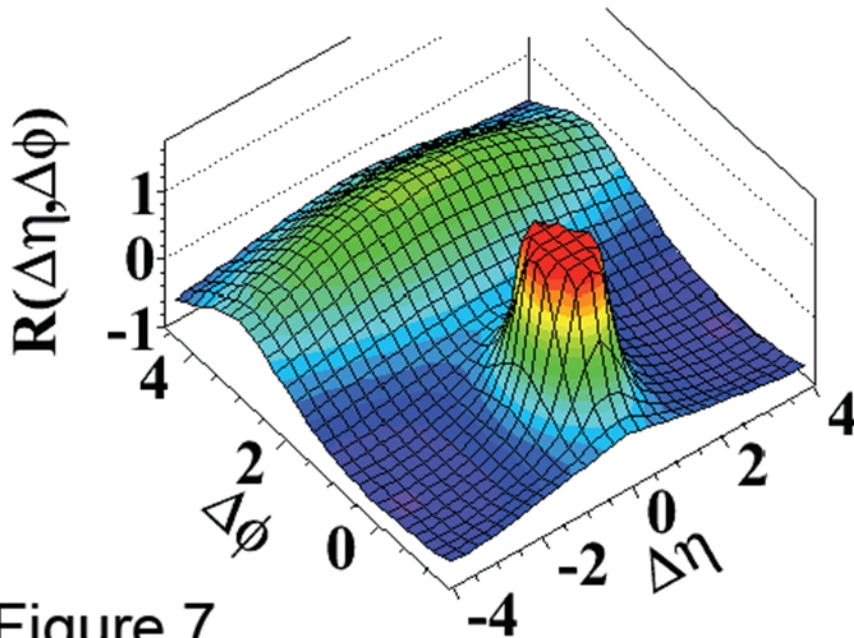
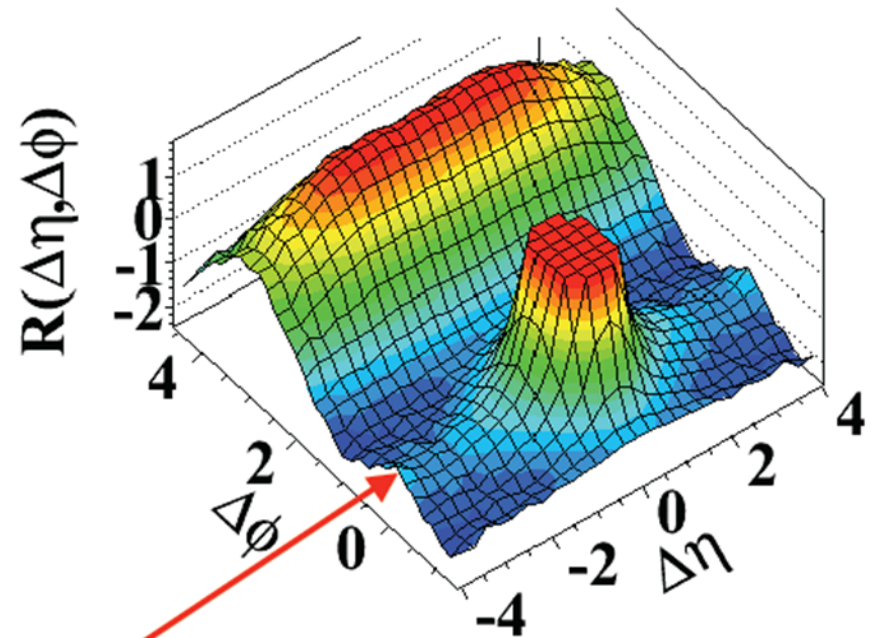


Figure 7

high multiplicity ($N > 110$)

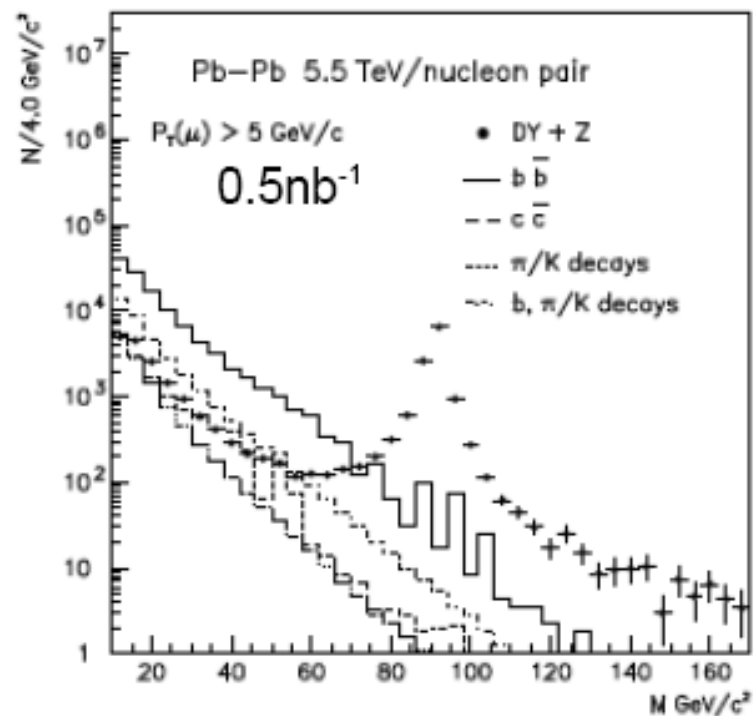
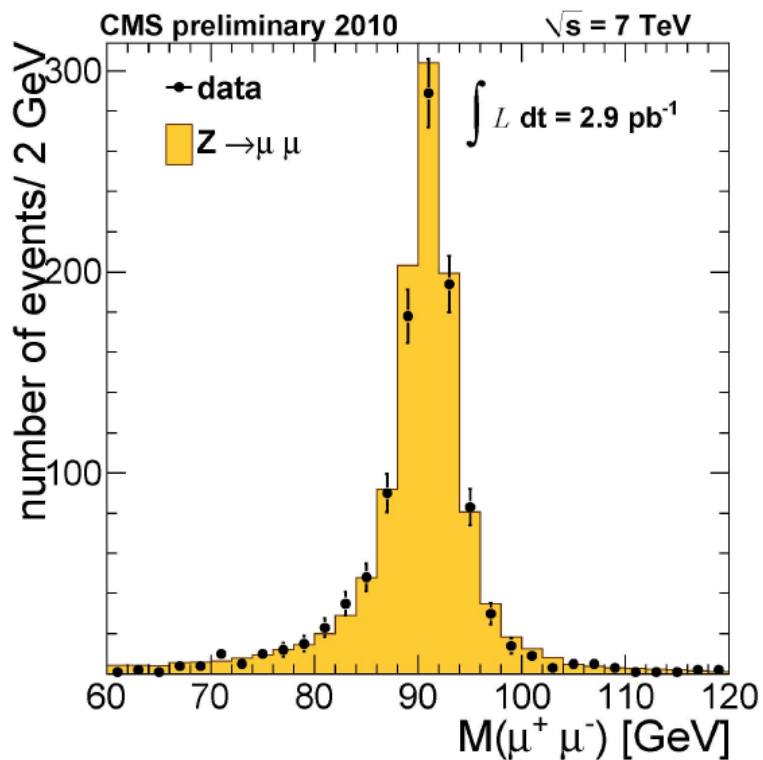
(d) $N > 110$, $1.0\text{GeV}/c < p_T < 3.0\text{GeV}/c$



CMS proton-proton data



Z⁰ production

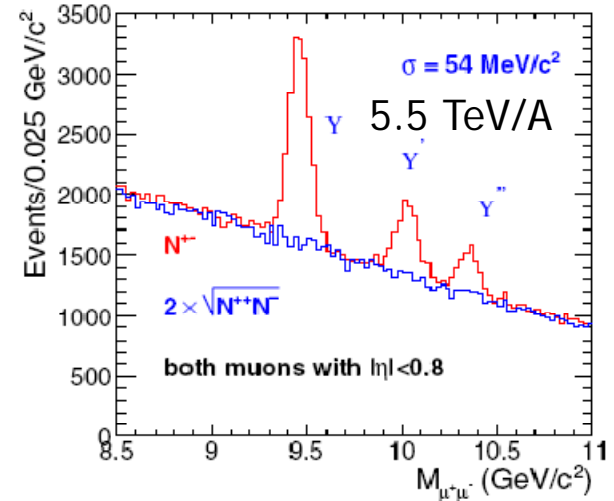
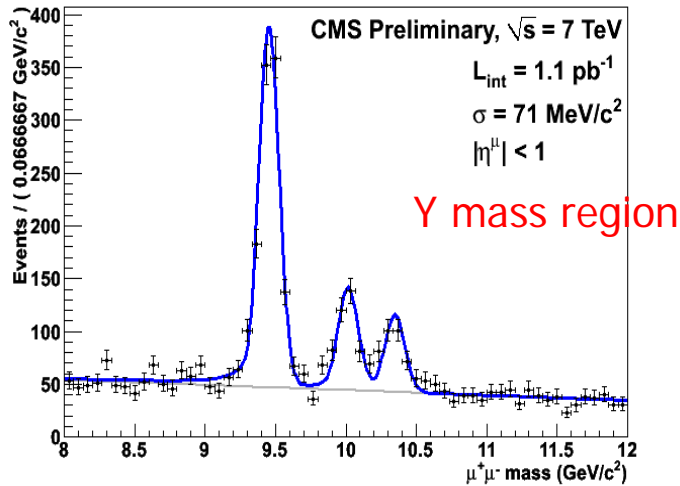
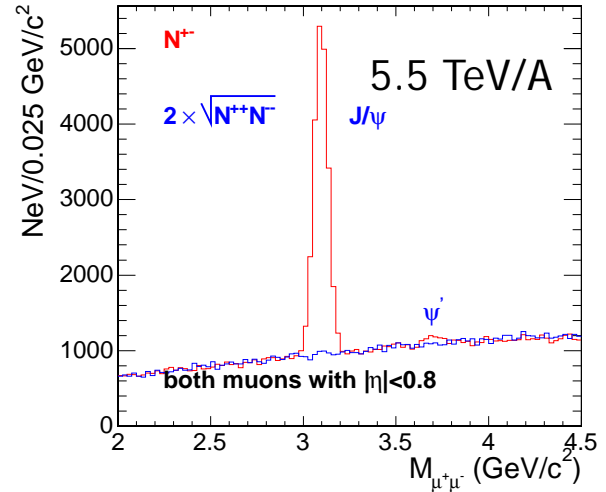
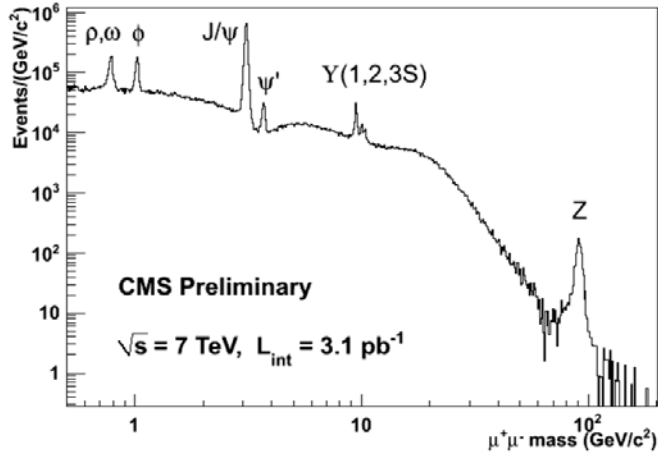


CMS proton-proton data

Pb-Pb simulation



Heavy Flavor (J/ψ , Υ)



CMS proton-proton data

Pb-Pb simulation, PTDR



Physics Plan for 2010

- **Physics driven by luminosity (and energy)**
- **First year expect $10^7 - 10^8$ collisions**
 - **Collect data at $O(100)$ Hz**
- **Enough data to conduct extensive studies of global properties of HI collisions**
- **Beginning of physics of rare probes: jets, quarkonia, Z^0**
- **CMS has already made several measurements in pp collisions that that can be used as references for HI**



Basic planning assumptions

- **Adjust CMS to collect larger events at lower rates**
 - Incremental changes to sub-detector configurations
 - Fine tuning of trigger and DAQ
 - Update software and computing to deal with the HI data
- **Preparations based on experience**
 - Many months of running with pp
 - Years of Monte Carlo simulations
 - First “reference” analyses of pp data
- **Uncertainties remain**
 - Much higher occupancies for most detector elements
 - Beam conditions
 - Luminosity and running time



Proposed CMS readout configuration

- **Pixels need to handle large events at low rate**
 - **Standard pp readout scheme but with trigger hold-off of 200-300 μ sec to prevent buffer overflows**
- **Silicon Strip Tracker**
 - **Due to very high occupancy in inner layers, we may experience significant baseline shifts and loss of some chip data due to highly ionizing particles.**
 - **Take non-zero suppressed data (Virgin Raw) and do offline baseline subtraction and chip signal recovery.**
 - **CMS has analog readout: we can apply sophisticated corrections if we have full data**
- **Electromagnetic and Hadronic Calorimeters**
 - **Take non-zero suppressed data to study and minimize biases in jet background subtraction**
- **Muon detectors**
 - **No change compared to pp**
- **NOTE: these changes are for 2010 only, use this year's data to optimize for future runs**



Running without zero suppression..

- **Decision to collect data in non-compressed mode has several important consequences**
 - **Event size will be about 12MB**
 - **DAQ peak writing rate is limited at Storage Manager to about 150 (200) Hz with (without) writing to Tier-0**
 - **Tape writing at Tier-0 is limited to 1.5 GB/sec, about 125 Hz**
 - **Total data volume may reach 1.5 PB with conservative assumptions**
 - **After zero suppression the data volume can be reduced by factor of 4 or more (after few weeks)**
- **We need to be prepared on several fronts**
 - **Optimize trigger: squeeze as many real collisions to tape as possible, aim for writing all MinBias events, we are prepared to do some HLT cleaning and selection at highest expected rates and depending on the background level**
 - **Make sure there is enough capacity at Tier-0 and Tier-1, preparing the workflow**
 - **Develop optimized zero suppression algorithm as soon as possible and permanently reduce overall data size**
- **We are expecting special test run with pp collisions shortly**



L1 and HLT triggers

- **Finalizing triggering scheme, customized trigger menu both at L1 and at High Level Trigger (HLT)**
 - **Aim to record all collisions**
 - **Expect up to ~50-140 Hz collisions. Maximum disk writing limit is 150 Hz (200 Hz with no Tier-0 transfers)**
 - **Preparing HLT trigger menus to deal with possible luminosity scenarios**
- **Arranging data streams, alignment and calibration etc.**
 - **Optimize data streams for HI physics plans**
 - **Converging on decisions about special calibration and alignment events, making sure we write only necessary things**



Trigger menu under development



The Menu



- “Min Bias” and monitoring triggers:
 - HLT_ZeroBias
 - HLT_ZeroBiasPixel_SingleTrack
 - HLT_HIMinBiasBSC
 - HLT_HIMinBiasCalo
 - HLT_MinBiasPixel_SingleTrack
 - HLT_L1Tech_HCAL_HF
 - HLT_L1ETT30
 - HLT_L1Tech_BSC_minBias
 - HLT_L1Tech_BSC_highmult
- “Physics” Triggers
 - HLT_HIJet35U
 - HLT_HIPhoton15
 - HLT_L1DoubleMuOpen
 - HLT_HIUpcEcal
 - HLT_HIUpcMu
- Activity Triggers
 - HLT_HIActivityPixels
 - HLT_HIActivityPixel_SingleTrack
 - HLT_HIActivityHF_Single3
 - HLT_HIActivityHF_Coincidence3
- AICa Triggers
 - AICa_HICentralityVeto

Example: special trigger to mark peripheral or pp-like events for calibrations



Offline Software

- **Coordinated effort to ensure all HI-specific code -- reco, gen, sim, db, alca, dqm, ana, hlt -- is prepared and integrated into next expected software release: 39X**
 - **Most code is re-used from pp but with adjusted configurations e.g. tighter quality criteria for fitted tracks**
 - **Few special purpose HI codes**
 - ◆ Centrality/impact parameter determination
 - ◆ Reaction plane calculation
 - ◆ Special silicon strip tracker zero suppression
- **HI-specific software has been integrated in the official releases for the last year or more**
- **Both simulation and reconstruction are integrated in standard CMS framework**
 - **Large scale HI MC simulation and reconstruction are run routinely in CMS**
 - **We expect prompt reconstruction to run smoothly on Tier-0**



Summary

- **Making steady progress on preparations**
- **The accelerator schedule and expected performance is quite uncertain, we are being conservative in our expectations**
- **We expect to collect non-zero-suppressed pp data, this will provide important input to preparations**
- **We are finalizing plans for calibrations, trigger, computing**
- **We will be ready to collect and analyze first heavy ion data from LHC**

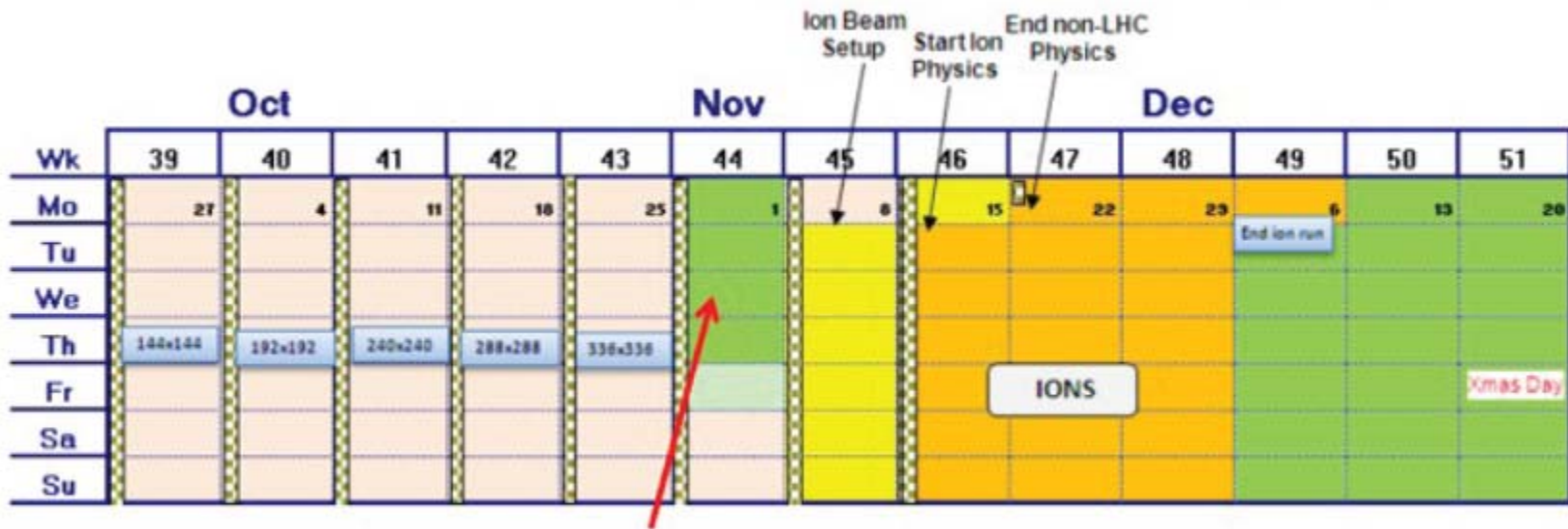


Backup



Schedule and startup plan for CMS

- **Schedule is still in a bit of flux**
 - **We need to plan for 3-3.5 solid weeks of running starting around 10-15 of November**

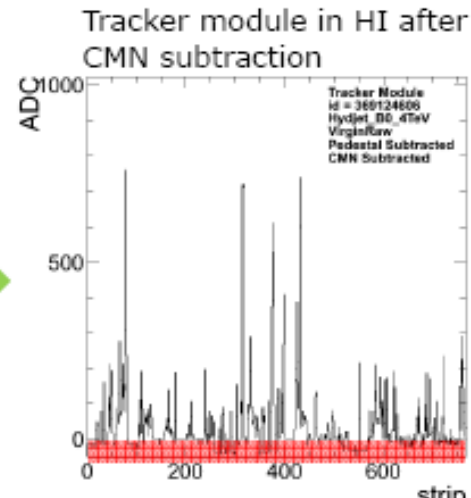
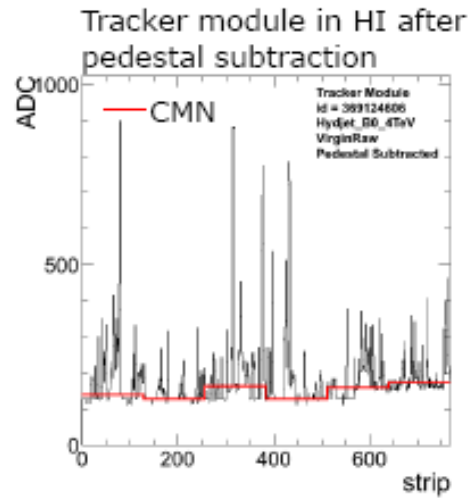
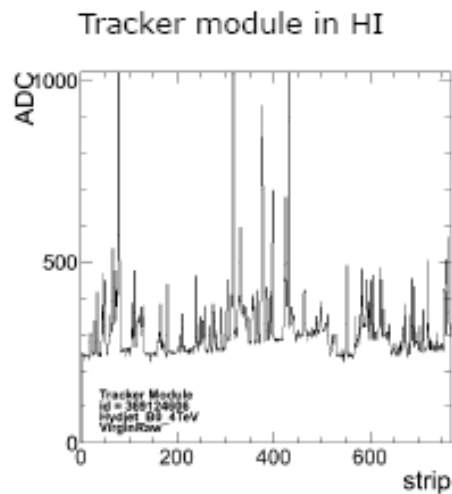
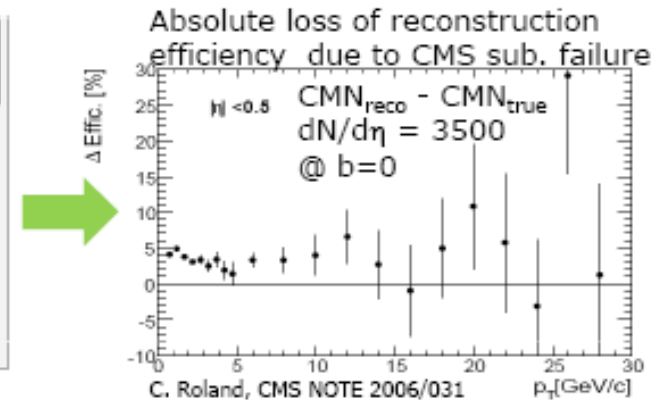
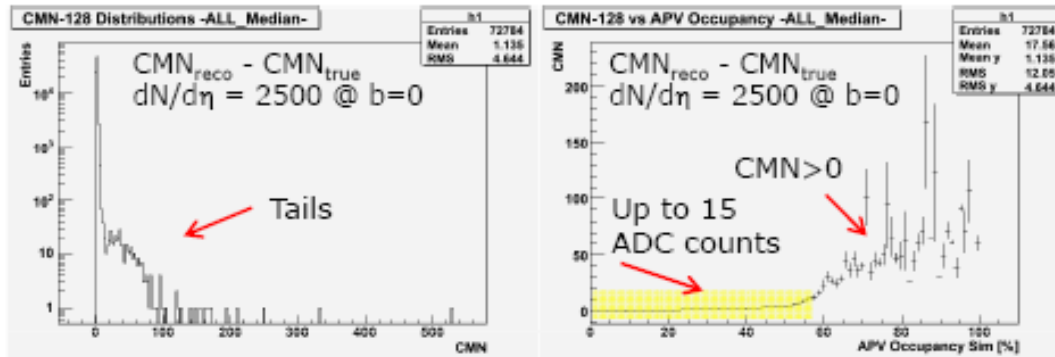


- **Luminosity estimates still vary by factors of 2 or more**
 - **Recent proposal to collide up to 140 bunches will result in luminosity of about $1.5 \cdot 10^{25}$**
 - **Prepare for over 100 Hz collisions in CMS**



Why Tracker VR? Example: Common Mode Noise

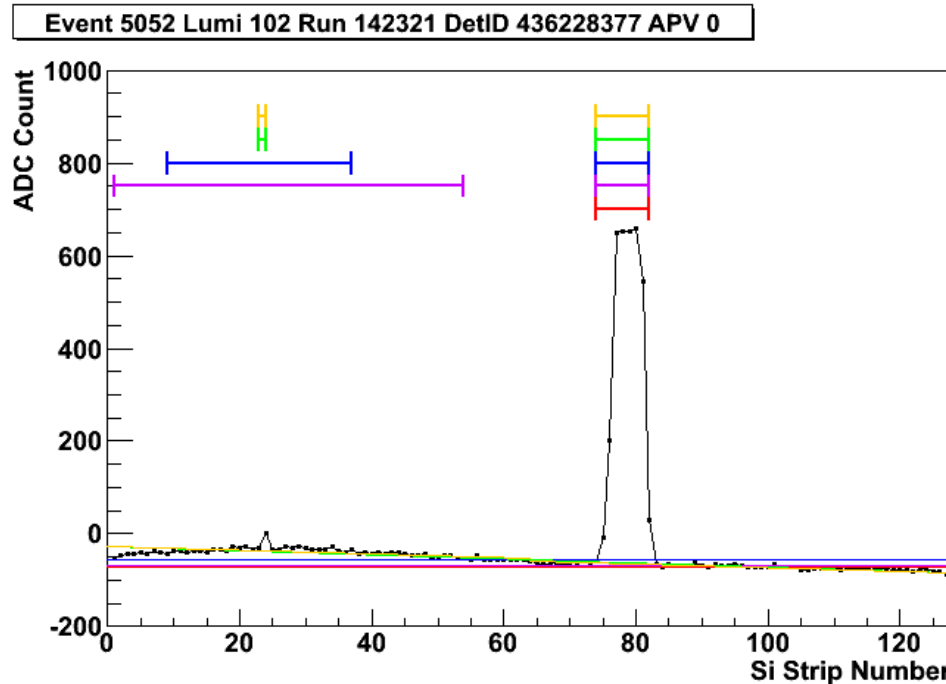
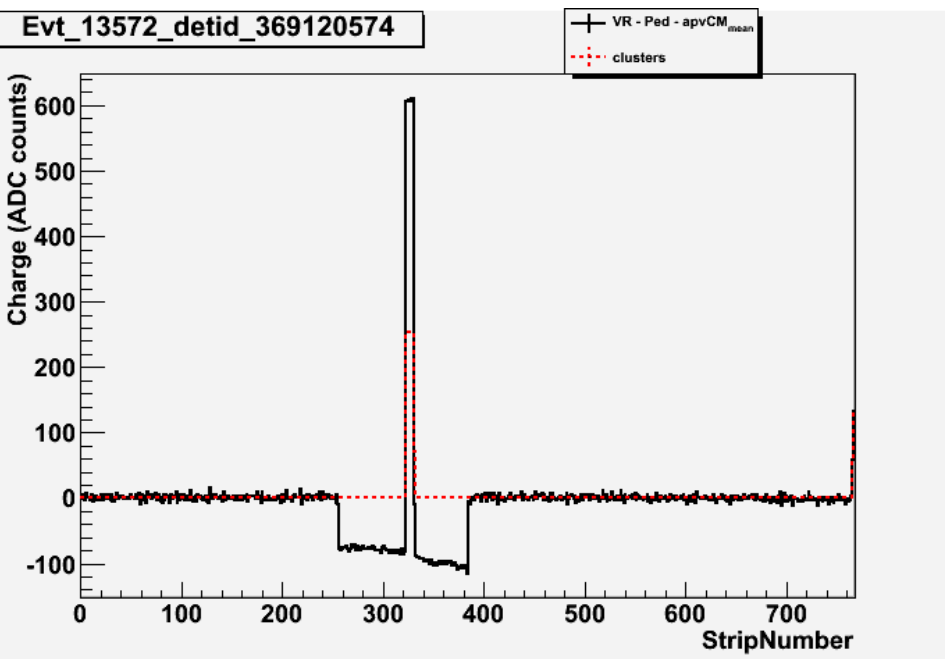
- CMN simulated as constant baseline shift: Mean = 128, $\sigma = 0$
- CMN reconstruction using offline CMN subtraction algorithm (MEDIAN)



High occupancy confuses baseline search algorithm in FEDs: Loss of efficiency



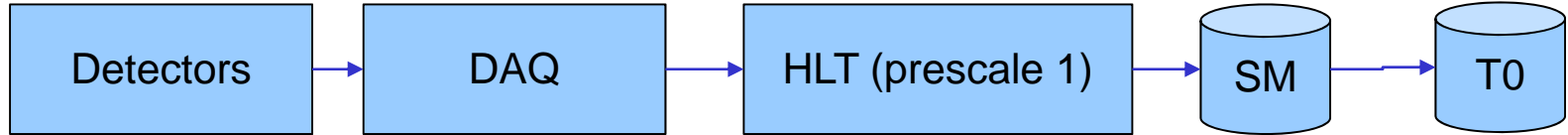
Some examples in pp



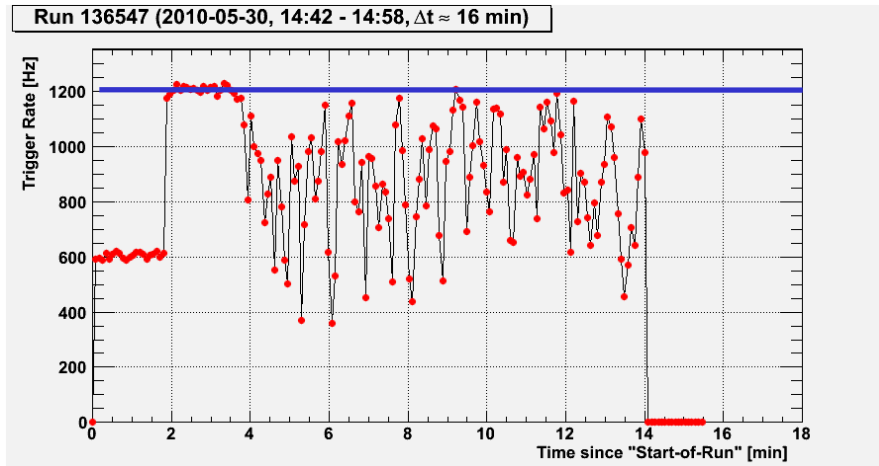
- First attempts to improve cluster finding using existing “Spy Channel” NZS data
- Several prototype algorithms are available, need more pp and HI data to finalize zero suppression
 - Setting up team of experts to quickly evaluate data



DAQ configuration studies



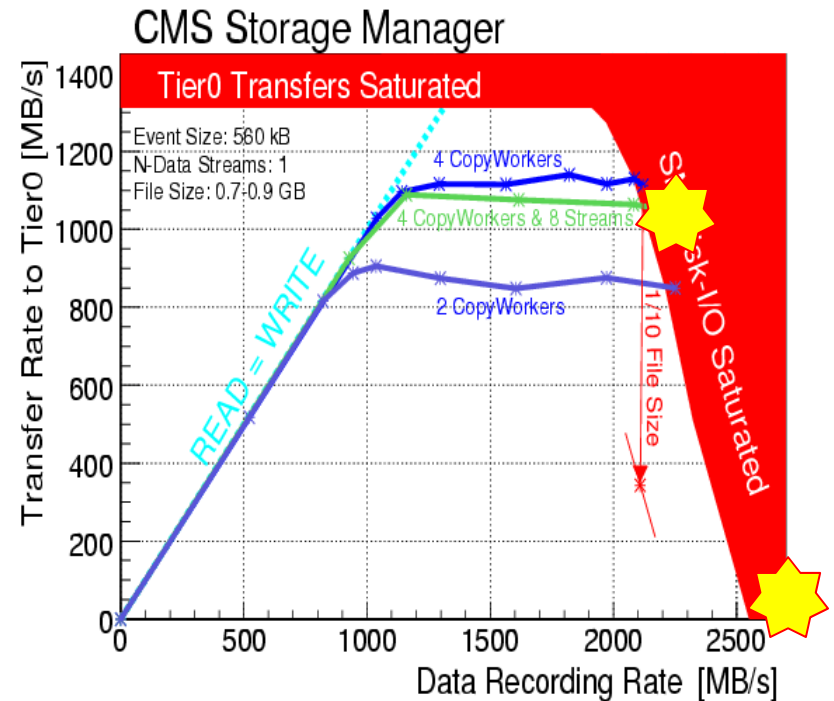
2.3 GB/s to SM



Data taking limited by Storage Manager with simultaneous transfers to T0

Note: actual data taking rate in arbitrary units

Expect about 150+ Hz





Updated CMS HI computing model

