Muon Reconstruction 3rd (integrated) chain

Stefania Spagnolo

INFN Lecce e Dipartimento di Matematica e Fisica "Ennio De Giorgi", Univ. del Salento

Muon Reconstruction Integration History

- Muon Reconstruction Integration Task force established in Jun 2010 (ATLAS+Muon Management initiative):

  - **composition**: Ahmimed Ouraou, Niels van Eldik, David Quarrie, Ed Moyse + (ex officio) D.Rousseau, Muon Project Leader or Deputy, Representative of ATLAS management.

  - **mandate**: understand details of Moore/Mboy+assess flexibility against common framework and tools/EDM+identify features to be preserved (by summer 2010)+define new framework+define integration path and migration plan+study impact on clients (by end of 2010)

  - First report on Aug. 3rd 2010:

    - https://twiki.cern.ch/twiki/pub/Atlas/MuonRecoIntegration/JulyReport.pdf **feasibility** of the project **established**

      - ✓ *In conclusion, it does appear technically feasible to adopt common APIs and muon EDM objects at a reasonable initial level of granularity. We believe wrapping components of Muonboy is a sensible next step, with the aim of drawing up some longer term plans once these studies are concluded.*

  - Second report on Jan 11th 2011:

    - https://twiki.cern.ch/twiki/pub/Atlas/MuonRecoIntegration/FinalReport.pdf **plan defined**

      - ✓ *approved by TOB with the suggestion/request of adopting the actions needed for an easy integration at EF*

Muon Reconstruction Integration History

- Final Report Strategy:

  - **Phase 1**. Specification of common APIs, development of components that implement those APIs and a common EDM. Creation of a single hybrid algorithm chain comprised of a mixture of FORTRAN and C++ components.

  - **Phase 2**. Validation and deployment of the new hybrid chain; deprecation of the existing Muonboy and Moore chains

  - **Phase 3**. The staged identification, re-implementation in C++ and validation of initially highly leveraged, and eventually all, FORTRAN sub-components, culminating in the deployment of a single algorithm chain based on C++.

- phase I: accomplished by summer 2011 - split reco in segment making and track finding (4 combinations available: MooMoo, MooMu, MuMoo, MuMu)

- phase II: first proof of readiness for Fall 2011 reprocessing; full integration in production system (one combination only) for 17.2.X, i.e. Tier0 in 2012

  - replacement of Moore/Muonboy targeted to release 18

- phase III ongoing: current path toward rel 18

Muon Reconstruction Integration History

- August 2011: Muon Reconstruction Selection Panel established with mandate:

  - The Muon Reconstruction Selection Panel is charged with selecting the components to form a single baseline standalone muon reconstruction chain to be used at Tier0, data reprocessing and for the processing of simulated data in 2012 onwards. Thus the timescale for making the decision is by the end of 2011 such that the new standalone muon chain may be fully integrated, further tuned for optimal performance and operational in time for the beginning of data taking in 2012. It is possible that components of this chain may need to be rewritten in C++ so as to be fully compatible with the ATLAS software standards and recommendations, in which case this should proceed in parallel during 2012 with the goal to be completed by the end of that year.

  - composition: David Quarrie (Chair), Edward Moyse, Alexander Oh, Aleandro Nisati, Ludo Pontecorvo (ex officio), Fabio Cerutti (ex officio)

- Muon Reconstruction Integration Meeting: https://indico.cern.ch/conferenceDisplay.py?confId=162597 Dic 8th 2011 prepared to allow the decision of the Selection Panel

  - https://cdsweb.cern.ch/record/140791 recommendation:

    - segment-finding Muonboy based

    - track-finding Moore based

Muon Reconstruction Integration History

🔘 recommendations in more details

- The Segment Finder component should be based upon the *Muonboy* Segment Finder.

- The Track Builder component should be based upon the *Moore* Track Builder.

Initially these components should be used in their current form since this is the form with which they have been well validated, but a migration should be started whereby the source code and packaging should adopt new naming conventions, including rewriting the *Muonboy* Segment Finder in C++. The deployment and migration strategies are described in more detail in the secondary recommendations:

1. Work should start promptly on the migration of the *Muonboy* Segment Finder to C++, with the goal being to complete this migration by the end of 2012 such that it fully conforms to ATLAS standards and conventions. Alongside this migration, the standalone reconstruction code should be modified and repackaged to remove references to the *Moore* and *Muonboy* components and naming conventions, replacing them by new names as decided by the muon reconstruction software community.

2. The migration should include an examination of the standalone tracking components that have not been selected (the *Muonboy* Track Builder and *Moore* Segment Finder) in order to identify subcomponents, designs, tools and strategies that could be adopted as alternative strategies in order to improve the performance of the selected components e.g. as a function of the event topology or running conditions.

Today: 3rd chain in 17.2.X

🔘 Rules / Clarification before 2012 data taking startup:
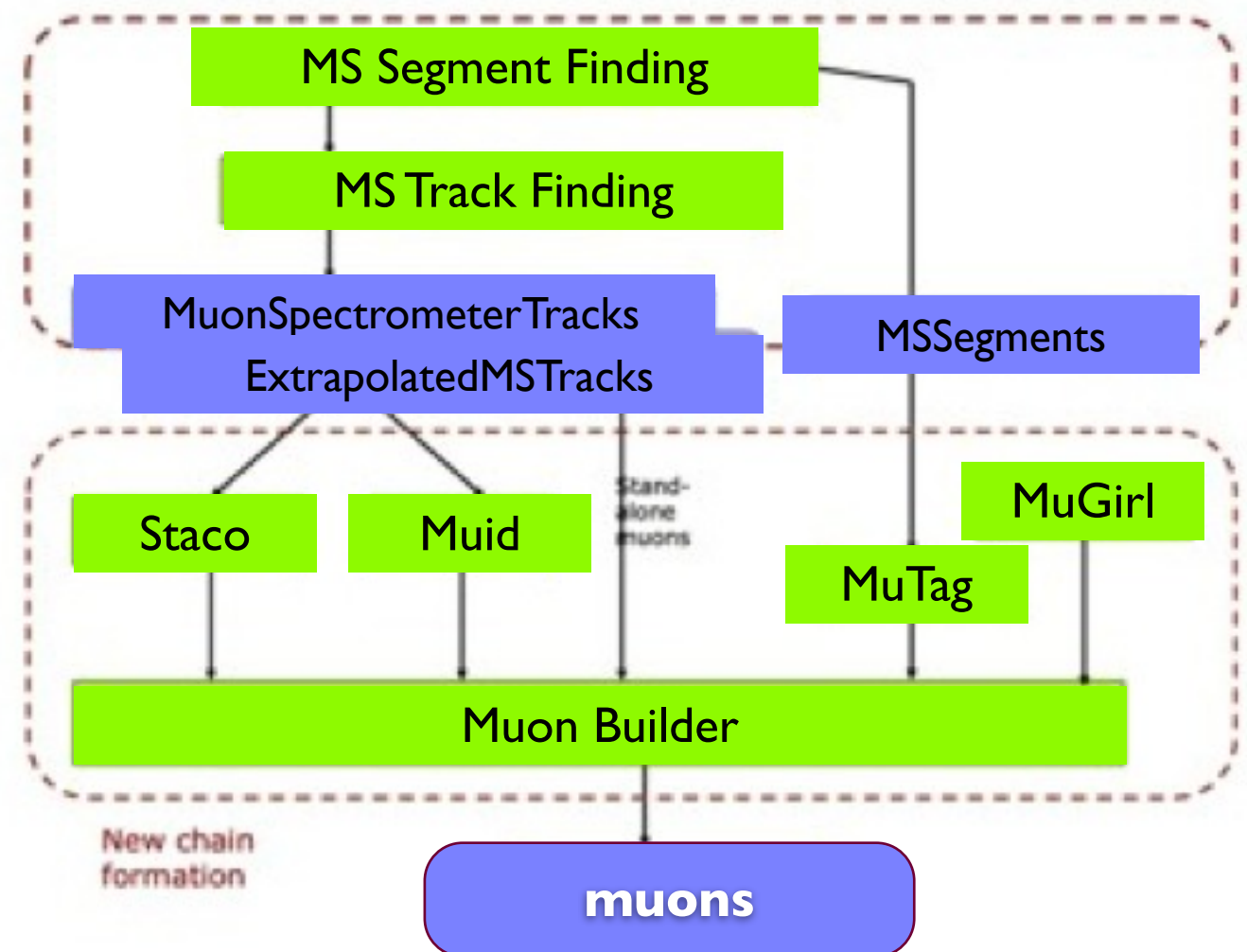
Muon 3rd chain in ATLAS

🔘 3rd chain deployed in 17.2.X.Y but in dev. (as all software toward rel 18 for phase 3)

🔘 Compromise proposed for MS,MCP, Muon P.L. **+ input from Physics Coordinators:**

> 🔘 apply strictly frozen Tier0 policy until the Summer Conferences; push for all physics objects that are muon clients to provide version 3 of their value in 17.2 (only b-tagging is late); MCP will provide scale factors, smearing function, recommendations during 2012 for the 3rd chain (+the others); no use for physics before the Summer Conferences;

> 🔘 review the situation just after ICHEP, and either:

>> 🔘 allow physics groups to start using the 3rd chain for 2012 data physics results, which in practice will be CONF notes during this period. If we go down this route, the 3rd chain would then have to continue to be frozen like any other component of the Tier-0 reconstruction.

>> 🔘 realize we need to make adjustments, so unfreeze the 3rd chain in Tier-0 and make the required changes. Depending on what is changed, this might require new MCP group work, and might mean we don't want to use the 3rd chain for physics with release 17.2.

> 🔘 encourage all physics groups to include the 3rd chain in DPDs from the outset, to facilitate studying its results and enabling 'early adopters' after the summer.

F. Rauscher, S. Spagnolo   Muon Software Meeting - CERN (Muon Week) - Mar 22nd 2012

Status of 3rd chain implementation

- Mboy Segment Maker wrapped in C++ (MuPatSegment)

- Moore Track Finding (MuPatTrack)

- MCP algorithms: OR of existing algorithms + overlap removal

Info on data model / interfaces / validation / configuration is collected at:
https://twiki.cern.ch/twiki/bin/viewauth/Atlas/MuonISR
https://twiki.cern.ch/twiki/bin/viewauth/Atlas/MuonRecoIntegration

- Output in a 3rd Muon Container   Muons

Status of 3rd chain implementation

- 2012 data from Tier0

- data12_8TeV.00200863.physics_Muons.merge.DESD_SGLMU.f431_m1117/
  data12_8TeV.00200863.physics_Muons.merge.DESD_SGLMU.f431_m1117._lb0247-lb0253._0001.1

909.926 kb	247.079 kb	0.171 kb	0.000	1449	(B) MuonContainer_p6_StacoMuonCollection
1099.085 kb	345.605 kb	0.239 kb	0.000	1449	(B) MuonContainer_p6_Muons
1230.803 kb	386.888 kb	0.267 kb	0.000	1449	(B) MuonContainer_p6_MuidMuonCollection

but also:

111.659 kb	22.814 kb	0.016 kb	0.000	1449	(B) MissingET_p3_MET_MuonBoy
111.627 kb	22.978 kb	0.016 kb	0.000	1449	(B) MissingET_p3_MET_Muid
111.638 kb	23.039 kb	0.016 kb	0.000	1449	(B) MissingET_p3_MET_Muons

3rd chain implementation

A SCHEMATIC OF NEW STEERING FLOW

segment extraction

Moore Segments → Muonboy Segments

MuPatSegment

track building +refinement

Moore Tools → Muonboy Tools

MuPatTrack

ambiguity solving

Trk::SimpleAmbiguityProcessorTool

MuPatTrack → Trk::Track
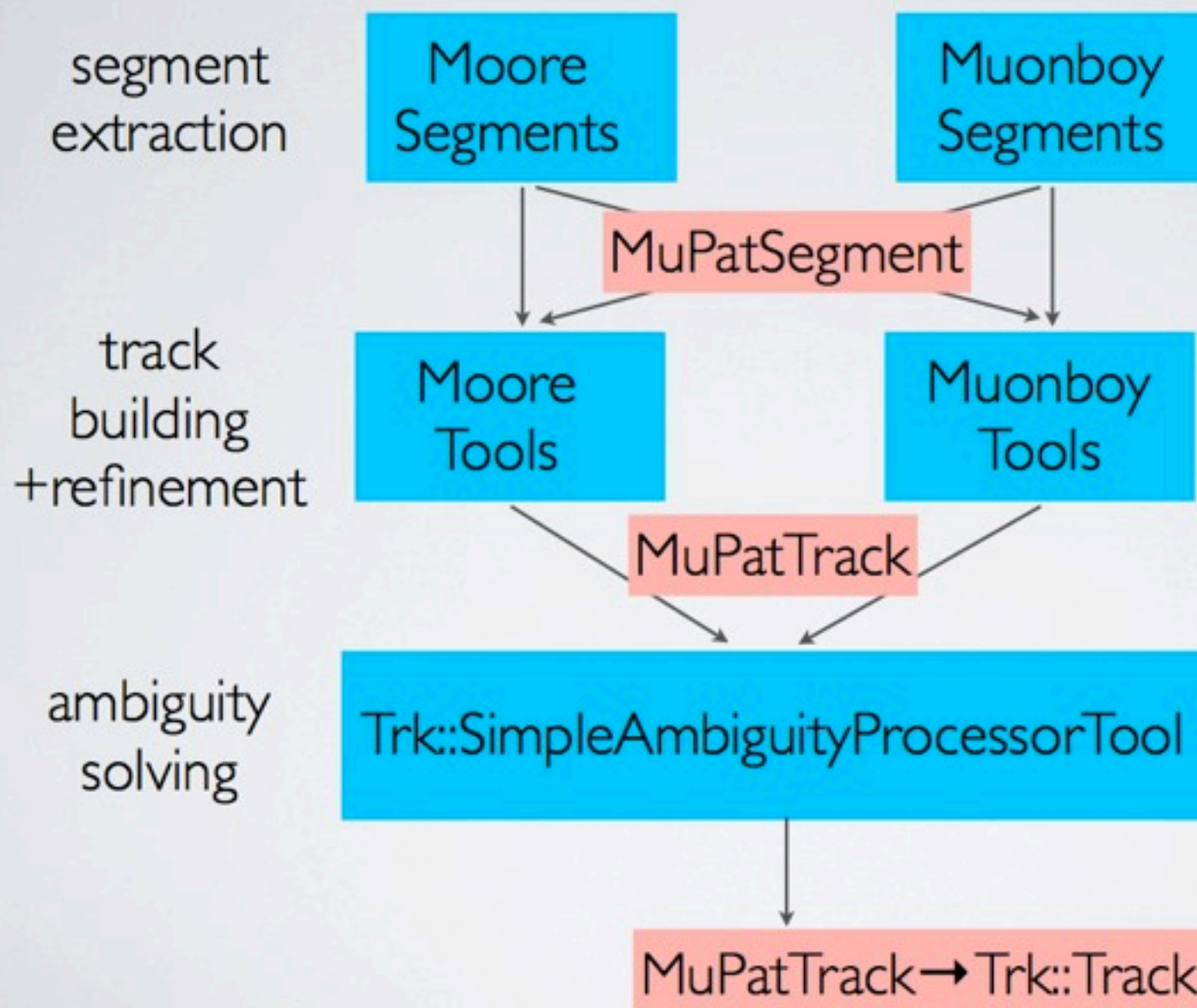
Track finding steering:
works based on strategies, i.e. combinations of stations with segments to be possibly combined in a track;
one segment can have the special role of "seed"

2 main track strategies implemented and studied:
Moore and Muonboy

3rd chain implementation

TRACKBUILDING: STEERING STRATEGIES

- List of chambers + ordering of chambers

  - Designate seed layer

  - Determine where to look for additional segments to build track

- For example: simple strategy using only small barrel chambers

  - [BMS, BOS, BIS]

📌 Muon Reconstruction Integration Meeting, Thursday, 8 December 2011 from 14:00 to 18:30 (Europe/Zurich)
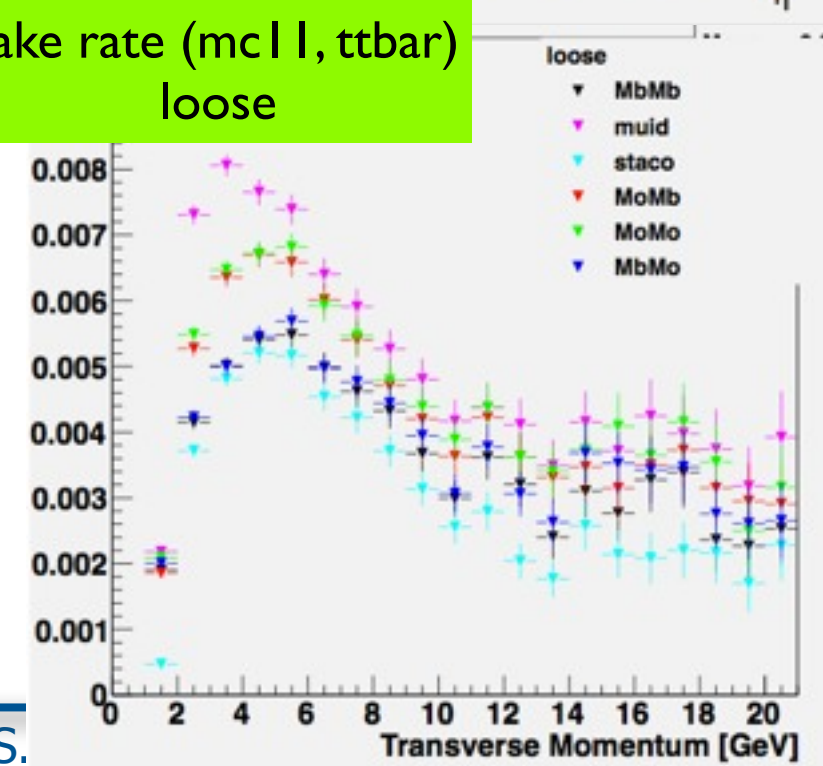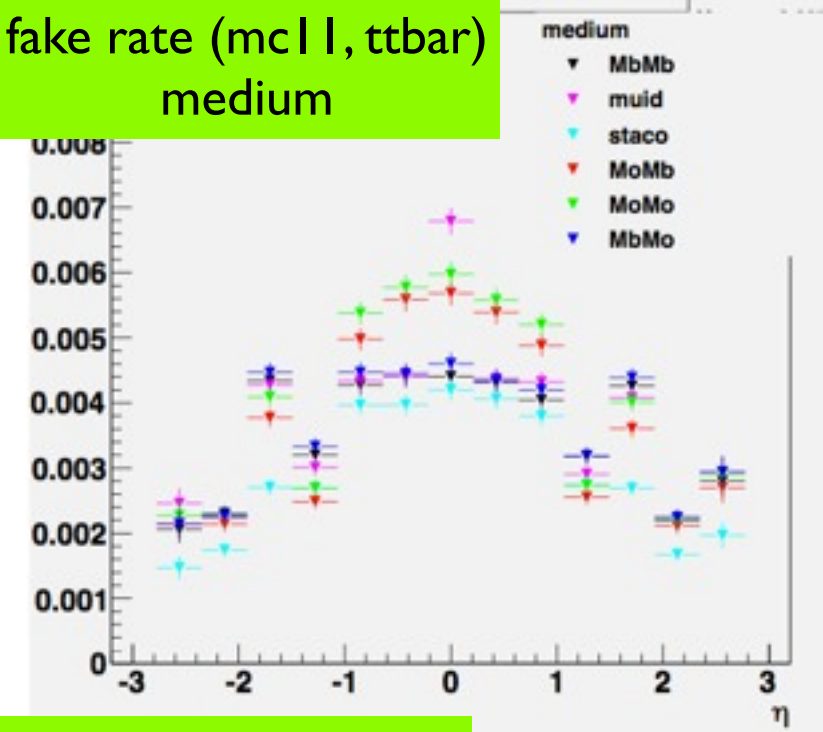
📌 Elisa Pueshel

BOS — 2) Look for segments

BMS — 1) Take as seed layer

BIS — 3) Look for segments
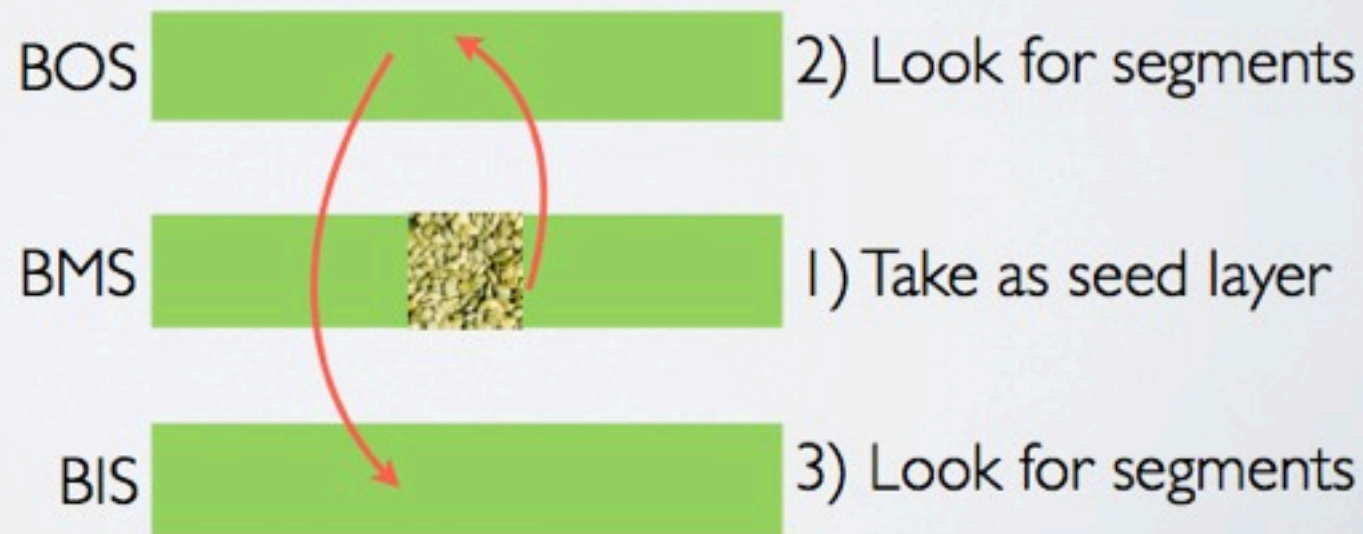
3rd chain implementation

STEERING STRATEGIES

- Strategies tuned for Muonboy and Moore trackbuilders to be similar to strategies of old chains

"BarrelCombinedLarge: BML;BOL;BIL"

"BarrelCombinedSmall: BMS;BOS;BIS"

"EndcapCombinedLarge: EML;EOL;EIL;CSL;EEL;BEE"

"EndcapCombinedSmall: EMS;EOS;EIS;CSS;EES;BEE"

"BarrelEndcapLarge: EML;BIL"

"BarrelEndcapSmall: EMS;BIS"

"EndcapBarrelLS: EML;EIS;BIS"

"EndcapBarrelSL: EMS,EIL;BIL"

Muonboy-like Strategy

Moore-like Strategy

"BarrelCombined: BML,BMS;BOL,BOS;BIL,BIS"

"EndcapCombined: EML,EMS;EOL,EOS;EIL,EIS;CSL,CSS;EEL,EES;BEE"

"BarrelEndcap: EML,EMS;BIL,BIS"

"EMandEE:EML,EMS;EEL,EES"

Muon Reconstruction Integration Meeting, Thursday, 8 December 2011 from 14:00 to 18:30 (Europe/Zurich)

Elisa Pueshel

3rd chain implementation and performance 8th Dec 2011

17.0.x.y

Comparison of various SF+TF combinations

	CB	Tight	Medium	Loose
Muid	MuidCB	+MuGirl-refit	+MuGirl/ MuTagIMO two stations, |eta|~0	MuidCB +MuGirl +MuTagIMO
Staco	StacoCB	+MuTag tight	+MuTag medium	StacoCB+MuTag
New	MuidCB+StacoCB	+MuGirl-refit +MuTag tight	+MuGirl two stations +|eta|~0 +MuTag medium	MuidCB+StacoCB +MuGirl +MuTag

fake rate (mc11, ttbar) medium

fake rate (mc11, ttbar) loose

data - Period M Z skim

data - Period M Z skim
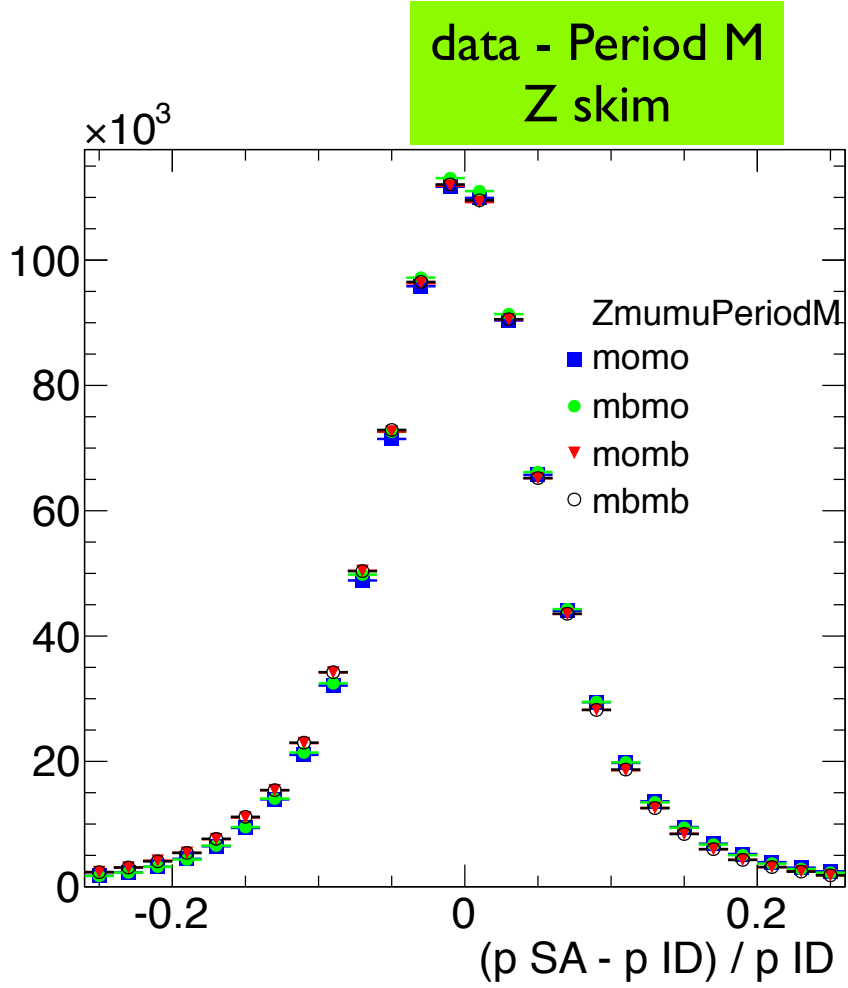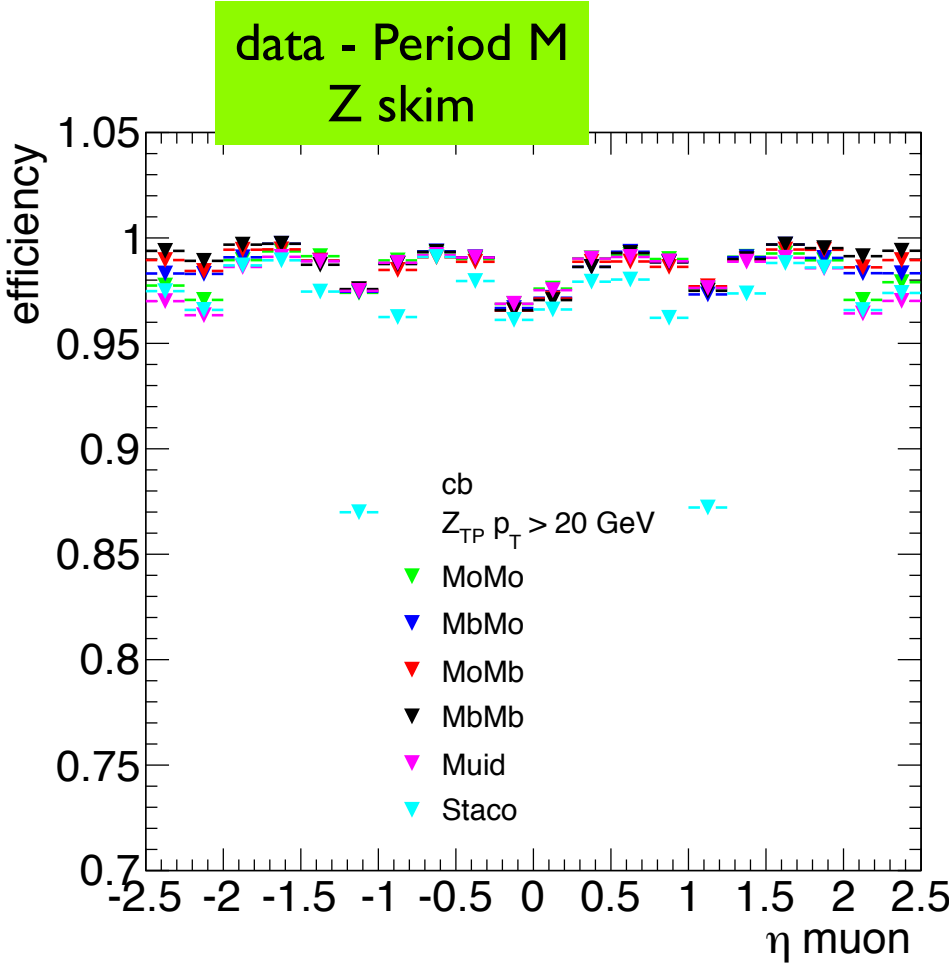
From December 2011 to today

- Steady development under the baseline strategy outlined in Dec. toward rel 17.2.x.y (Tier0 2012)

  - refining implementation and fixing understood problems:

    - charge misidentification rate reduced in Moore/Muons track finding

    - earlier FSR bias by using measured energy in back extrapolation removed

  - New features

    - change of definition: MuGirl refitted muons are upgraded to combined muons

    - combined muons with forward pixel tracklets

From December 2011 to today

- Clients:

  - **MET**: full MET calculation available for the new chain in 17.2.0; **b-tagging**: muon chain added to default reconstruction, available in the latest caches; **Monitoring code** to handle the third chain ready in a new Phys. Monitoring framework (to be deployed at Tier0); **D3PD makers**: overall size increase small when Muons are stored along with Muid and Staco (3% for SM D3PD) physics groups are strongly encouraged to add the muon chain to their physics D3PDs

Muon+Staco+MuidMuonCollection: M$_Z$ Mass

MuonTrkPhysMonitoring

Missing Et
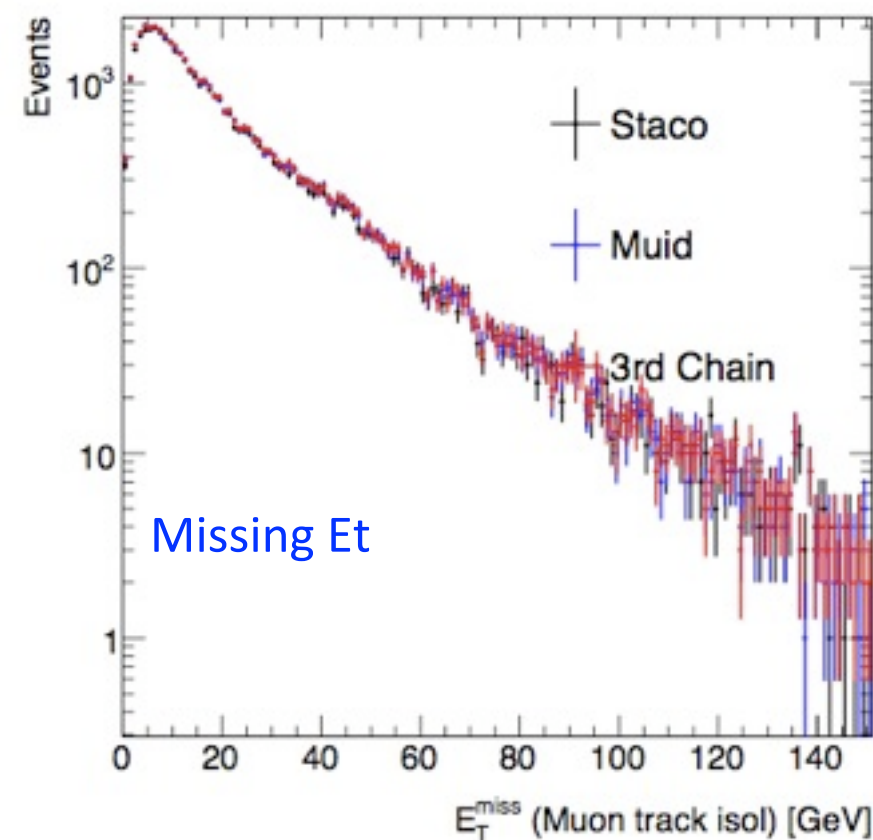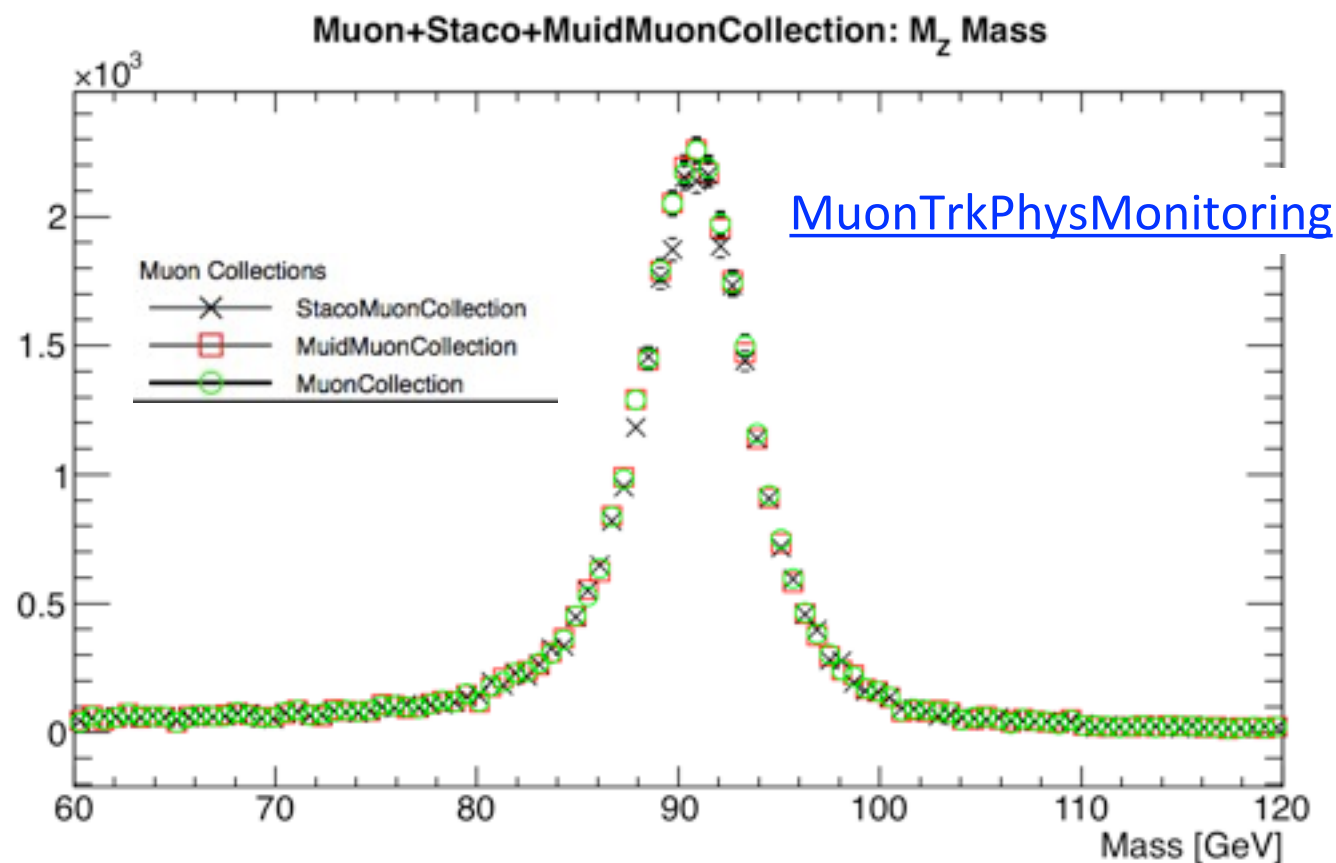
Status of the 3rd chain performance: efficiency

- Mainly from N. van Eldik at Muon Combined Session in last P&P

- Validation on 2011 data and MC: Z tag and probe: Run190975; Latest v83 processing
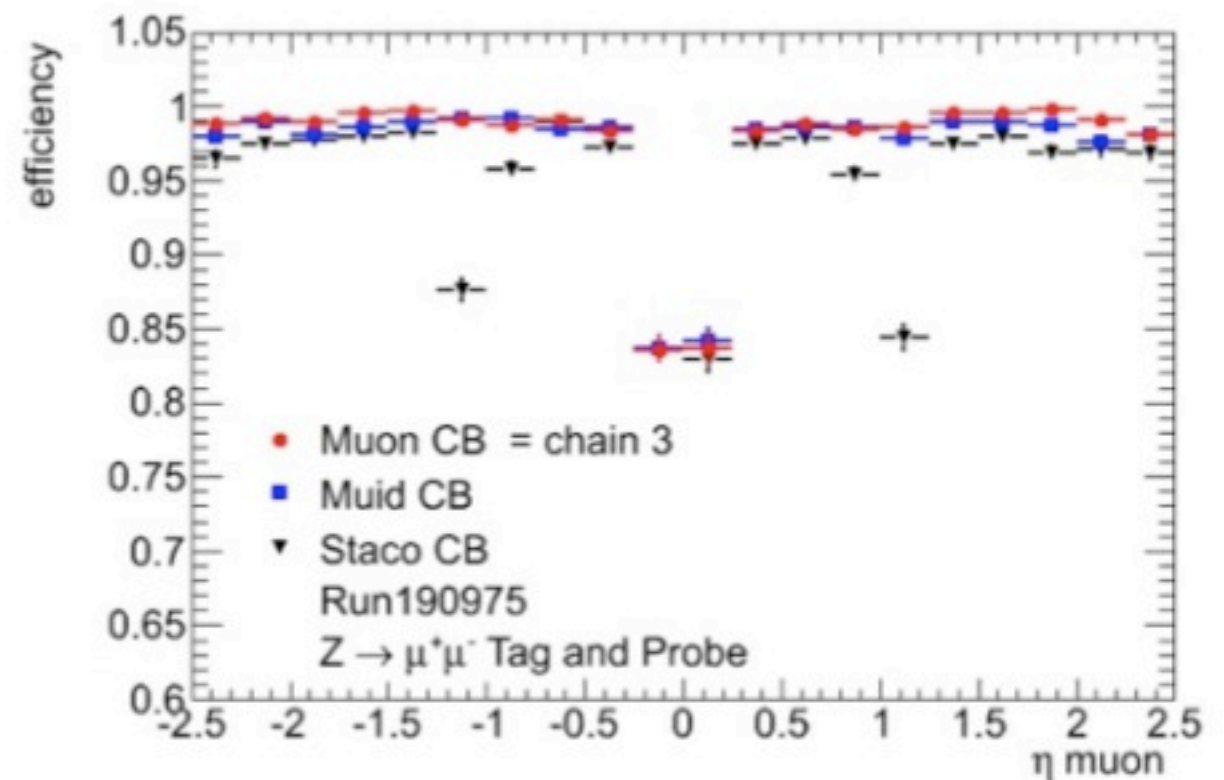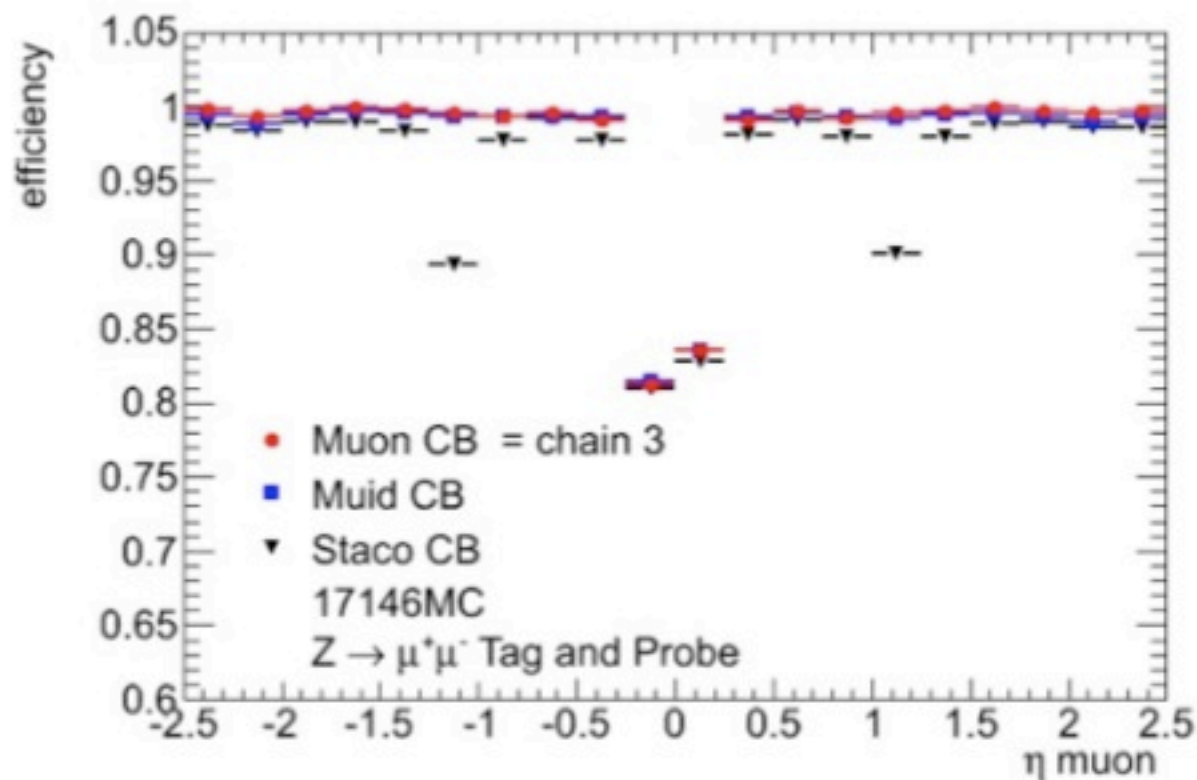
Status of the 3rd chain performance: π/k decays in flight

- Validation on MC: π/k rejection

- Cut at 4 on MS/ID momentum balance significance
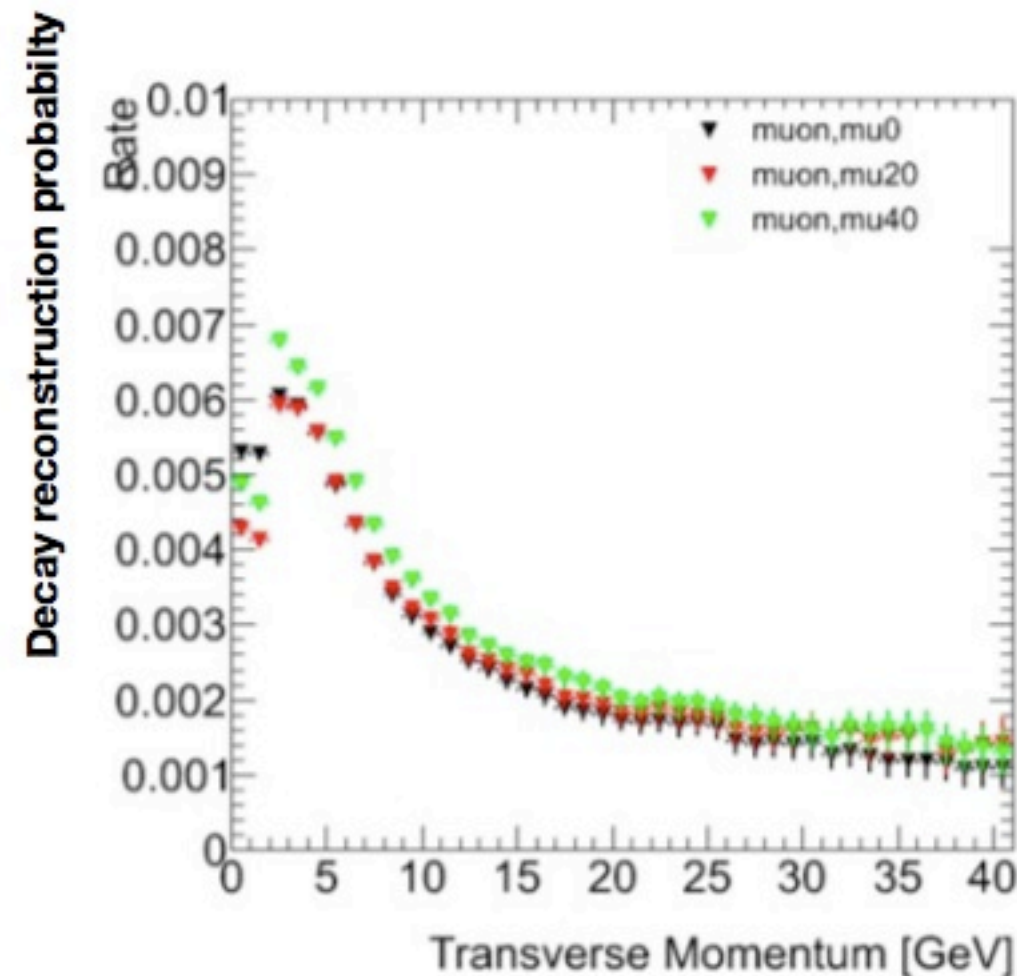
  - +cuts on # of layers with holes on track +cut on χ2

10 < pt < 15 GeV
Muons from W
Pion/Kaon

Momentum balance significance
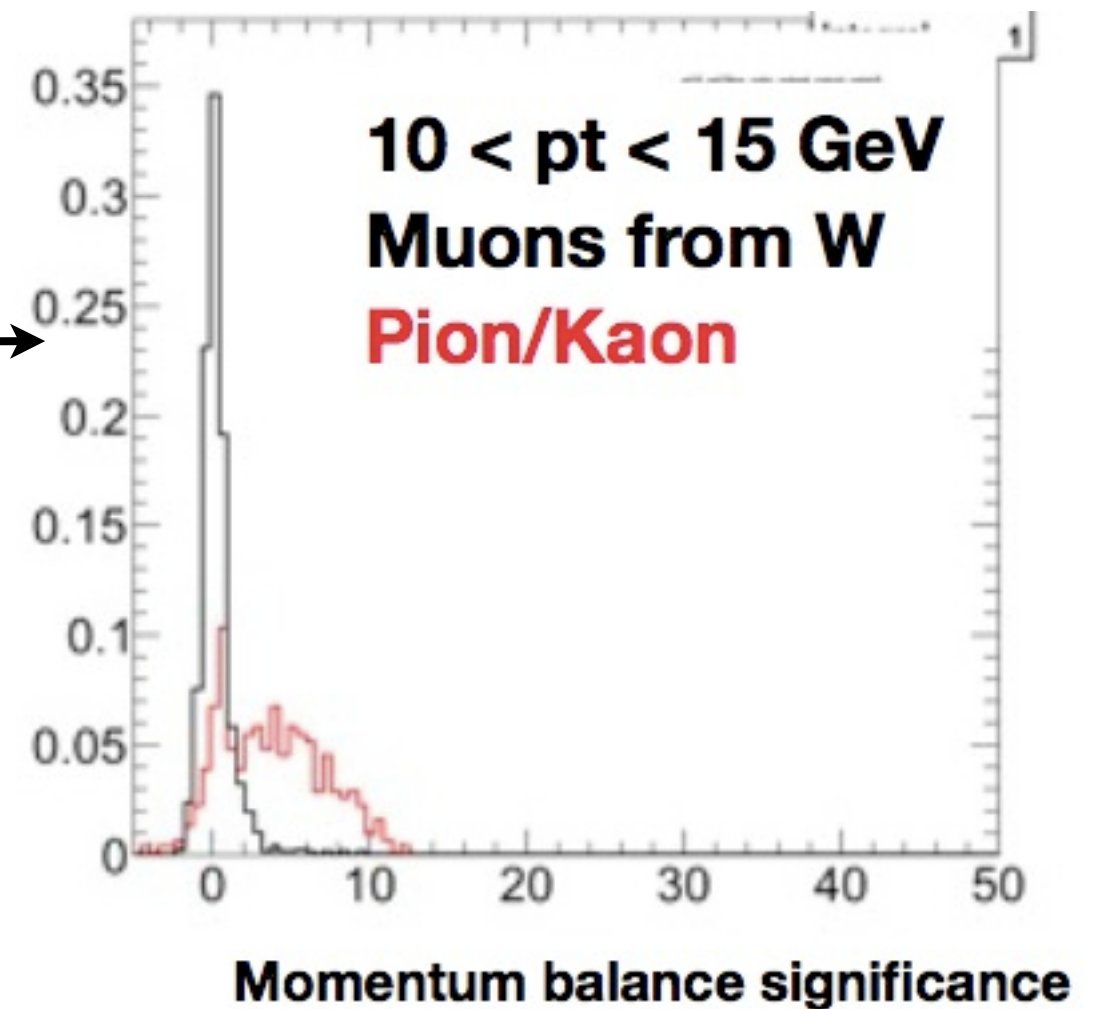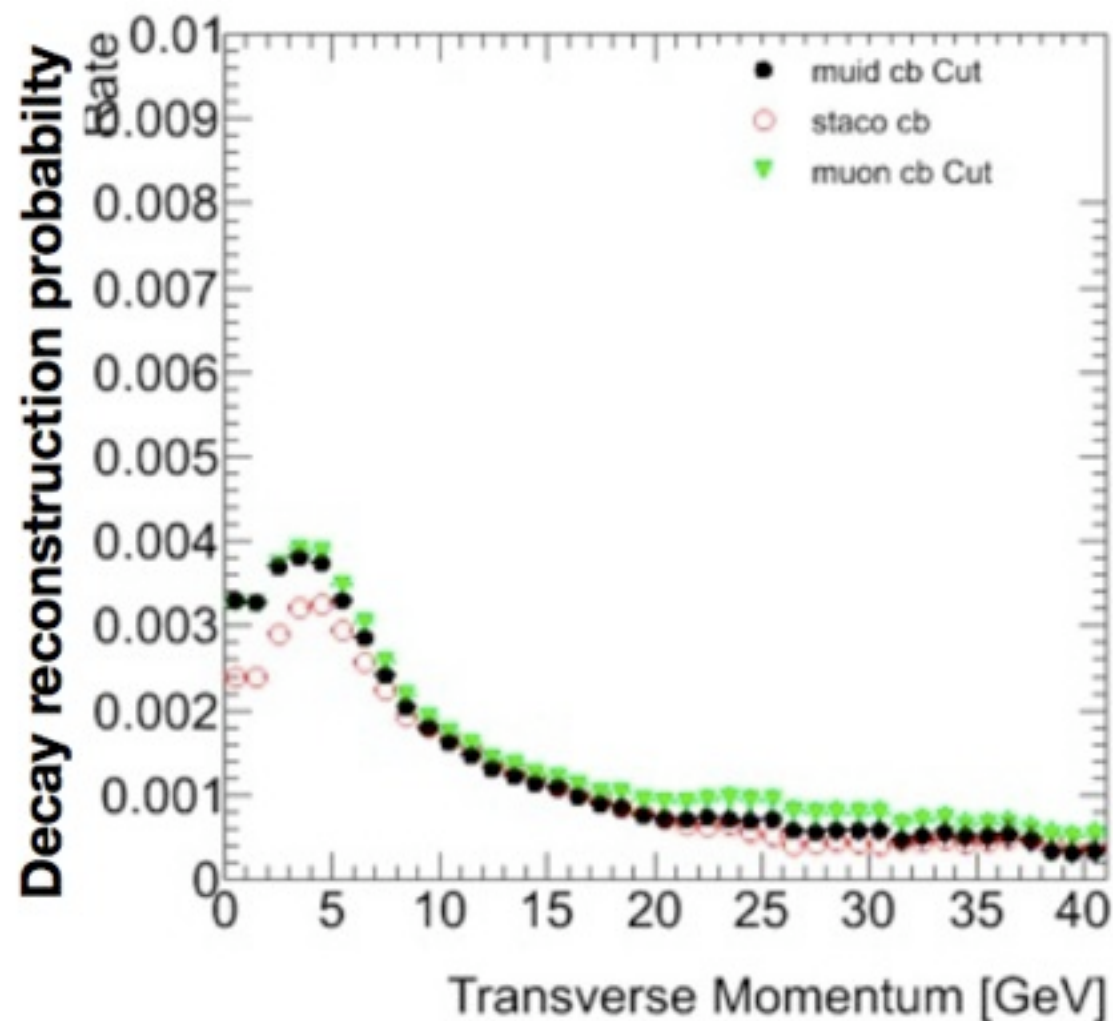
Status of the 3rd chain performance: Pile-up dependence

negligible

MC: muons from W
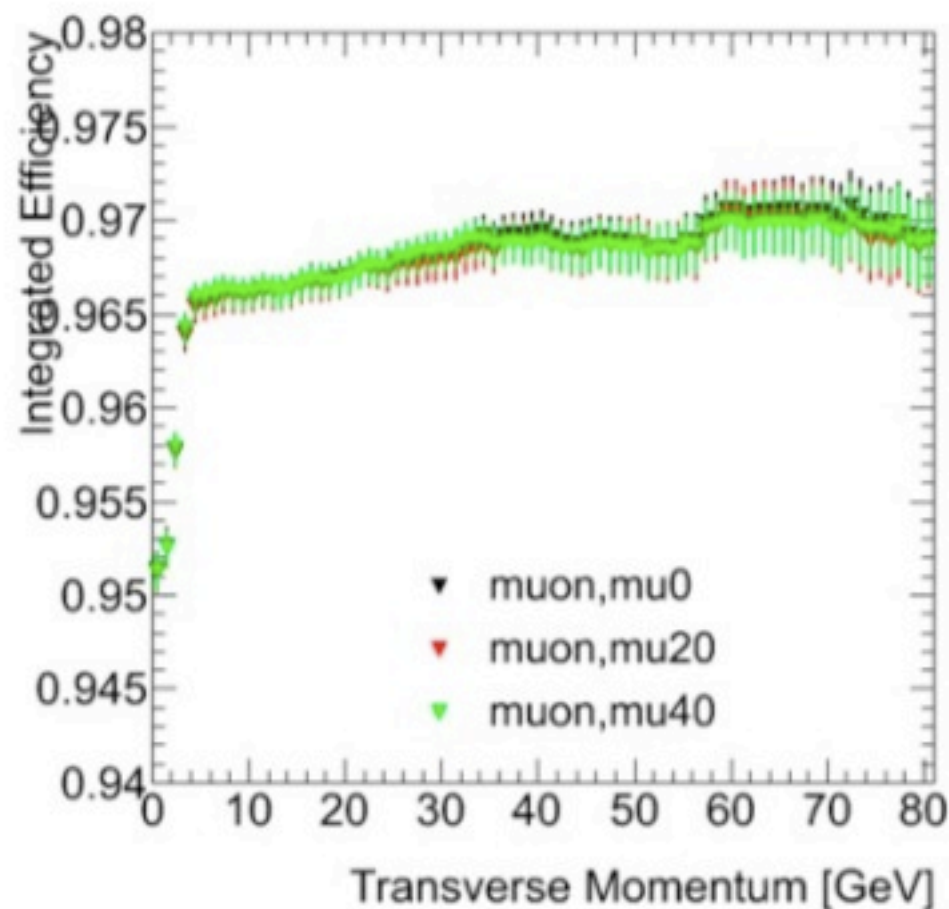
Integrated Efficiency:
Eff. of rec. µ with $p_T \geq$ Thr
Thr (on x axis)

Probability of misidentify a π/k decay
as a prompt muon
for momentum balance
significance >4

Status of the 3rd chain performance: fix of FSR bias & mass resolution

- No bias due to FSR photons as in 17.2 parametrization is used for EM part if the measured energy in the EM is above 2.5 GeV and there is a photon like deposit in the first layer of the EM calorimeter (same is true for the Muid container)
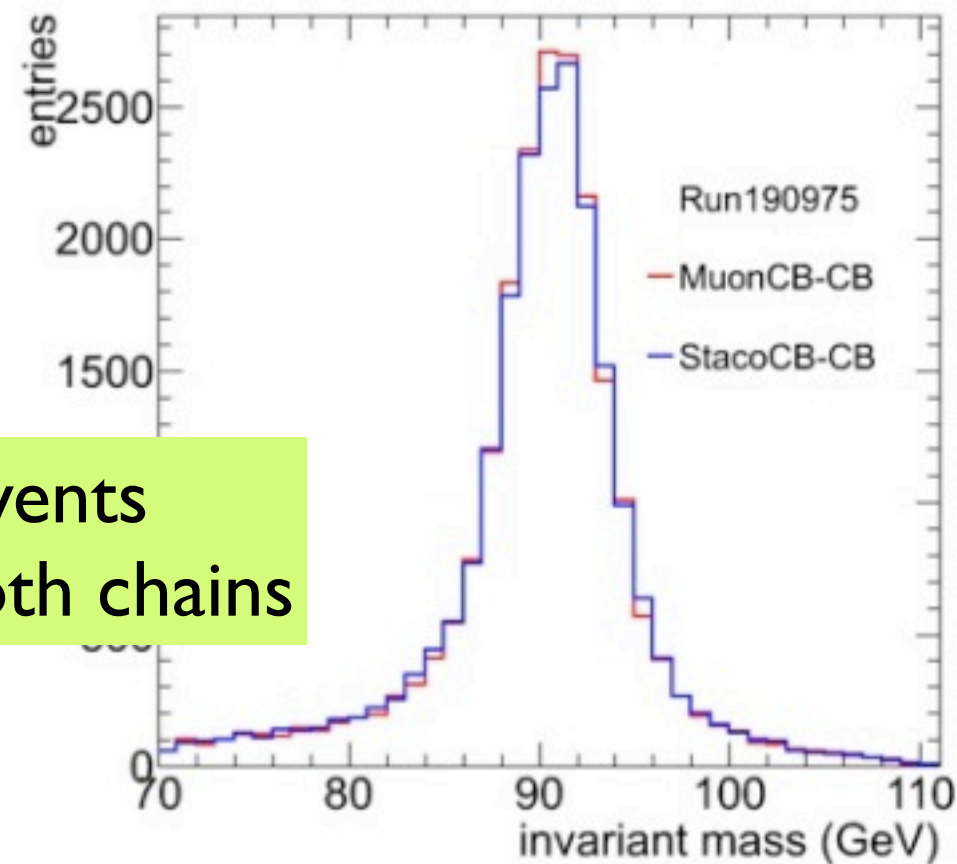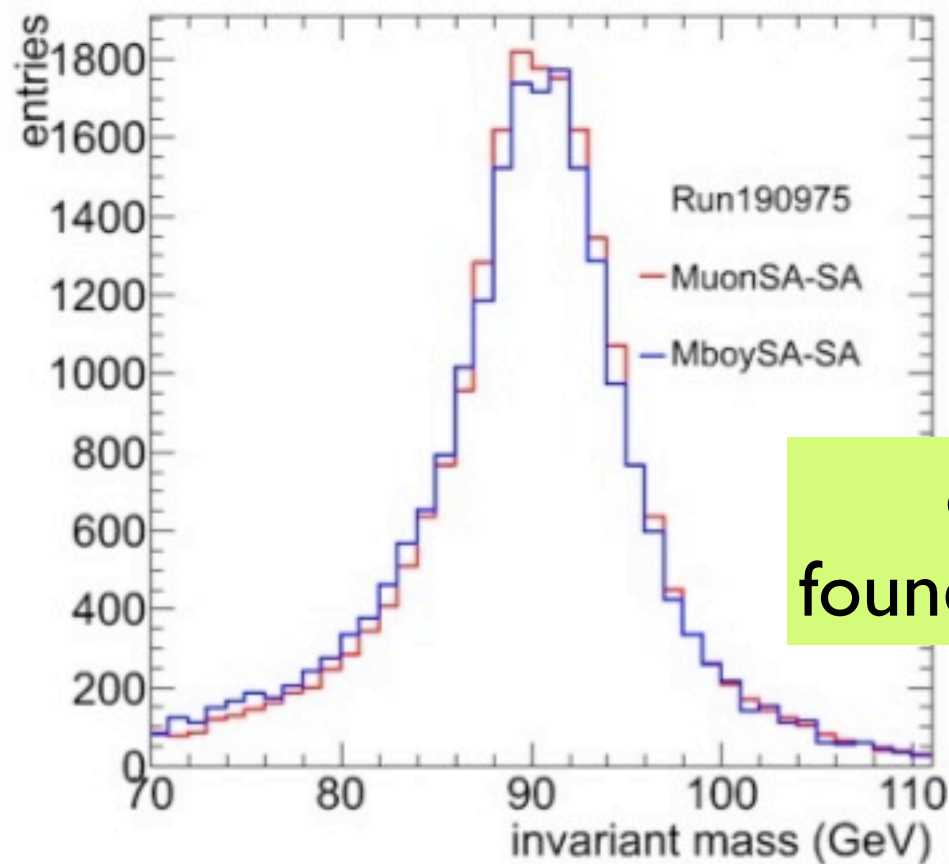
only events found in both chains

- usage of calorimeter measurements in standalone and combined fit, leading to slightly better resolution that in case of STACO (using Eloss parameterization)

# Status of the 3rd chain performance: Charge flip rate

- in 17.0.x.y higher charge flip rate in Muid/Muons than in Staco

- ...optimization done

- Study done with 17.1.1.1.1 using MbMo which is equivalent to the new chain

  - will be redone using the latest release development under the baseline strategy outlined in Dec. toward rel 17.2.x.y (Tier0 2012)

ZmumuPeriodM
Isolated CB muons
mass > 70 GeV

▾ Muons
● MuidCB standard
□ StacoCB standard
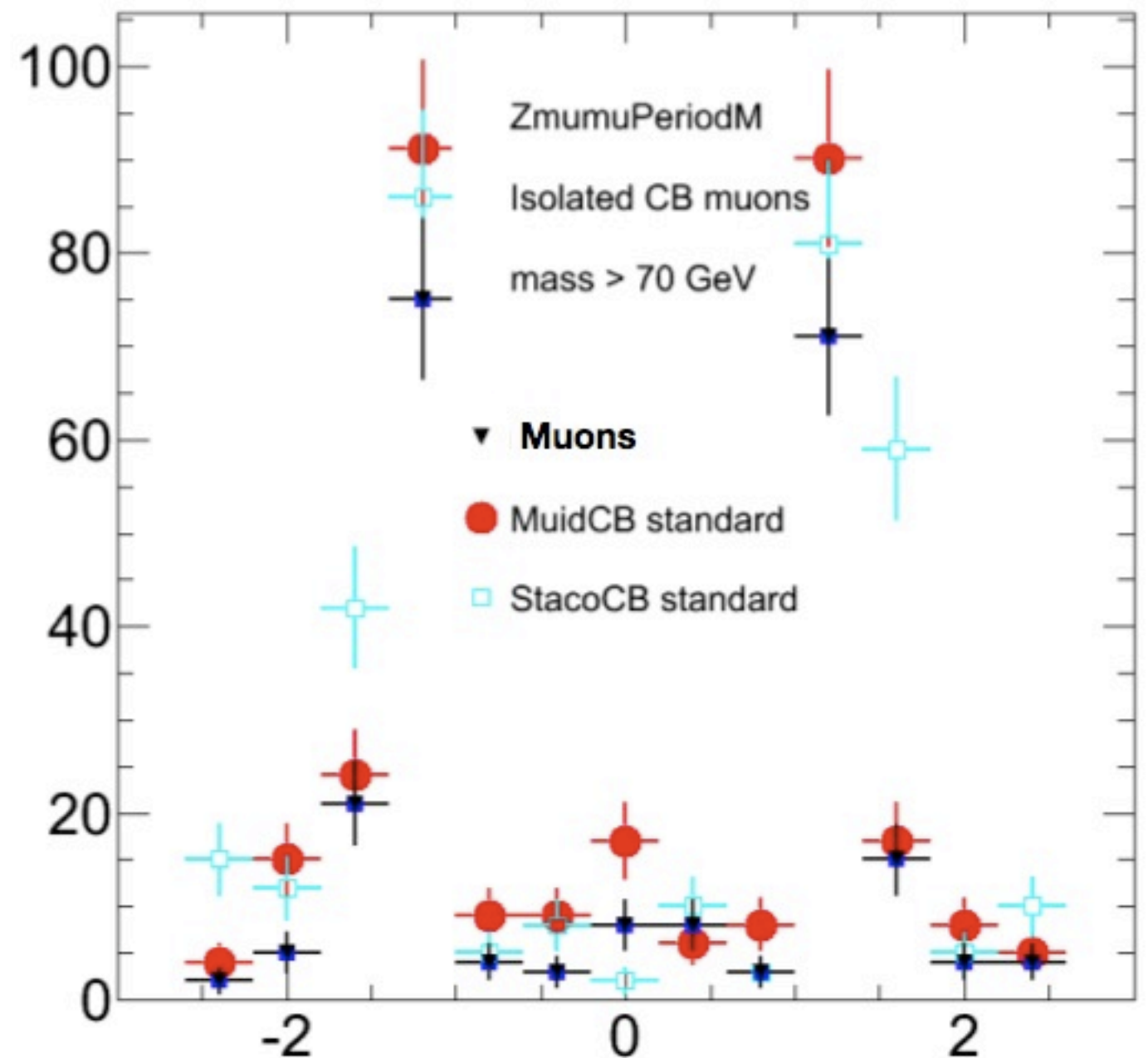
Status of the 3rd chain performance: Muons CB at |η|>2.5 (using Pixel tracklets)

Efficiency vs η

ttbar MC
dev staco impl.

- A few Pixel hits combined in tracklets matching SA muons

  - MS coverage |η|<2.7

  - SCT coverage |η|<2.5

  - Pixel single b-layer hit |η|<2.7

  - Pixel tracklets |η|<2.65

- In Z→µµ MC sample

  - Pixel tracklets add 0.6% to the total single muon efficiency

  - Corresponds to about 15% at |eta| = 2.6

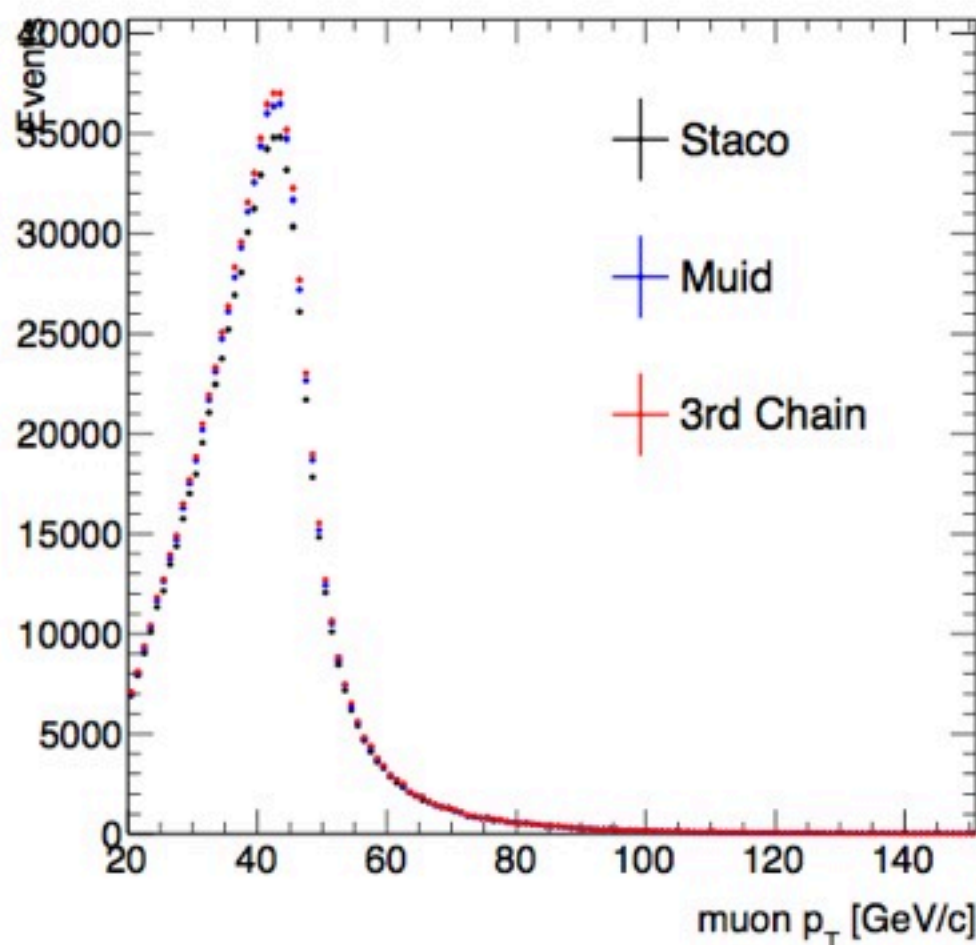 - improved d0, z0 resolution (no p_T)

Muons: 3rd chain

Z MC
mu 20
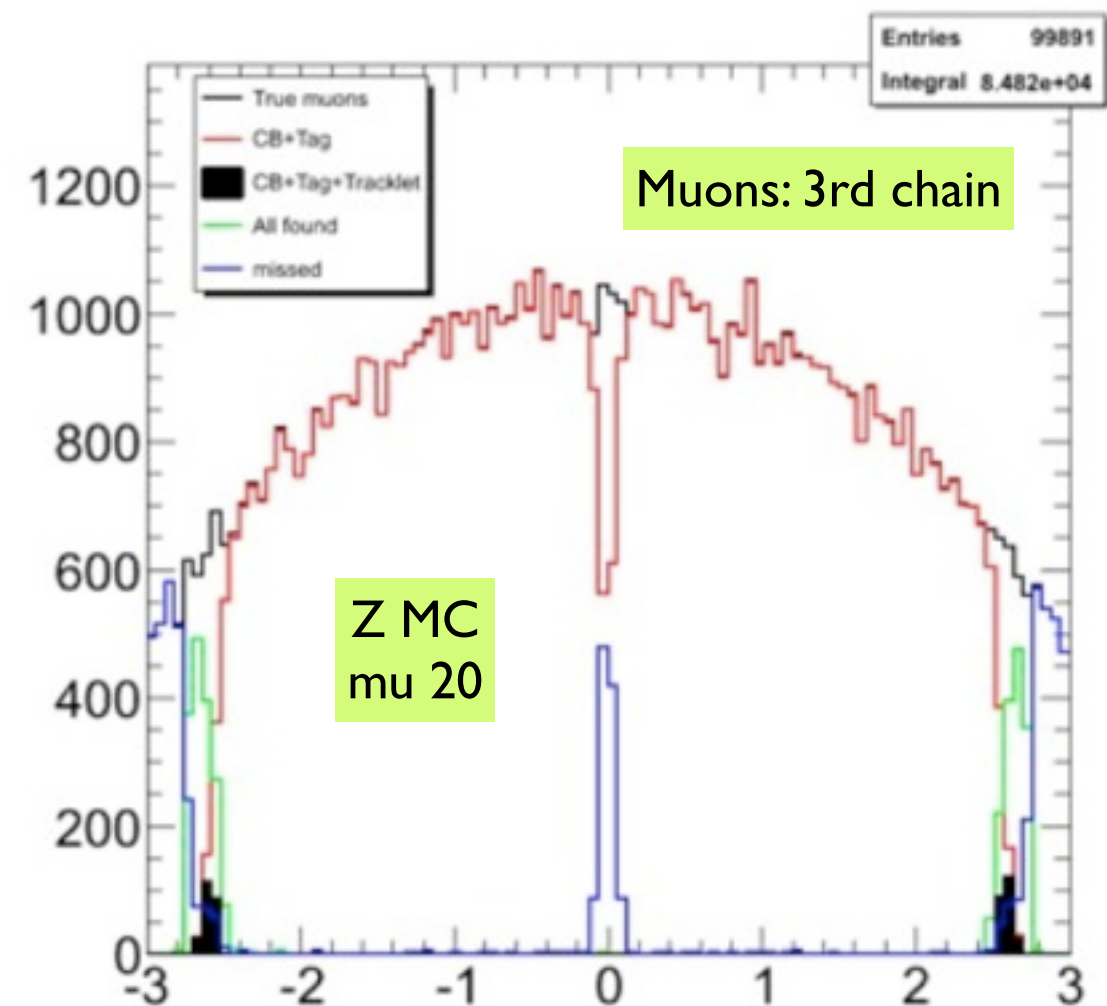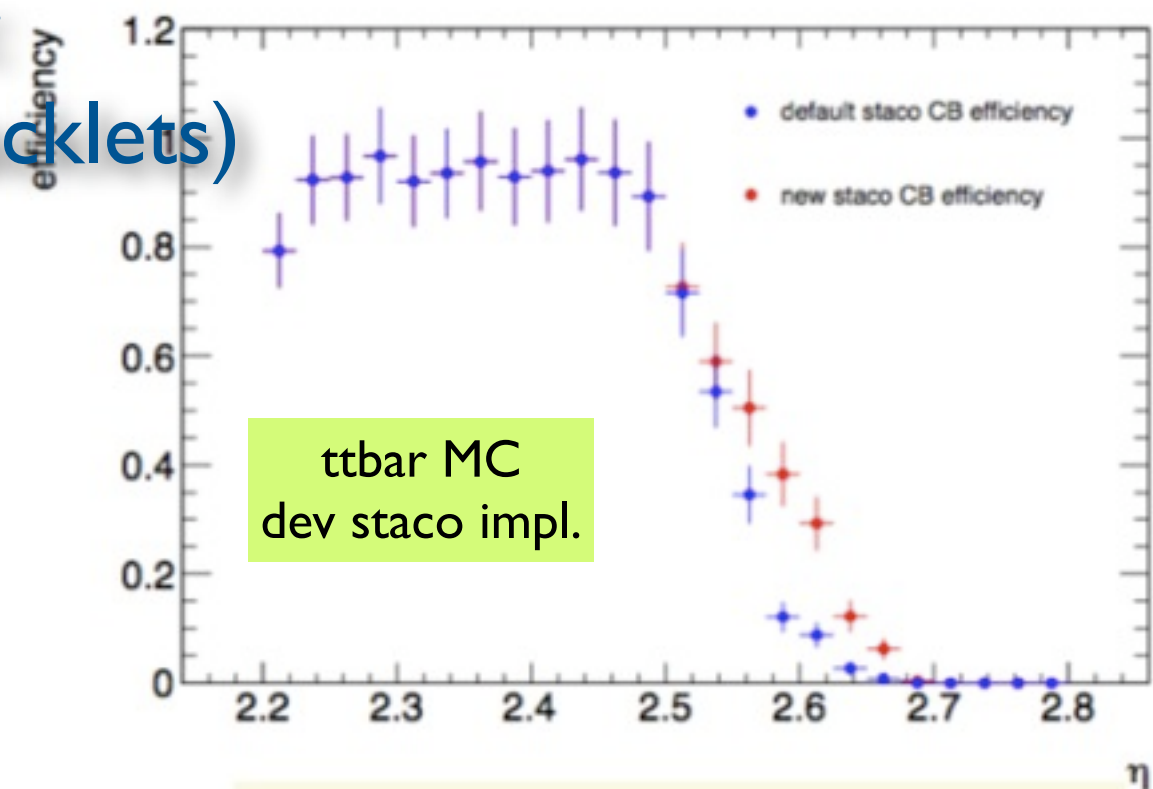
Physics Clients

D3PDMaker /3

- Data 2011 (periodM), events selected with $Z \rightarrow \mu\mu$ baseline W,Z group selection AtlasProtected/WZElectroweakCommonTopics2011

D3PD Makers ready to include Muons

see M. Bellomo at past Atlas Week
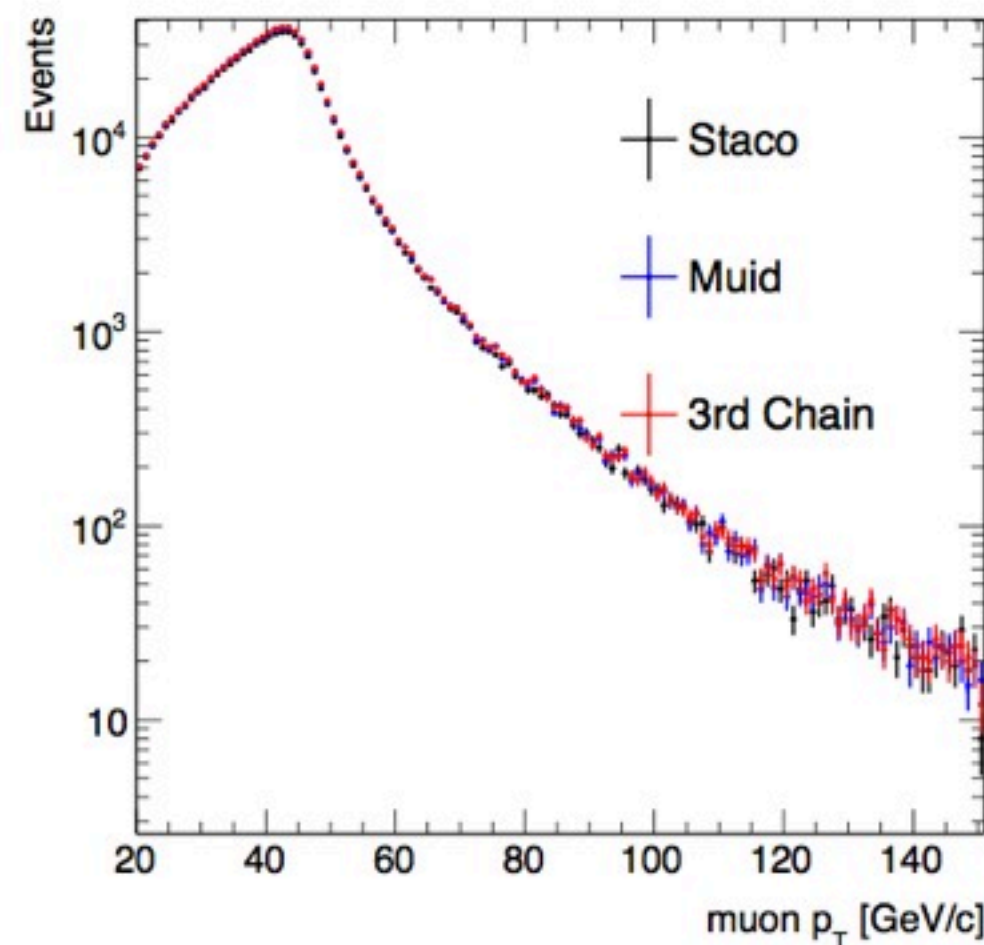
Physics Clients

- Muons fully integrated in missing E_T calculation:

 - Default MET RefFinal stored in D3PDs is from Staco tracks:

To compute RefFinal for Muid/ new chain muons one need to apply

- MET RefFinal (Muons) = MET RefFinal - MET MuonBoy - MET RefMuon - MET CellOut Eflow + MET Muons + MET RefMuons + MET CellOut Eflow Muons

  - ✓ Note that due to muon-cell overlap removal the MET CellOut Eflow term also depends on the muon reconstruction

E_T^{miss} muon terms comparisons

- MC $Z \to \mu\mu$ sample, events selected with $Z \to \mu\mu$ baseline W,Z group selection AtlasProtected/WZElectroweakCommonTopics2011

- E_T^{miss} muon tracking+calorimeter terms (total muon contribution)
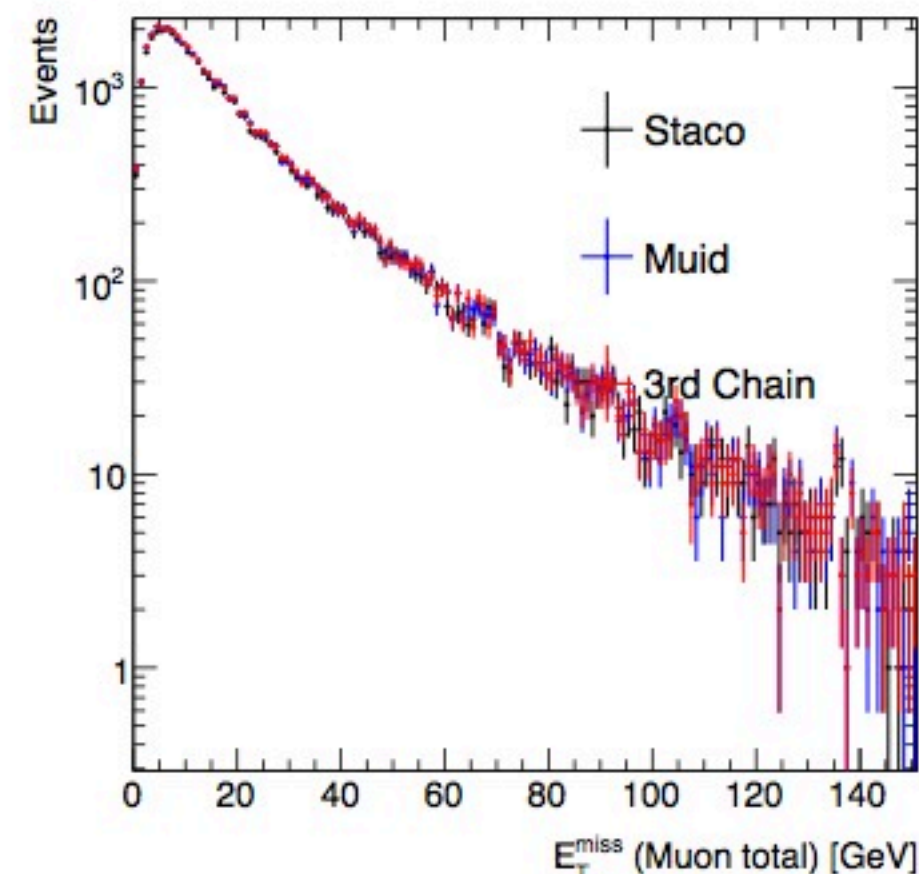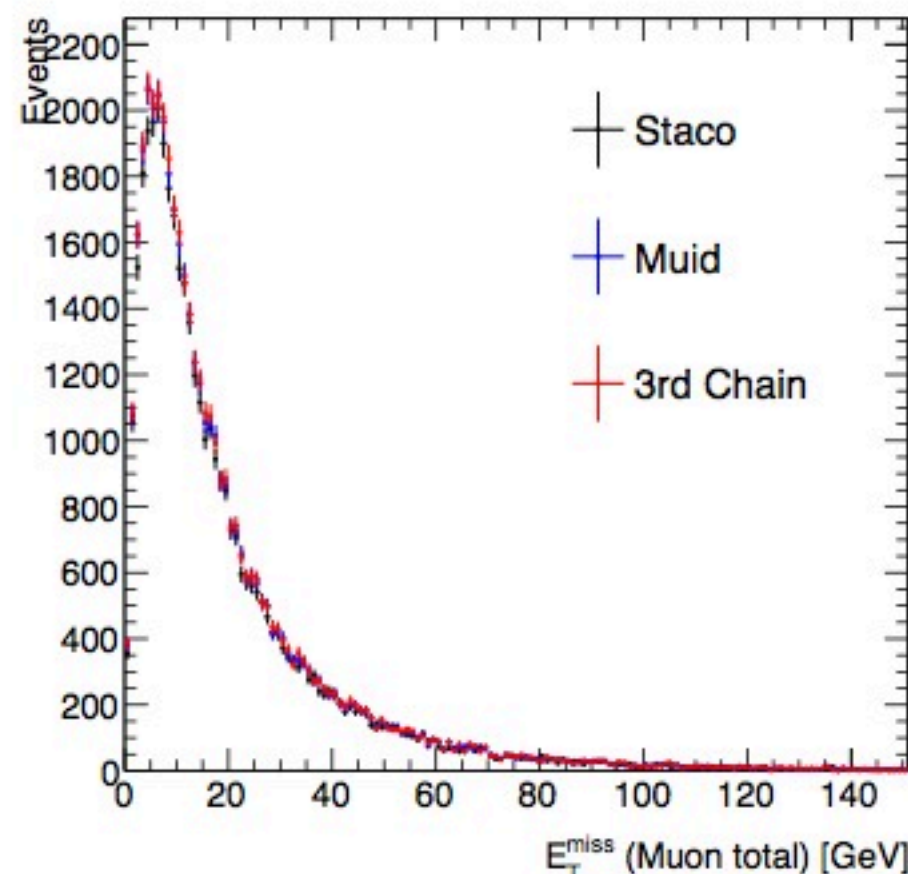
Muons: Performance on 2012 8 TeV collisions

- From Muon Reconstruction Meeting of Apr. 16th 2012: Peter K, Niels van E., Alan P.

    - https://indico.cern.ch/getFile.py/access?resId=0&materialId=slides&confId=170499

    - using period A3; Z skims (now allowing unbiased TP efficiency measurements: require two muons p_T > 25 GeV; one MS muon and one Calorimeter muon or 2 MS muons; Mass > 55 GeV
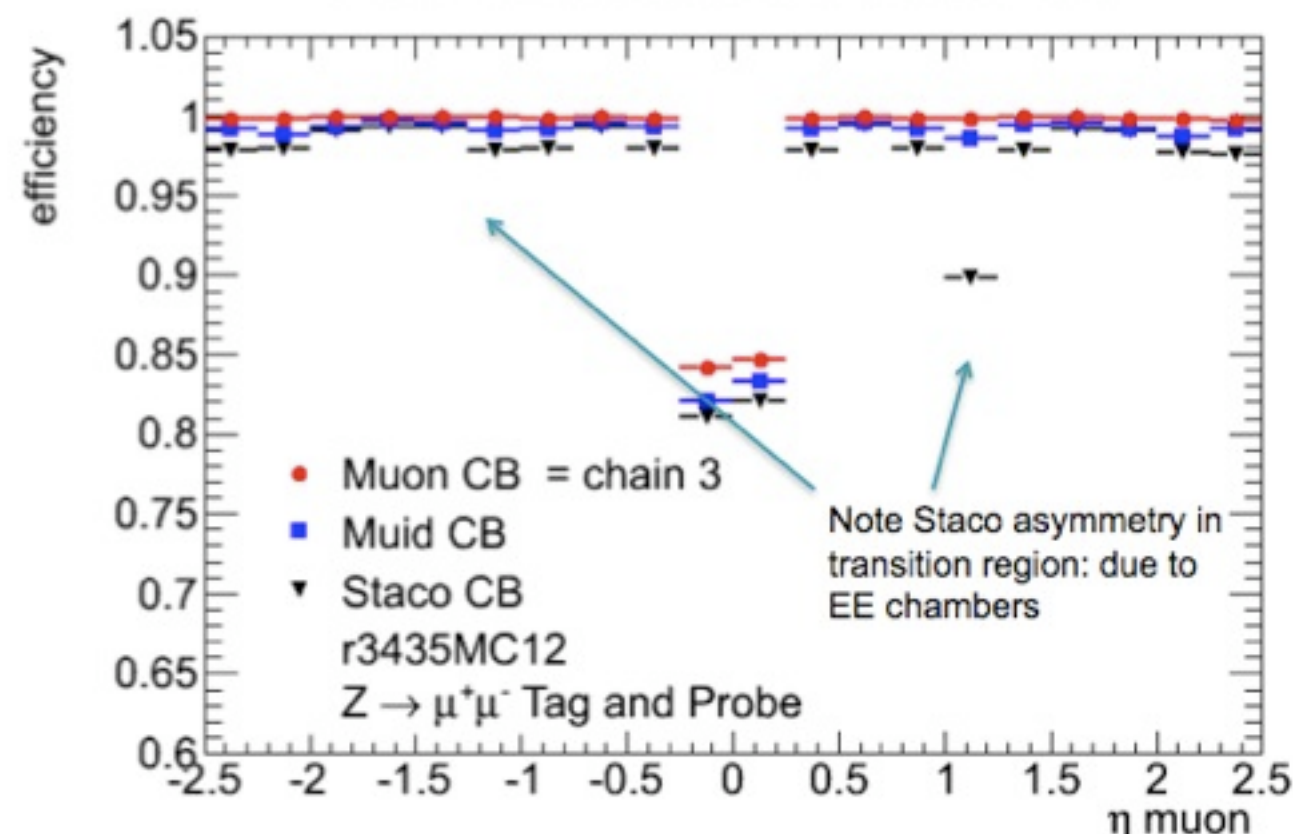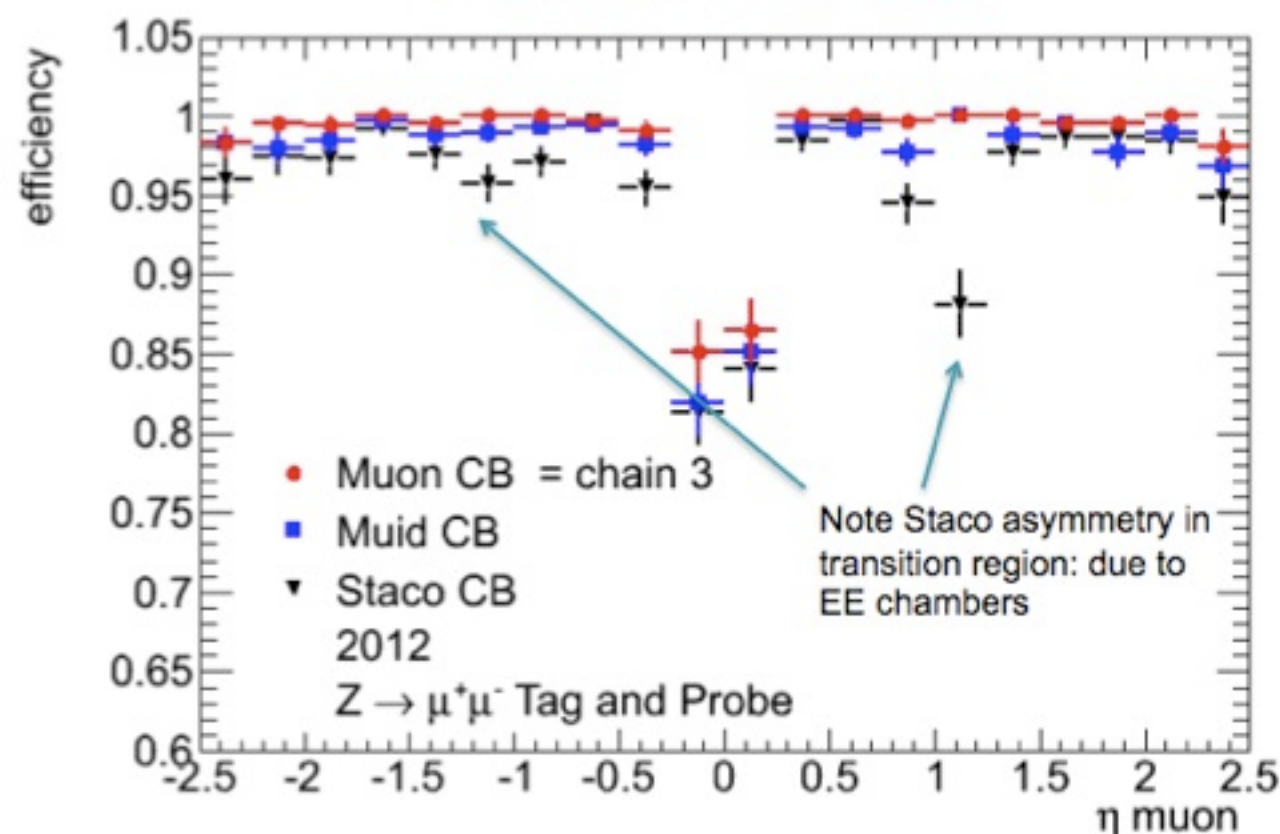
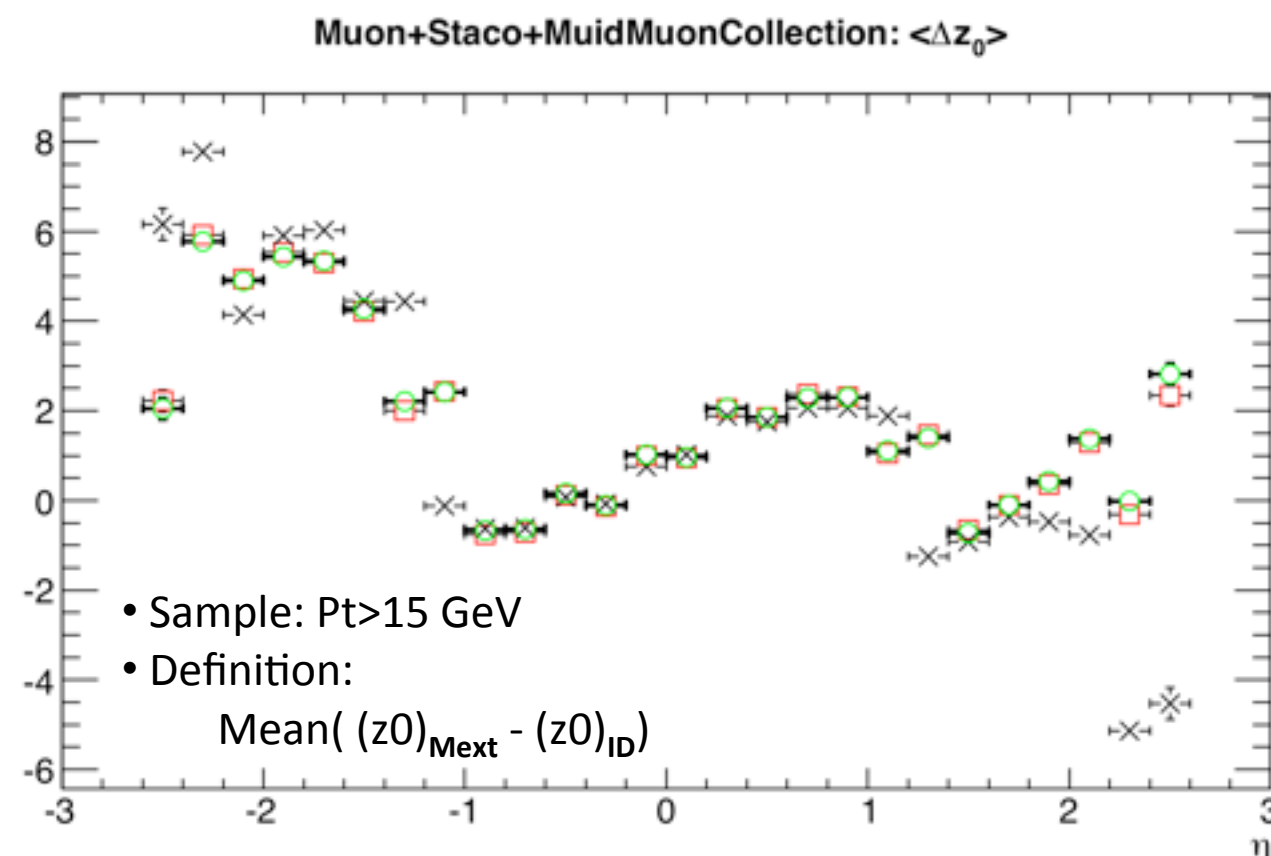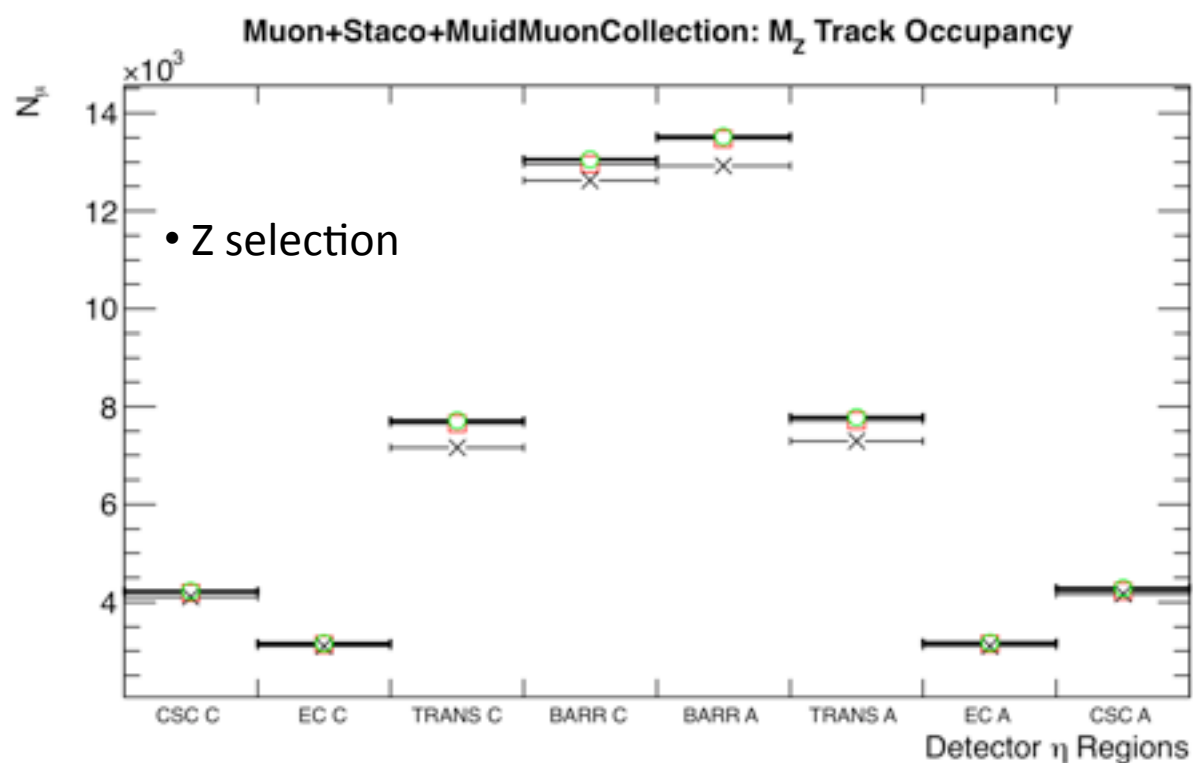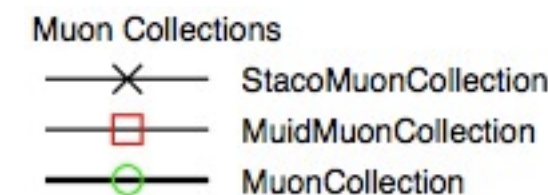# Muons: Performance on 2012 8 TeV collisions
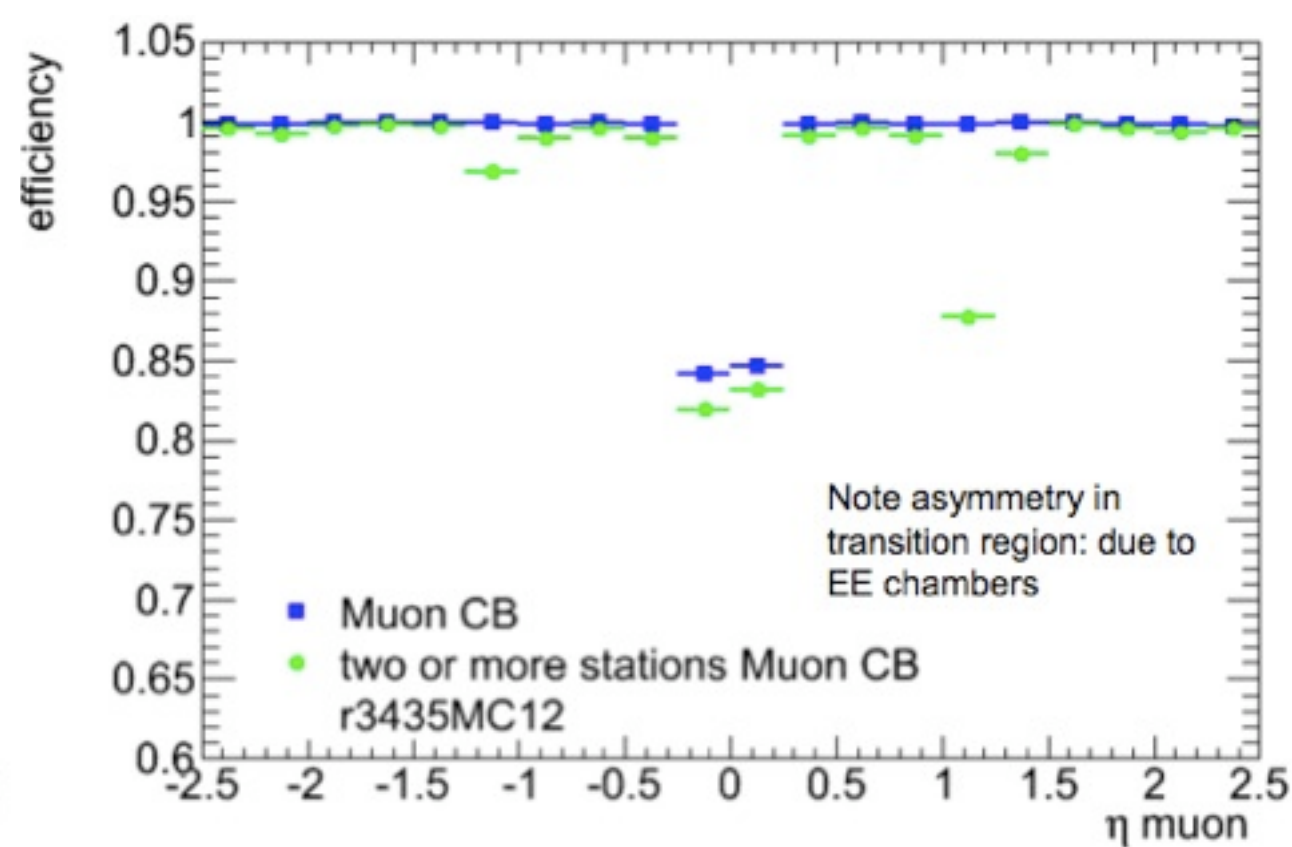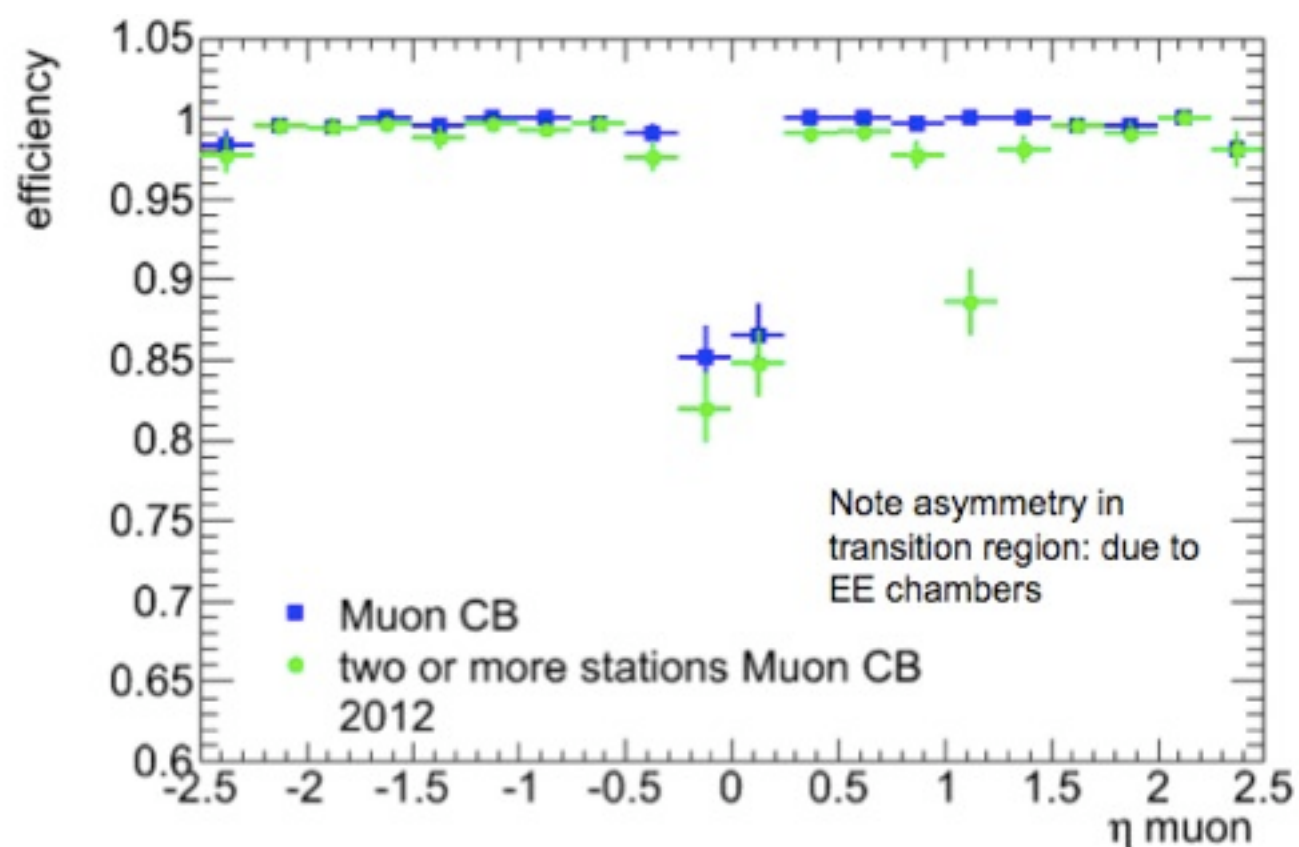
Integration in Offline Monitoring on the ES

- Current muon high level offline monitoring only checks Moore/Muonboy

- MuonTrkPhysMonitoring new -candidate for production at Tier0- waiting integration

  - Package utilizes all 3 Muon Chains

    - Alignment and B-Field Monitoring

    - General Tracking Performance Monitoring

    - Z-Based Physics Monitoring

  - Detector Specific Monitoring Most recent validation run: Release 17.2.1.1 on data11_7TeV. 00191426.physics_Muons.recon.ESD.v83

from A. Basye: https://indico.cern.ch/getFile.py/access?contribId=23&sessionId=7&resId=0&materialId=slides&confId=181713

Muon Collections
- ✕ StacoMuonCollection
- □ MuidMuonCollection
- ○ MuonCollection

Muon+Staco+MuidMuonCollection: M_z Track Occupancy

- Z selection

Muon+Staco+MuidMuonCollection: $\langle \Delta z_0 \rangle$

- Sample: Pt>15 GeV
- Definition:
  Mean($(z0)_{Mext}$ - $(z0)_{ID}$)

What's left

- Production level Validation

- Decoupling from Muonboy/Moore

  - still some sharing of tools

- Phase 3:

- one step: Muon Reconstruction workshop on Feb, 29th-March 1st:

  - https://indico.cern.ch/conferenceDisplay.py?confId=174523

  - migration to C++ of Muonboy segment maker - Aim at rel 18:

    - work in understanding/decomposing in OO blocks under way; two proposed strategies

    - what else is good to borrow from Muonboy TF into the new Muons ?

  - segment making steering option

  - MCP related issues under study: CPU optimization in forward extrapolation, merging of segment taggers

Conclusions

- Integrated Muon Reconstruction chain successful so far

  - timely progress along side the schedule

  - already very good performance in 17.2.x.y and good stability - Tier0 in 2012 -

  - Physics clients using Muons (+Staco+Muid)

- MCP plan during 2012: qualify Muons in 17.2.x.y at the same level of Staco/Muid muons (scale factors, smearing corrections) to demonstrate full ability of physics analyses to use Muons

  - must be ready for rel 18; plan: staco/muid decommissioned by rel 18

- ... meanwhile (by ICHEP) blessed physics with Staco/Muid but Phys Groups getting ready to use Muons

  - plan may possibly be revised after ICHEP