MUON STATUS

C.Guyot (Saclay)

WP1: Muon identification and momentum measurement

- Status of key ingredients:
  - Alignment
  - Calibration
  - Reconstruction/tagging
  - Simulation
  - Trigger efficiency
  - Data Quality Monitoring

Mostly Muon Spectrometer, a few ref to the Inner detector

Optimizing the Muon Spectrometer performances

- Muon identification, reconstruction efficiency and momentum resolution in the spectrometer depends on the knowledge of the following effects :
  - Chambers Positions (Alignment)
  - Chamber Deformations (Including Temperature Effects)
  - Wire Sag
  - Tube calibration (T0, R-T Relations, inefficiencies)
  - Trigger chamber efficiency
  - Dead / Noisy / Anomalous Channels
  - B Field (good progress,should be OK)
  - n / γ Cavern Background
  - Geometric Material Distribution
  - Energy loss correction in the calorimeter
  - Reconstruction Algorithm Optimization

Use first data to evaluate the cavern background level and the validity of the MC calculations

Optimizing Inner Detector performances

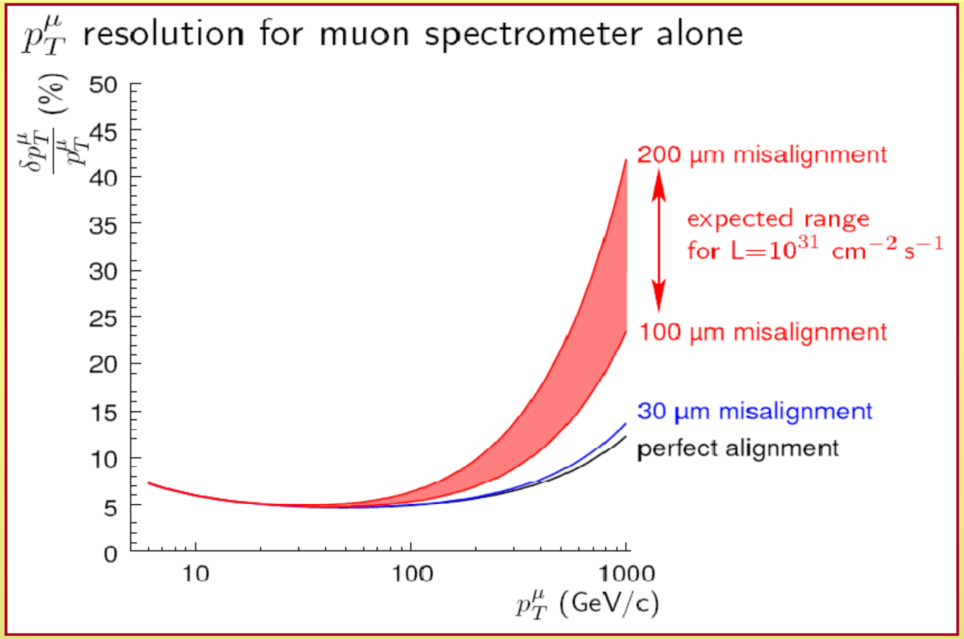
- In the momentum range of muons from Higgs decay chain, momentum measurement is dominated by ID.
- The performance (identification/reconstruction efficiency, resolution) of combined muon reconstruction depends mainly on:
  - ID alignment (also for flavour-tagging)
  - Relative MS/ID alignment (for matching)
  - Calibration: channel response (pixel, SCT), T0,R-T (TRT), dead/noisy channels, clustering parameters (pixel, SCT)
  - Control of material distribution
  - B-Field (solenoid, well under control)
  - Reconstruction algorithms

Muon system alignment

- Final performances not needed for light Higgs searches
  - For muon momenta < 100GeV, should be at the level ~100μm on sagitta measurement (final goal is 30 μm).
- First internal tests with EC big wheels shows that it should be achieved for EC chambers positioning using the optical system.
- In the barrel, no test yet with chambers in the pit, although a large fraction (>90%) of the optical sensors are installed and only 5% have still a bad behaviour.
  - Hints (X tomo) that a rather large fraction of them are not properly positioned on the chambers (error> 50μm, up to several 100μm)
  - It will necessary to first align the detector with straight tracks (cosmics for top/bottom sectors + B=0 runs at the beginning of pp data taking)
  - Work in relative mode (optical system to trace the departure from a reference geometry) validated in CTB 2004.

MS alignment with tracks

⇒ Alignment with pointing straight tracks (run with B=0 in the toroids) is required. With ~1000 tracks per chamber tower (600 towers in ATLAS, run a few days at L=10^{31})), a precision of ~100µm on sagitta measurement can be reached.



Use the optical system in relative mode (precision<20µm) to measure the movements when field is switched on

Full precision obtained with ~10000 muons/towers (2009).

MS alignment Status and work plan for next year (1)

- Optical alignment (mainly Saclay for the barrel):
  - Provide a set of alignment constants, even very preliminary, for:
    - Whole detector from simulation (better than random chamber positions used up to now for CSC studies)
    - Sectors 4,5,6 for M4-MX studies
  - Test/calibrate with cosmic tracks
  - Complete the geometry reconstruction software for the barrel part (Saclay: almost done)
  - EC: alignment of CSC
- Alignment with tracks:
  - Complete studies for small/large chambers (MPI)
    - Add the track segment constraints (pseudo-track sensors) in the reconstruction software (Saclay)
  - Start work on EC vs Barrel (MPI?)
  - Straight tracks alignment to provide the reference geometry:
    - Cosmics (Saclay+?)
    - Beam halo runs (End Cap studies=> US labs)
    - B=0 runs with pp collisions (Saclay + MPI)
      - Start with simulation
      - Trigger issues (rate of very pT muons at LVL1)

MS alignment Status and work plan for next year (2)

- Software infrastructure:
  - Output the reconstruction results in the COOL Cond data base (Saclay) -> A (positions) and B (deformations) lines
  - Retrieve alignment constants from COOL and use them in reconstruction programs: done for A lines, not for the B lines.

- Other effects not yet addressed:
  - Temperature effects (chamber expansion)
    - To be included in reconstruction programs
  - Intrinsic chamber deformations (e.g. relative multilayer displacements, lab dependent tube pitch…). Up to several 100μm.
    - Use X tomo information
    - Include it in the Data Base and in reconstruction programs

ID alignment with tracks

- Weak modes problem:
  - When using only pointing tracks, the fit nicely converges (residuals <10μm), but towards a geometry leading to momentum shifts (presence of so-called weak modes)
    - Need to add non-pointing tracks (e.g. cosmics)

•Present issues:

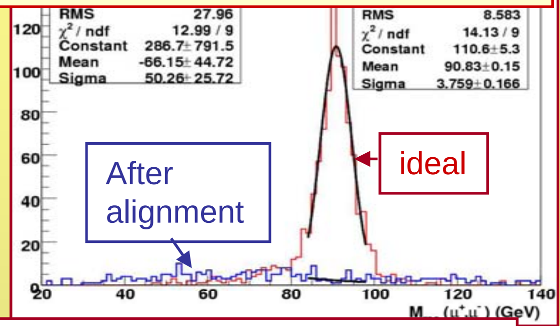
–Track/event selection for feeding the algorithms (how to build the ID alignment stream). Selection at L2 like muon stream being investigated

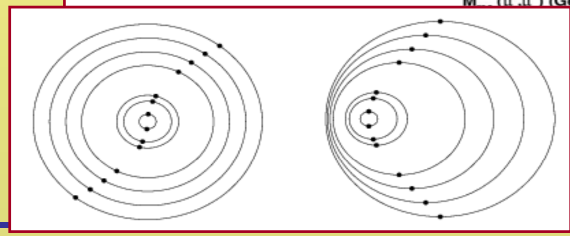
–Impact on b tagging

– How (when) to trigger on cosmics? Long gaps, in between fills?

– Alignment monitoring with J/ψ and Υ (at the beginning) and Z->μμ

M(Z->μμ) after alignment



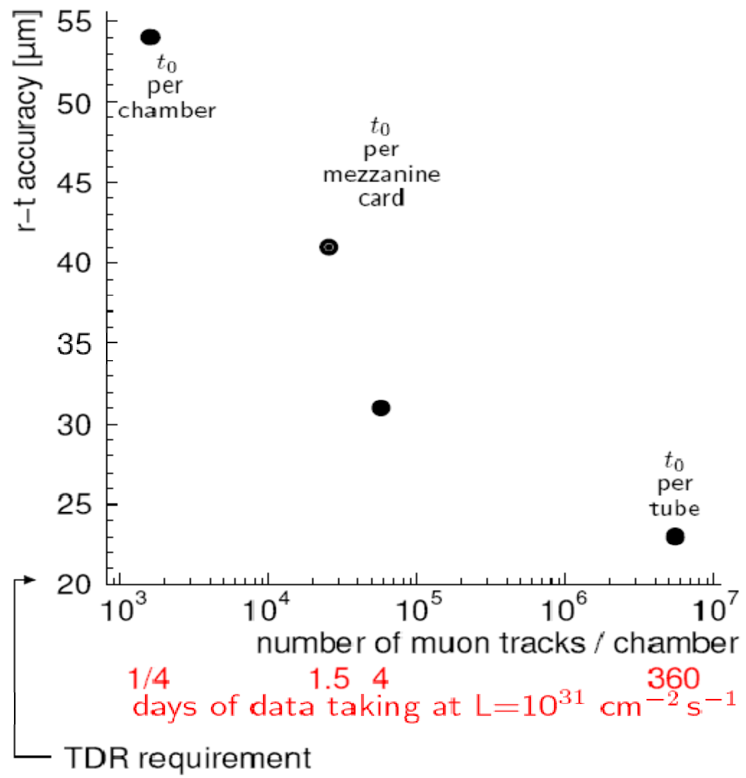


MS/ID alignment

- Goal: Relative alignment of the MS sectors w.r.t. ID with a precision of ~100-200 μm (to possibly improve measurement of very pT muon). For muon tagging (matching ID and MS tracks), 1mm is enough.
- Preliminary work (only 3 dof per MS sector) by Tony Liss + Nectarios Benekos shows that a 1mm alignment can be achieved with only 100 tracks (from Z->μμ) per sector.
- Need to be redone with all 6 dof and for all MS sector (Egg shape model used for CSC) and with low pT muons.
- The scheme for modifying the A lines per sector (while keeping the constraint between neighboring sectors coming from optical/track internal MS alignment) is to be worked out.
- The implementation in the ATLAS calibration/alignment model has not yet been addressed (work on express stream data)

MDT R-T calibration

r-t accuracy after time synchronization and autocalibration



Assumptions:

- L=10^{31} cm^{-2}s^{-1}
- Calibration stream at a rate of 100 Hz, i.e. 0.25 Hz/chamber.

Conclusions:

- Reasonable r-t accuracy already after 1 days of data taking.
- 30 μm r-t accuracy close to TDR requirement after 1 week of data taking!
- TDR requirement of 20 μm unreachable due to missing statistics for a tube-by-tube synchronization.

Single tube resolution will not restrict the spectrometer performance at the start

MDT calibration stream

- Stream of spectrometer data containing low momentum single muons at a rate of 2 kHz, i.e. 5 Hz/ muon chamber, extracted at L2 level.
- Processing of the stream with a latency of 24 h at calibration centres in Michigan, Munich, and Rome
- The calibration framework and the calibration algorithms are ready.
- Technical runs done in summer to demonstrate the streaming of Events and the Data Base replication from Tier0 to calibration centres
- Goal: test it with M5 data (except for rate...)
- To be used also for identifying dead and noisy channels and more generally for Data Quality monitoring

Muon reconstruction/tagging

- Several reconstruction algorithms (MS, ID, combined) are available. Similar performance under normal conditions. Muonboy/Staco much less sensitive to cavern background (Efficiency, fake tracks).
- Complemented by a tagging algorithms (Id track + MS segments) especially for low pT (<6GeV)
- What is still missing:
  - Handling of dead and noisy channel
  - Wire sag
  - Chamber deformations (from construction or from alignment)
  - Implementation of energy loss improved by measurement in the calorimeters
    - Algorithm exists

Improving muon tagging efficiency

- To increase statistics on constrained multi-muons events (e.g. H->4l with Z constraint), it is useful to implement loose muon identification algorithm:
  - ID track + calo cells + isolation: CSC note being written (Saclay, Thessaloniki involved)
    - Can be used in particular for $\eta=0$ crack region (no MS ID)
  - MS track + calo cells activity + isolation (no ID track matching found):
    - Could be used for $2.5<\eta<2.7$ (beyond ID acceptance)
- Could help for validating/invalidating large EtMiss events

- Question: status of their implementation in the muon containers?

Detector description and simulation

- Dead matter inside muon spectrometer underestimated in GeoModel (~5-10% in between coils?):
  - Part of the missing matter already described in Amdb (xml file), but we miss an automatic tool to transfer it to the Oracle DB and the GeoModel (work started but not completed: Manpower needed)
  - More material needs to be included (cable trays, pipes...)
- Big concern: No simulation coordinator(s) for the Muon System and a lot of simulation work ahead:
  - Solve remaining volume clashes
  - Launch a study on optimizing G4 parameters:
    - Range cut: recently moved from 5μm to 50 μm. Sytematic study to be done without and with the new multiple scattering of G4.8
    - Make a decision on physics list to be used: Do we need the new MS? (CPU time x 2). Do we need Bertini cascade description for Hadron showers? (CPU x 2 but possible impact on punch through)

Dectector description: Impact on momentum scale

- Knowledge of material in the ID has an impact on momentum scale:

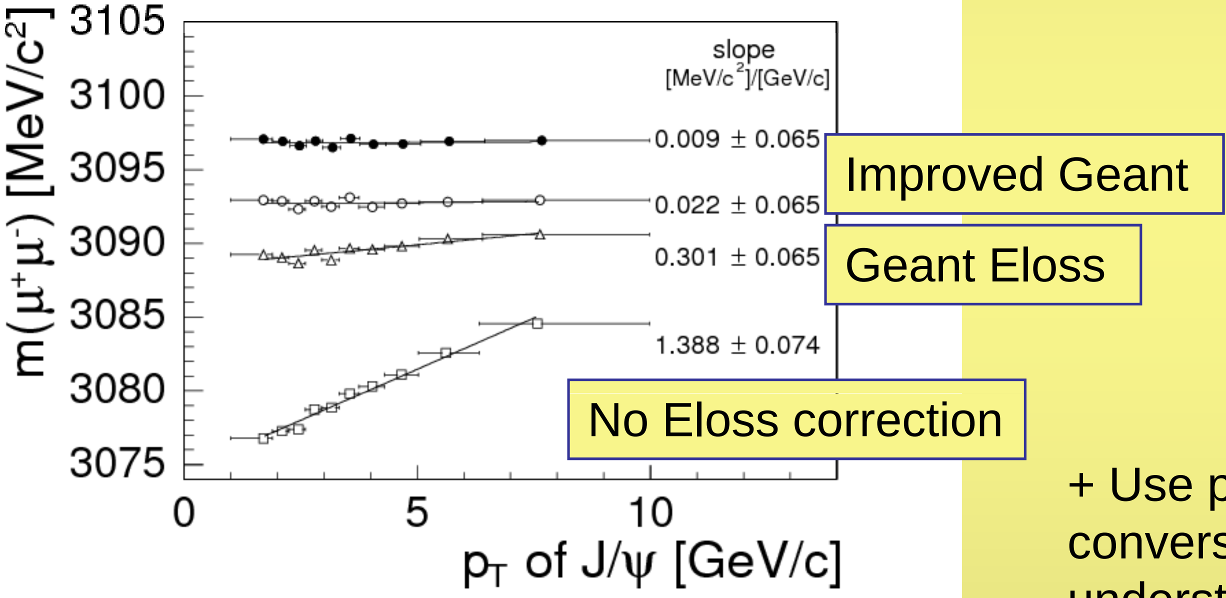


FIG. 2: Dependence of the J/ψ mass on the p_T of the J/ψ. The open squares show the mass dependence for tracks with no energy loss corrections. Open triangles show the result after applying the energy loss for the material accounted for in the GEANT description of the detector. Open circles account for the missing material modeled with the additional layer. Filled circles show the effect of the B field tuning in addition to accounting for all the missing material.

+ Use photon conversions to understand material distribution

Muon Trigger efficiency

- Good trigger efficiency (and purity) is in the first ingredient for optimizing final statistics
- Need a fast feedback from trigger aware offline studies on trigger efficiency calculations
  - Using L1 and HLT Pass Through events (Minimum bias + L1/HLT PT), L1 + HLT PT...
  - Using multiple trigger events
    - e.g. $Z \to \tau\tau \to e\mu$..., $WW \to e\mu$
  - Pure dimuon samples
    - $Z \to \mu\mu$, from single muon trigger
- Not covered in Artemis yet:
  - do we need some involvement?
  - Work to do in commissioning runs to understand trigger rate:
    - e.g. tile vs muon trigger rate,
    - Profit from field on commissioning runs

Offline Data Quality Monitoring

- At calibration centres:
  - large statistic available (2kHz) but only muon system hits
  - Hit maps (check online maps)
  - MDT/RPC(TGC) matching
  - Flag Dead/Noisy channels (part of calibration =>CDB)
  - Q: Are dimuon resonances available in the calib stream?
- At Tier0:
  - First based on express stream (~10% of total data, processed with a 1-2 hours delay)
    - ID/MS track reconstruction comparisons, combination
    - Z, J/ψ and Υ reconstruction:
      - use tag&probe method for assessing tracking and trigger efficiencies,
      - Assess quality of new calibration/alignment constant coming from alignment systems and calibration centres
- Build a DQ flag fabrication tool out of DQM results (online+offline)
- Test the infrastructure at the Mx cosmic commissioning runs

Related CSC notes

- Muons In Calorimeters: Energy Loss and Tagging (Hassani, Lopez Mateos, Ordonez Sanz)
  - https://twiki.cern.ch/twiki/bin/view/Atlas/MuonsInCaloCSCNote
- Performance from data (Schott, Kortner) :
  - Study of the effects of misalignment, magnetic field and miscalibration of the MDT-chambers on the efficiency, fake-rate and momentum resolution of the ATLAS Muon Spectrometer
  - https://twiki.cern.ch/twiki/bin/view/Atlas/CSCNoteInSituDeterminationOfMuonSpectrometerPerformance
- Algorithms (Willocq, Ouraou)
  - presents the results of detailed performance studies of the various ATLAS muon reconstruction and identification algorithms as a function of transverse momentum, pseudorapidity and azimuth
- Trigger (Biglietti)

Comments and Conclusions

- CSC notes by the muon combined performance group being written address part of the issues that have been raised but not the ones flagged "missing"
  - Still a lot to do to face an imperfect detector (simulation are not yet "as built"!)
- Do as much as possible with cosmics and single beam (+halo) commissioning runs before the pp collisions come:
  - Alignment (optics + tracks): MS, ID, MS/ID
  - Setup calibration/alignment chain
  - DQM tools

Suggestions for an Artemis work plan in the muon domain

- Continue simulation/reconstruction work after CSC/CDC notes completion toward a more realistic detector description by including:
  - dead/noisy channels handling
  - wire sag
  - Temperature effects
  - more realistic mis-alignment simulation (MS, ID, MS/ID)
  - Cavern background
- And complete basic work not addressed in CSC/CDC notes:
  - getting reference geometry from straight tracks runs
  - Momentum scale determination using resonances (J/ψ, Υ and Z)
  - Estimate actual misalignment (ID and MS), detector description realism, fake rates from these resonances

Suggestions for an Artemis work plan in the muon domain (2)

- Important work can be done with cosmic commissioning (in addition to debugging):
  - Validation of dead/noisy channel, wire sag, temperature handling
  - Combined ID/calo/muon matching
    - -> first MS/ID alignment
    - Eloss correction
  - Straight track alignment
  - Muon trigger efficiency (e.g. tile vs muon triggers)
  - Understand absolute cosmic muon rates

- Participate to FDR data analysis
  - Learn how to work with actual data structure (streams, LB) and analysis model tools (AODs, DPDs, Tag DB)
  - Without MC truth