# *Preparazione per il Run 2017: Muon POG*

**C. Battilana** *(Università and INFN Bologna)*
*per il Muon POG*

**Riunione CMS Italia 2016**
***14-16 Dicembre 2016, Perugia, Italia***

# Outline

- Summary of Italian contributions to Muon POG
- Highlights on muon performance in 2016
  - Not the main topic, mostly exploited to frame road ahead for 2017
- Ongoing *(or planned)* updates for 2017
  - Muon HLT
  - Reconstruction
  - Identification and isolation
  - Analysis tools
- Person-power coverage
  - Plus open tasks and opportunities for joining existing efforts
- Summary

# Muon POG core team and "Italians" contributing to MUO

## Muon POG core team:

**(~42% IT)**

Validation
- *Rocio Vilar (IFCA)*
- *Nicola de Filippis (BA)*

HLT Conveners
- *Sara Fiorendi (MIB)*
- *Benjamin Radburn-Smith (SNU)*

Offline SW Coord. / RECO Contact
- *Riccardi Bellan (TO)*
- *Junghwan Goh (Hanyang Univ.)*

**Group Conveners**

**Hugues Brun (ULB)**

**Alicia Calderon (IFCA)**

MG Generators / Production
- *Alessandra Fanfani (BO)*

DQM / Data Certification
- *Pablo Martinez (ETH) new!*

Upgrade Studies
- *Cesare Calabria (BA)*
- *Jason Lee (Seoul Univ.)*

## Muon Object Contacts with PAGs

- *J. Pazzini (PD), R. Castello (CERN) (1+1 out of 15 MOCs)*

## Other "italian" contributors in 2016

*(piked from EPR tables + browsing this year's presentation, not being exhaustive)*

- *G. Abbiendi (BO), P. Traczyk (TO), R. Radogna (BA), S. Chhibra (BO), N. Trevisani (IFCA), G. Miniello (BA), E. Manca (PI), L. Cristella (BA), D. Trocino (Northeastern Univ.), A. Magitteri (UCL), L. Benato (PD), C. Battilana (BO) …*

# Muon HLT

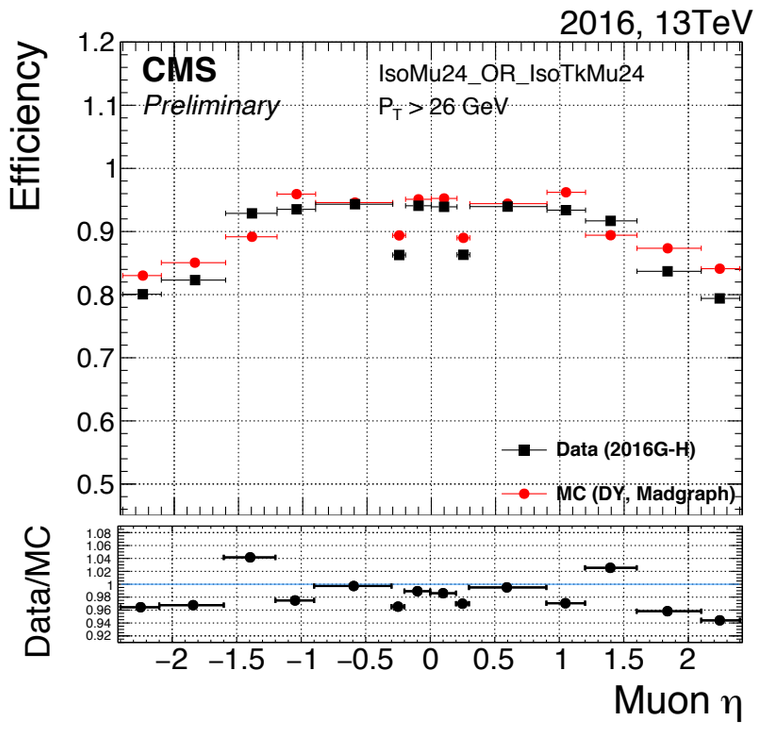
# Muon HLT in 2016 "one slide summary"

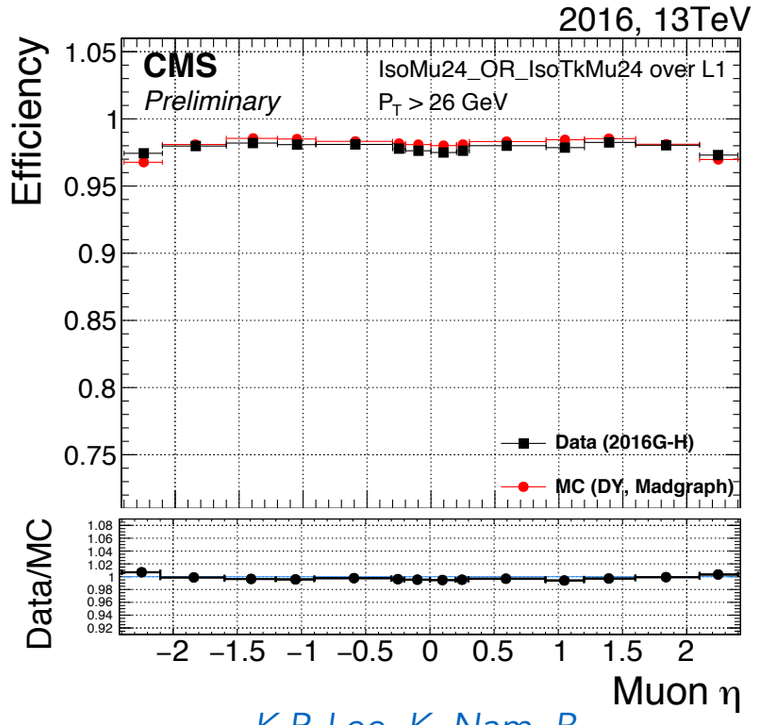
Overall good muon HLT performance in 2016

- Example: efficiency of "Iso(Tk)Mu24 OR" *(Run2016G+H / EOY conditions MC)*
  - Preliminary results for both HLT+L1 and "HLT only" efficiency, more details *here*
  - First iteration, being refined to provide recommendations for Moriond17
- A more complete overview of muon HLT along the full run in *this report*

Main challenges during 2016 operation

- "Trigger inefficiencies at high $p_T$"
  - Mostly inefficiency for L1 muons with same CSC sector
  - Affecting data up to Run2016F, more details *here*
- L1/L2 seed interface "issues"
  - "Patches" applied along the run, need code updates for 2017
- Tracker Dynamic Inefficiencies, and testing of new APVs
  - More details *here*




*K.P. Lee, K. Nam, B. Radburn-Smith, Y. Yoo*

# Updates for 2017: new L3 reconstruction overview

## Motivation and "history"

- Initially developed during LS1 + 2015 aiming to:
  - **Simplify code** and **reduce duplication**, fully **exploit iterative tracking** for muons at HLT
  - **Overcome some original muon L3** *("cascade")* **limits** and **improve performance** *(e.g. on specific signatures, as displaced muons)*
- Code baseline available since ~1 year *(B. Radburn-Smith)*
  - Not deployed until now due to lack of a complete tuning/testing
  - Critical for 2017: **simplifies transition to new pixel geometry**

## Algorithm strategy

- ***Starting point*:** L2 muons updated at vertex, used to seed:
- One ***Outside-In (OI) inner tracking algo:*** based on offline trk iter10 + custom trajectory seeder code
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- **Plus code for combination OI/IO results:** apply quality cuts for track selection to each sequence, cleanup of L2 candidates building OI tracks when seeding IO, "final" combination of OI and IO candidates
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## Status of developments

- A significant update: needs clear milestone definition
- + must proceed in parallel with geometry updates
- Presently running "just" a couple of weeks late w.r.t. initial planning

## *Milestones and timeline*

Machinery setup, migration of configs to 80X and recent menus
**End of summer**

Tuning of IO sequence:
**31st Oct**

Tuning of the OI sequences:
**6th Dec**

Tuning of the combination step:
+ Eventual further IO/OI tuning
**beginning-of-2017**

Check the performance with new geometry (+ release code to PAGs):
**Feb 2017(?)**

Explore possibility/need to merge new L3 with TkMu reconstruction:
**late Feb 2017 (?)**

*S. Folgueras, N. Neumister [1] [2]*

# Updates for 2017: new L3 reconstruction performance highlights

*S. Folgueras, N. Neumister [1] [2]*

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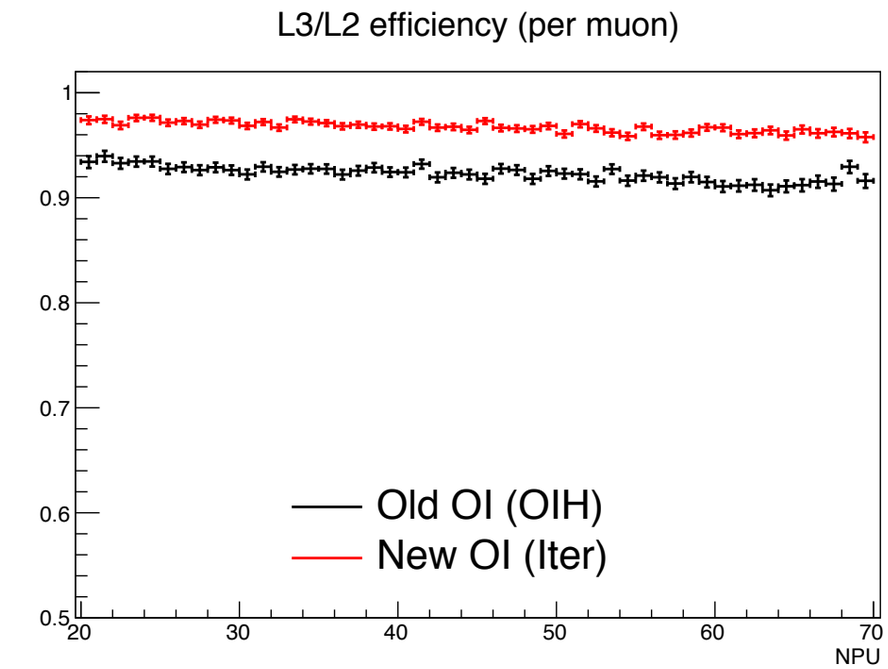
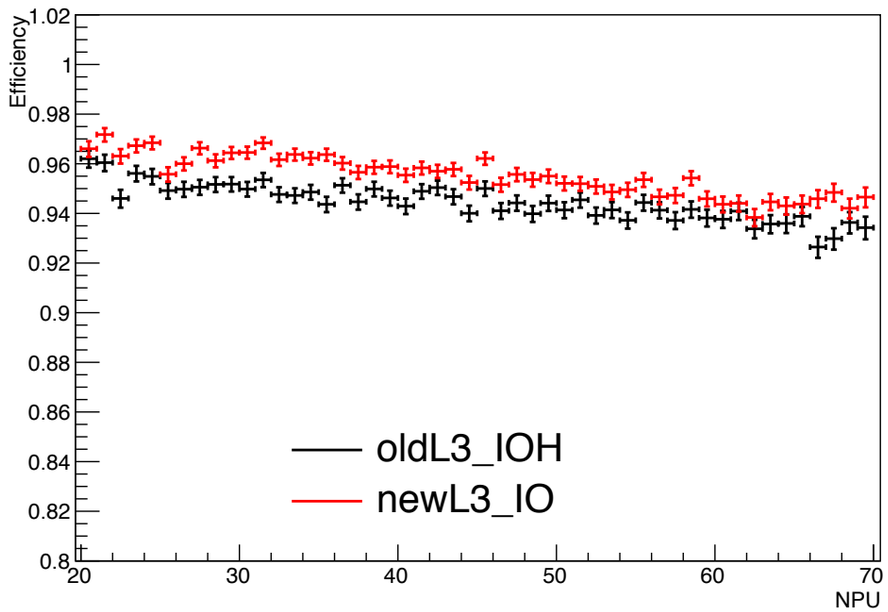
## Optimization studies and performance highlights

- Examples of parameters probed during tuning:
  - IO: tuning of tracking regions of interests (ROIs)
    - Also comparing dynamically computed vs static ROIs
  - OI: tuning of seeding
    - Use of trackerless L2 or L2 + Outer Tracker hit to initiate seeding
    - Number of trk layes used by seeding, number of seeds per tk layer
- "Per muon" efficiency in DY+Jets MC *(present tuning - vs"true" PU [20:70])*
- Computed w.r.t. GEN muons matched with L2 candidates
- Slightly higher efficiency of each step
- For a present 5-30% timing penalty for "new L3" sequences
  - **Anyhow: need to wait for combination code for a "complete" review**



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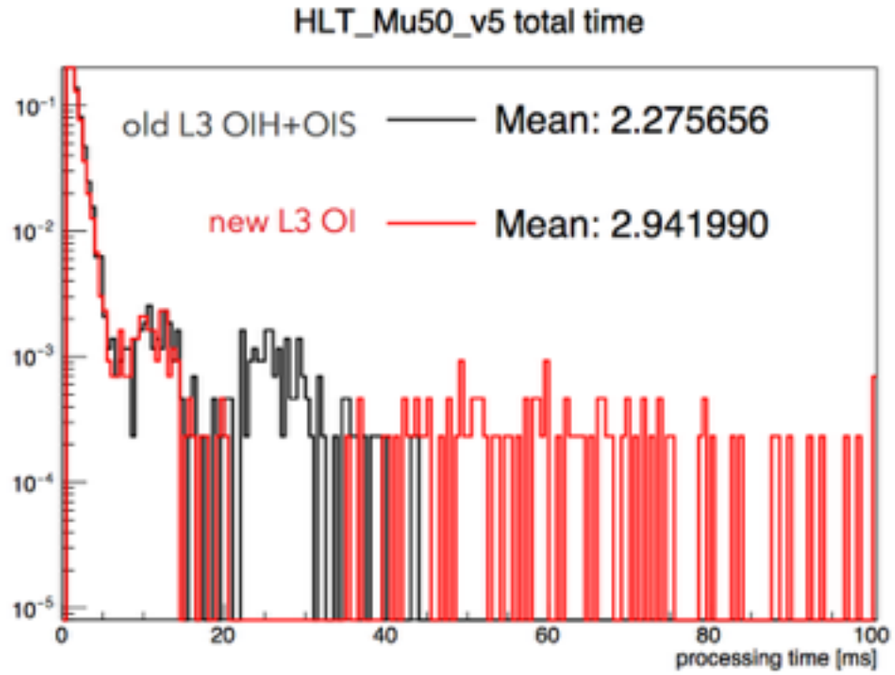
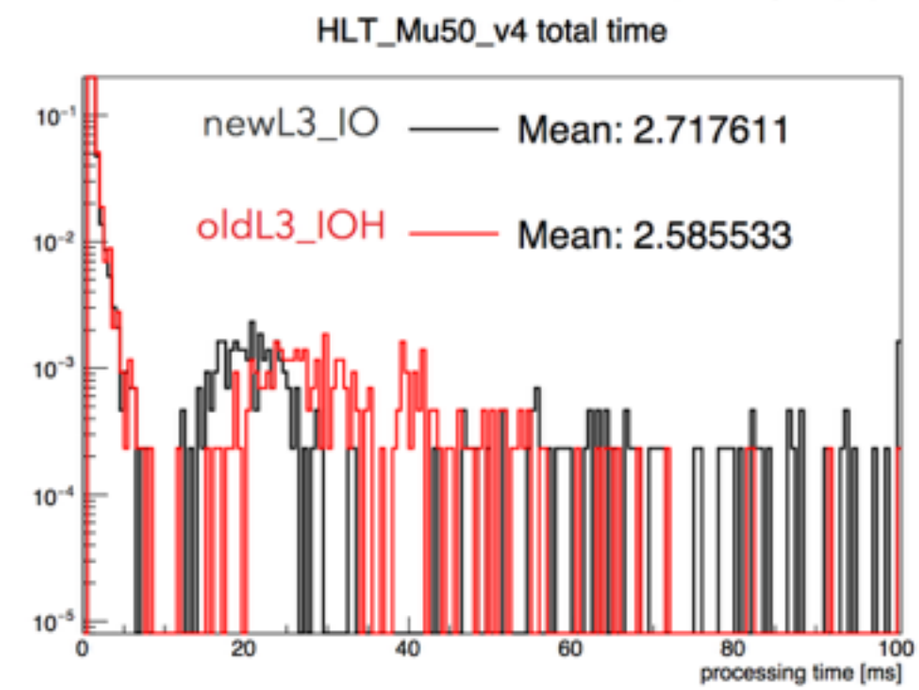


# Updates for 2017: L2 seeding (and further studies)

L2 interface with stage-2 L1 updated few times during 2016

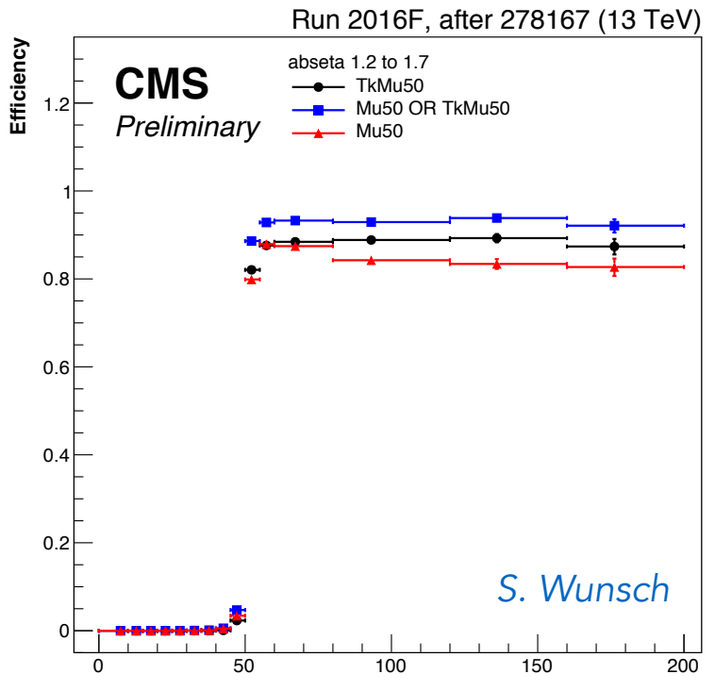
- Mostly to cope with matching issues of stage2-L1 with L2 seeds
- Some short term fixes performed by updating L2 configuration
  - Non clean patch, but had just "small" drawbacks in 2016 menu
- **Need for a clean fix from code update** *(not performed during the run)*
  - Example of an issue: Mu50 vs TkMu50 efficiency comparison, drop vs $p_T$ from L2

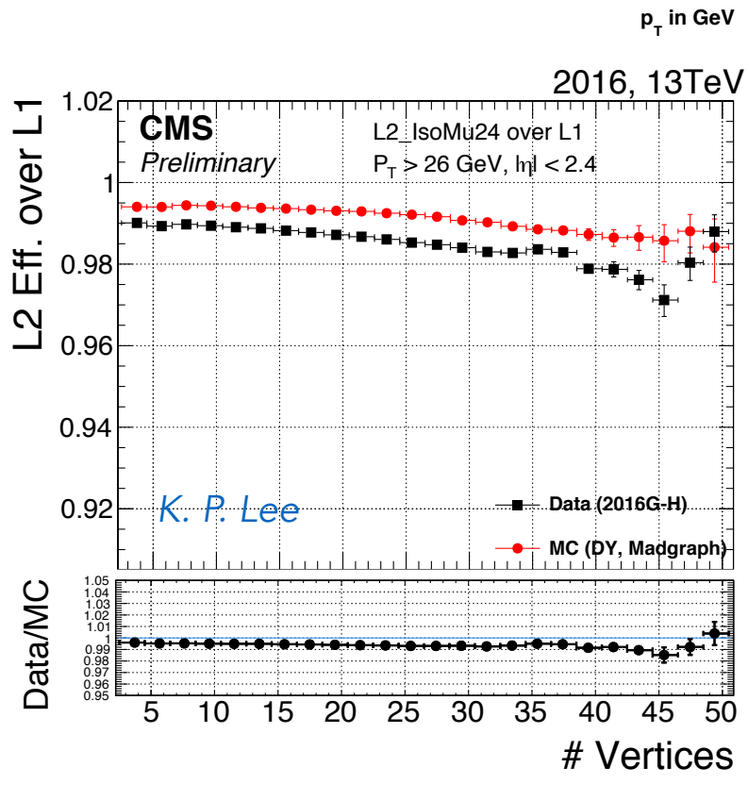
Moreover mild L2/L1 efficiency drop at increasing pile up deserves investigation

- Mitigated in triggers with TkMu backup *(e.g. single muon triggers)*
  - But impacting all "the rest"
- First obvious check: revision of L2 track quality and quality cuts
- Can be performed, in large part, with existing datasets
  - *Not contingent to availability of samples with new detector geometry*

Not a huge task, but still one to be accomplished

- Strategy for changes defined + tools for studies available
- Could be taken care of by HLT conveners …
  - …but a very good starting task for somebody willing to join muon HLT!

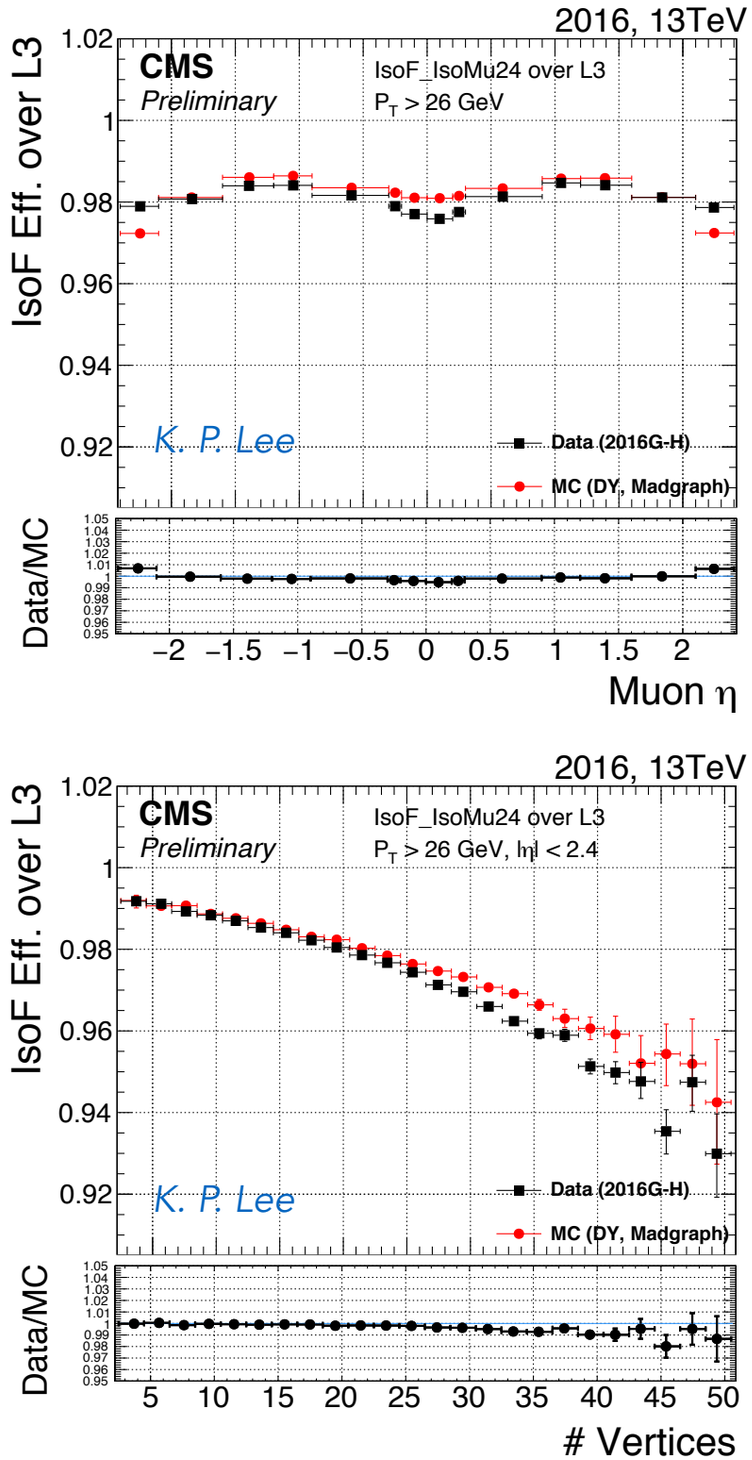


# Updates for 2017: isolation strategy

A review of isolation strategy and cuts applied to single muon triggers is also planned

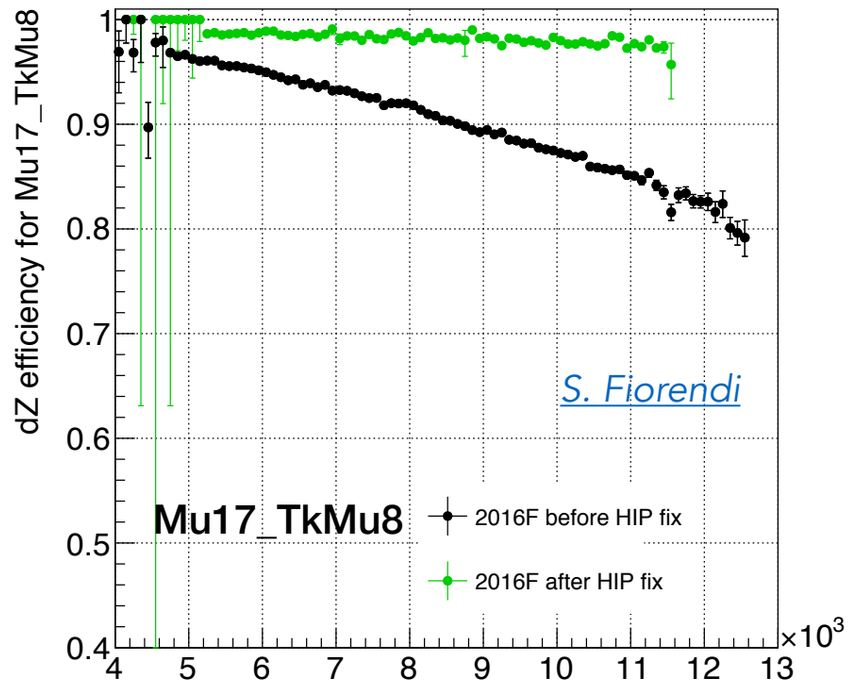
- Present strategy: cuts applied in steps *(relative isolation from ECAL/HCAL PF-cluster energy sums and TRK $\Sigma p_T$)* - using ρ corrections *(with calibration of EAs)*
- 2016 configuration suffering from rather strong PU dependence
- Asses of performance of single components/cuts ongoing *(M. Barrio, M. Soares)*
  - Prime goal: recover stability vs PU
  - Also: aim at achieving any possible improvement QCD rejection *(present strategy, applied to 27 GeV triggers, would give > 220 Hz at $2.0 \cdot 10^{34}$ $cm^{-2}$ $s^{-1}$)*
  - *NOTE: All this to be studied accounting for offline isolation updates (see later)*
- Plus the usual maintenance
  - Make algorithms work with new HCAL geometry
  - Perform final retuning targeting 2017 conditions
    - Also considering L1 thresholds
- In theory a covered task, but additional person-power would allow to work on multiple fronts in parallel on a "critical" topic



# Muon HLT updates for 2017: double muon / single tracker muon triggers

No major updates foreseen on double muon triggers

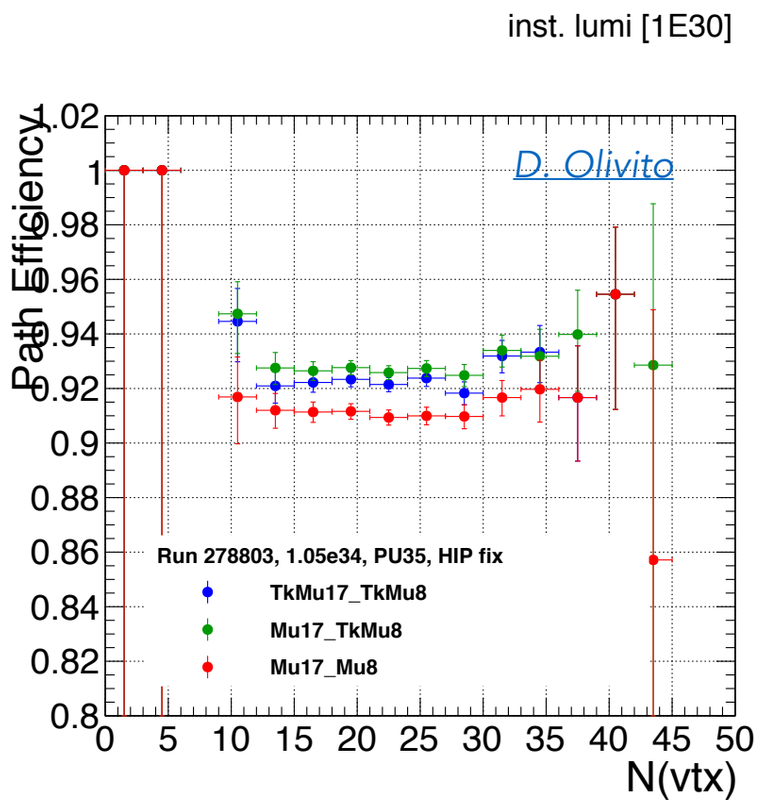
- Most troublesome issue during 2016 run: *dZ inefficiencies*
- Anyhow:
  - HLT operated without dZ cut for the first part of the run
  - Inefficiency understood to originate from L3 tracks without pixel hits
  - Got "fixed" with update of APV settings
- After enabling dZ cuts double muon triggers rates scale well up to luminosities around $2.0 \cdot 10^{34}$ $cm^{-2}$ $s^{-1}$
  - Main threshold bottlenecks coming from L1




Main pending action concerns strategy update for "similar" paths

- Three flavours of double muon triggers (Mu+Mu, Mu+TkMu, TkMu+TkMu) presently deployed
  - They exploit different tracking algorithms
  - Can live with "replicas", but a simplification would be desirable
  - Any decision contingent to:
    - Performance of "new L3" reconstruction
    - Decision about inclusion of TkMu sequences within the new L3

Besides potential inclusion into new L3, presently no planned activity on TkMu triggers beyond maintenance

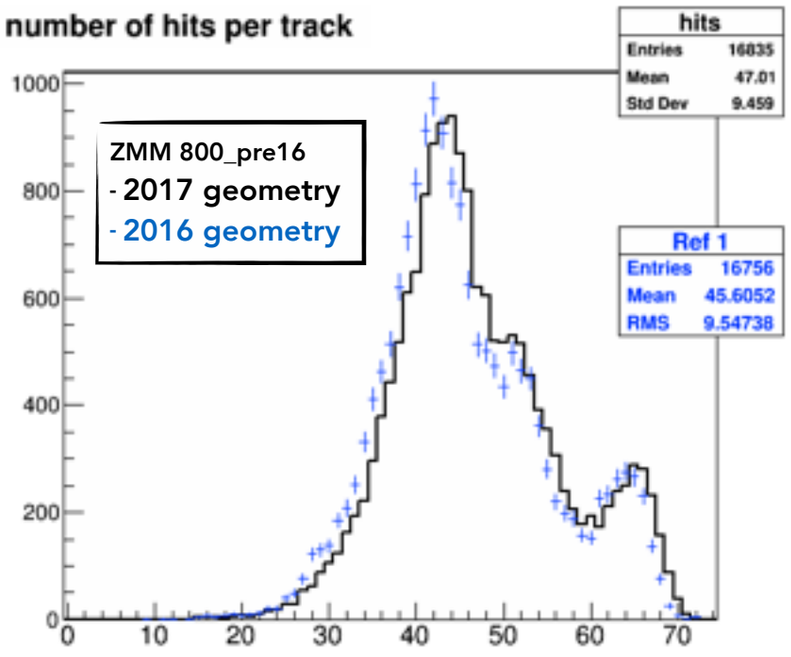


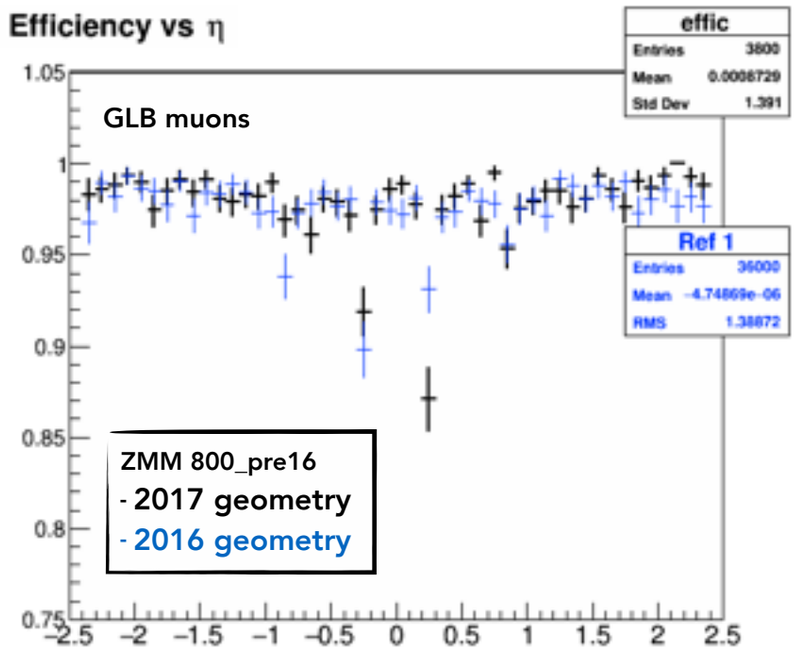
# *Offline muon reconstruction*

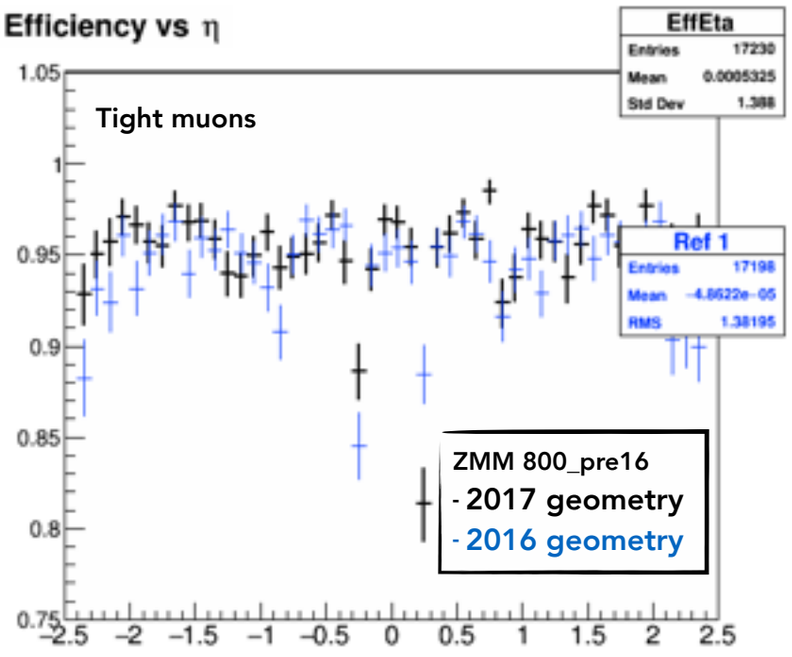
# Offline reconstruction
# Ongoing activities summary

Actual work to include updates from tracker/HCAL geometry into muon reconstruction does not significantly exceed code maintenance

- Improvements from tracking propagate, in general, rather transparently to offline muons
  - Reconstruction being monitored with RelVals waiting for larger 81X samples for more in depth checks



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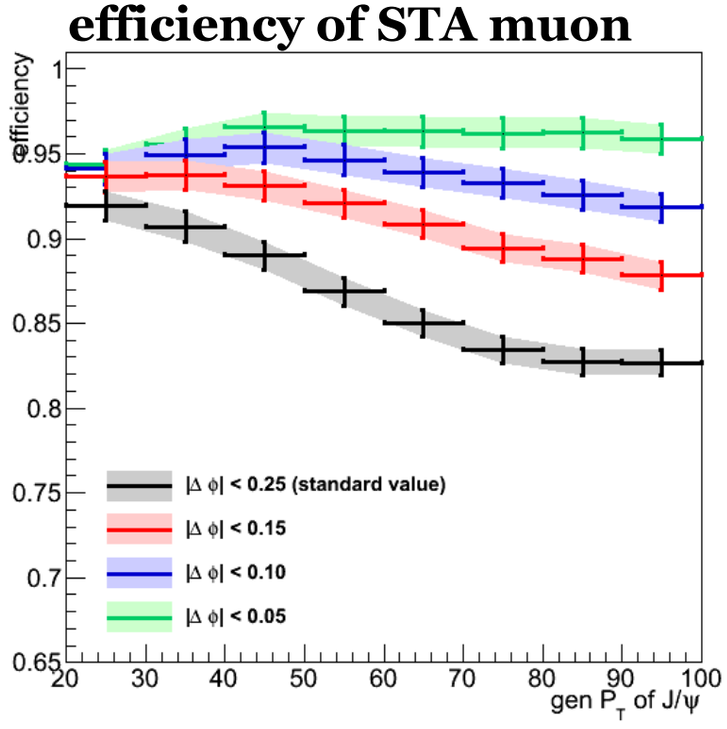
Nevertheless few improvements are in MUO "wish-list" for 2017

- Increase standalone reconstruction performance for close by muons *(I. Kratschmer)*
  - By attempting a tuning of seeding configuration *(90X)*
  - Trying to improve seeding/reconstruction code logic *(later in 2017)*



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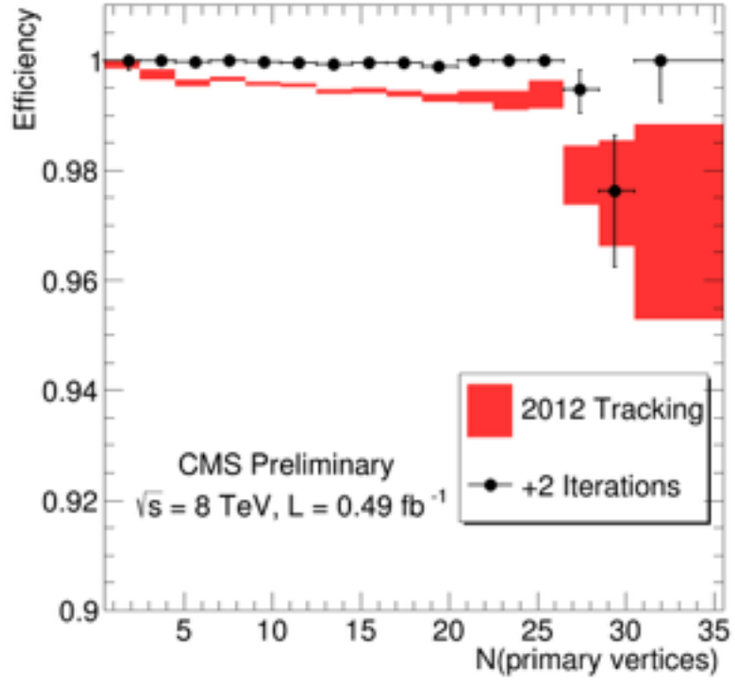
- Retuning of muon specific tracking iterations *(nobody on the task at present)*
  - About lowering 10 GeV $p_T$ thresholds used by standalone seeded tracking iteration
  - Measure performance improvements and + monitor CPU timing increase
    - Tune/add cuts (e.g. muon time) on STA tracks used to initiate seeding if needed



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- Revise/improve performance of particle flow muon identification *(D. Trocino, A. Hortiangtham)*
  - Attempt more regular reviews of muons in PF, increase pool of MUO PF experts
  - Daniele's and Apichart's activity focusing on improving PF ID is specific scenarios (e.g. close-by muons) for 90X
  - Possibility to add contributor(s) to cover in parallel other aspects (e.g. PF momentum assignment at high $p_T$)

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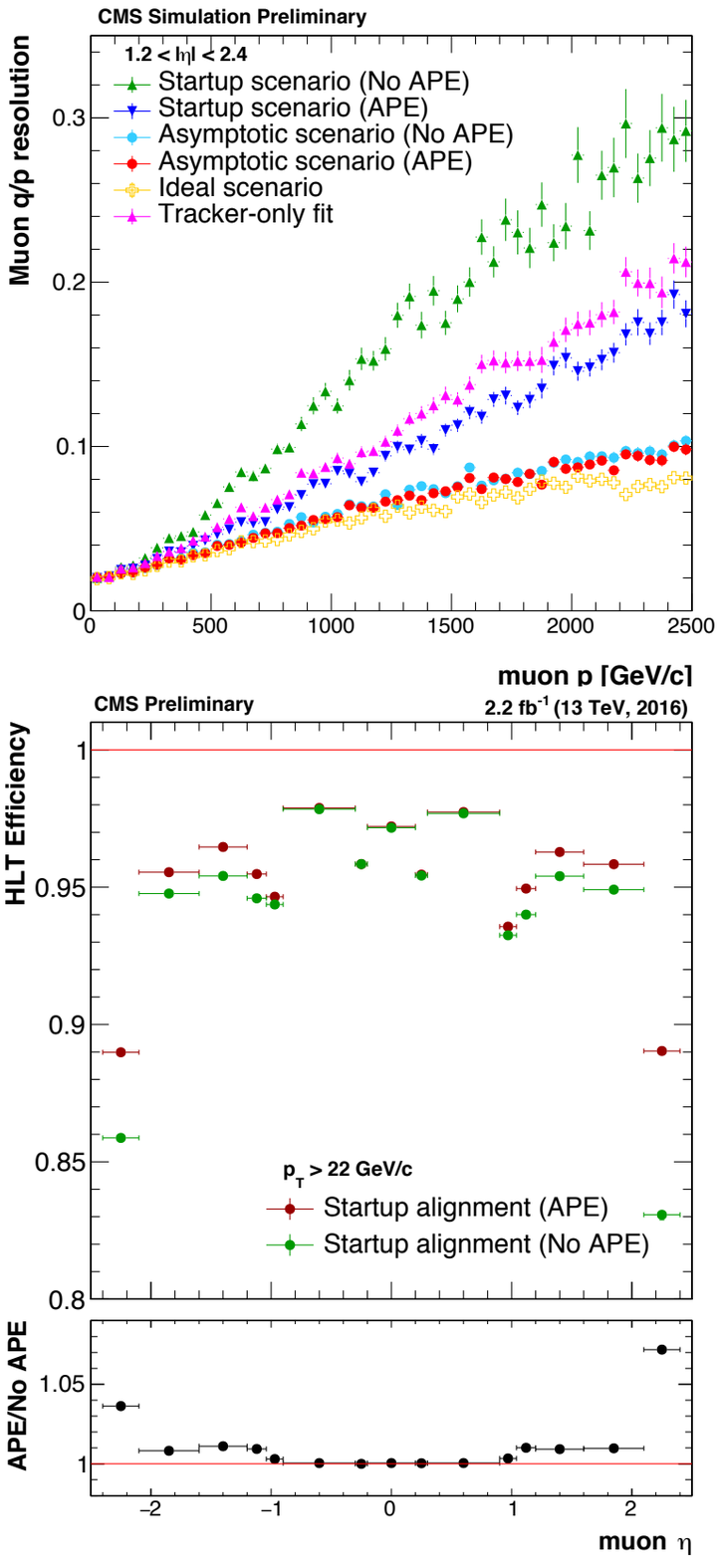
Plus a few other, medium size, "technical" activities

- E.g. cleanup of unused isolation algorithms/dataset/validation sequences from reconstruction *(T. J. Kim - 90X)*

# Offline reconstruction
# Alignment Position Errors and high-$p_T$ muon refits




*G. Abbiendi, S. Chhibra [CMS-DP-2016-067]*

Non-zero APEs deployed in muon reconstruction in 2016

- For the first time, after a complete performance review *(G. Abbiendi and S Chhibra)*
- Starting from code implemented during LS1 *(A. Sviatkosky)*
  - Impact more significant for startup alignment *(both at HLT and offline)*
  - But smaller, positive, effects expected also for asymptotic conditions
  - Measurement in data mostly consistent with MC expectations
- Main missing ingredient: development of an APE calibration workflow
  - Present values based on MC estimations *(asymptotic)* or HW measurements *(startup)*
  - To be finalized before the 2017 run together with "technical validation step"

Also implies "physics" validation of each high-$p_T$ muon refit as well as fo cocktail used for muon momentum assignment *(tune-P)*

- Measured up to now in MC *(R. Radogna)* and with cosmics *(J. Chaves, J. Tucker)*
- Repetition of end-to-end physics performance studies after APE calibration is part of 2017 preparation/commissioning plans
  - Even though, from previous experience, no retuning of tune-P is expected

# *Identification, isolation and analysis tools*

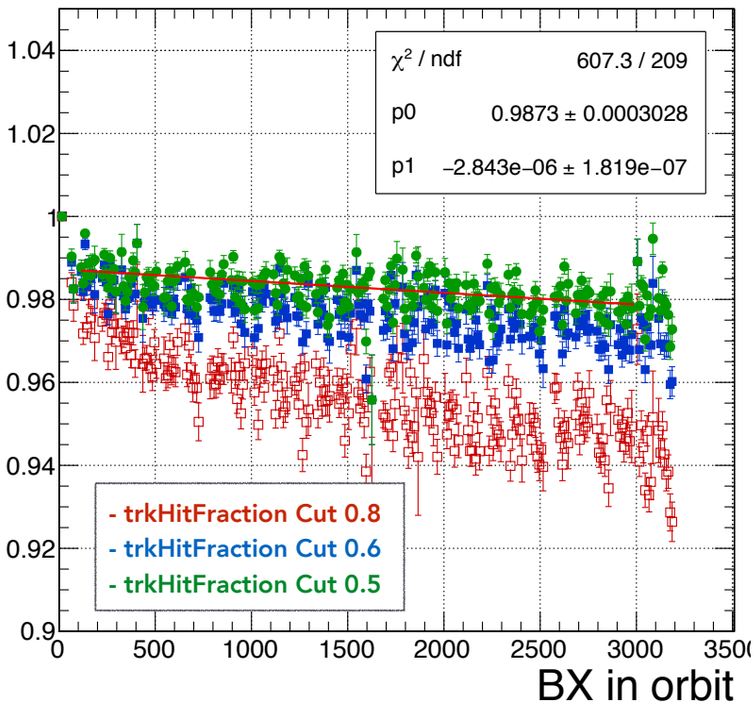
# Muon identification
# 2016 recap and plans for 2017

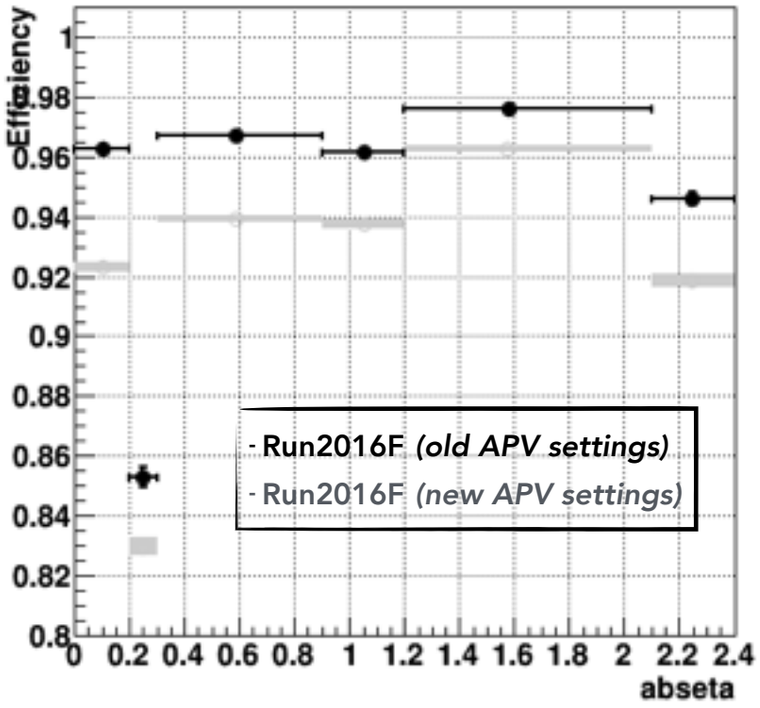
Main ID related challenge faced during 2016: *tracker dynamic inefficiency*

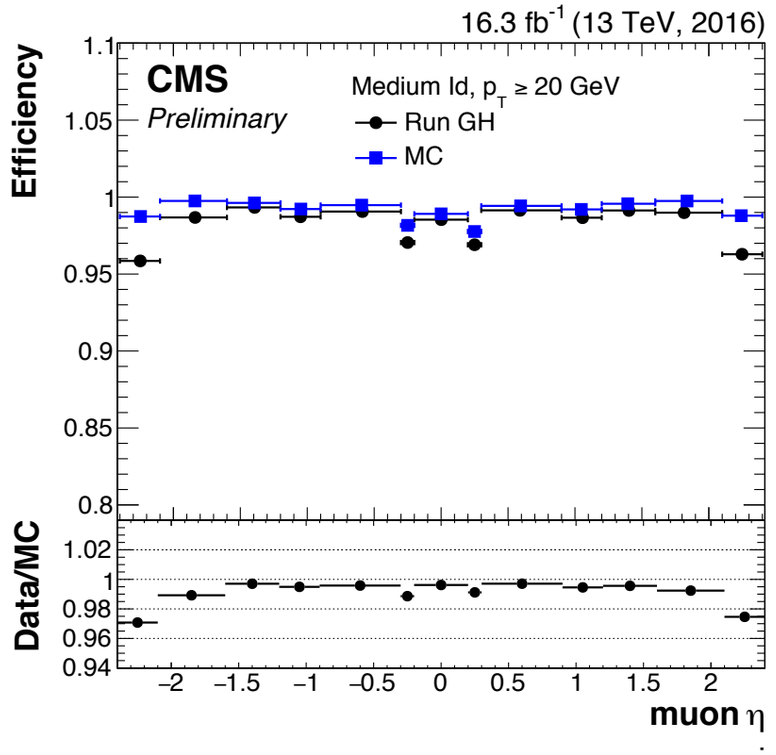
- Mitigated for ICHEP16 by applying "quick retuning" to most affected IDs, overcome by APV settings update
- Studies drained person-power committed to "smooth corners" on existing IDs *(e.g. MediumID efficiency at high-η)*
- In parallel tuning of some IDs started by/in-collaboration-with PAGs *(e.g. on (Tk)HighPt-ID: B2G, EXO)*

A revision of the performance of the main IDs planned before the 2017 run when large simulation samples including new geometry will be available

- No big changes expected *(when used)* pixel hit cuts applied in muon ID are rather mild
- Anyhow, follow-up on "open points" about IDs performance can largely proceed in parallel
- All this to be done directly on AOD/miniAOD



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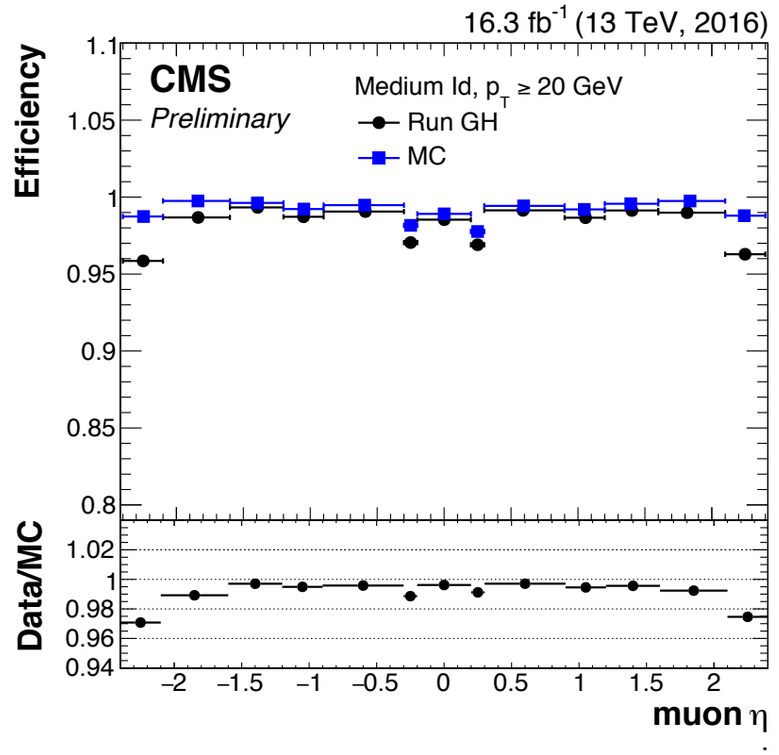
**Answering yesterday's question from Roberto from MUO perspective:**



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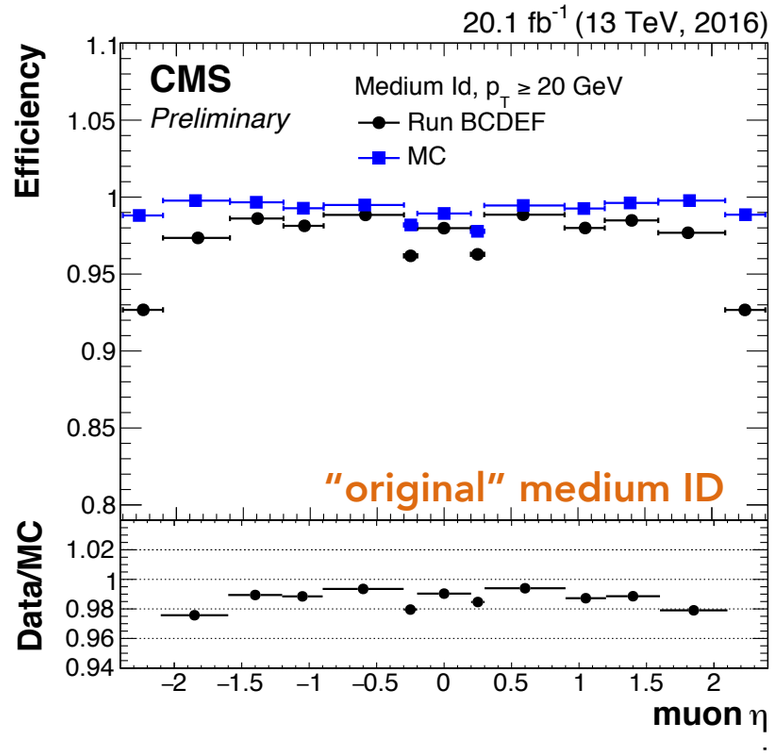
- In parallel tuning of some IDs started by/in-collaboration-with PAGs *(e.g. on (Tk)HighPt-ID: B2G, EXO)*

A revision of the performance of the main IDs planned before the 2017 run when large simulation samples including new geometry will be available

- No big changes expected *(when used)* pixel hit cuts applied in muon ID are rather mild
- Anyhow, follow-up on "open points" about IDs performance can largely proceed in parallel
- All this to be done directly on AOD/miniAOD

**Answering yesterday's question from Roberto from MUO perspective:**



# Muon identification
# 2016 recap and plans for 2017

Main ID related challenge faced during 2016: *tracker dynamic inefficiency*

- Mitigated for ICHEP16 by applying "quick retuning" to most affected IDs, overcome by APV settings update
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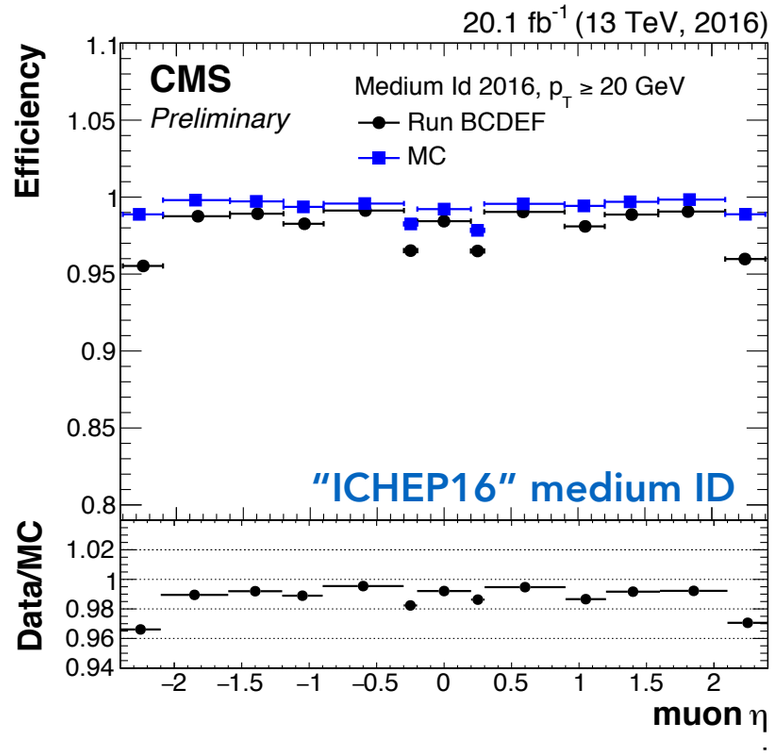


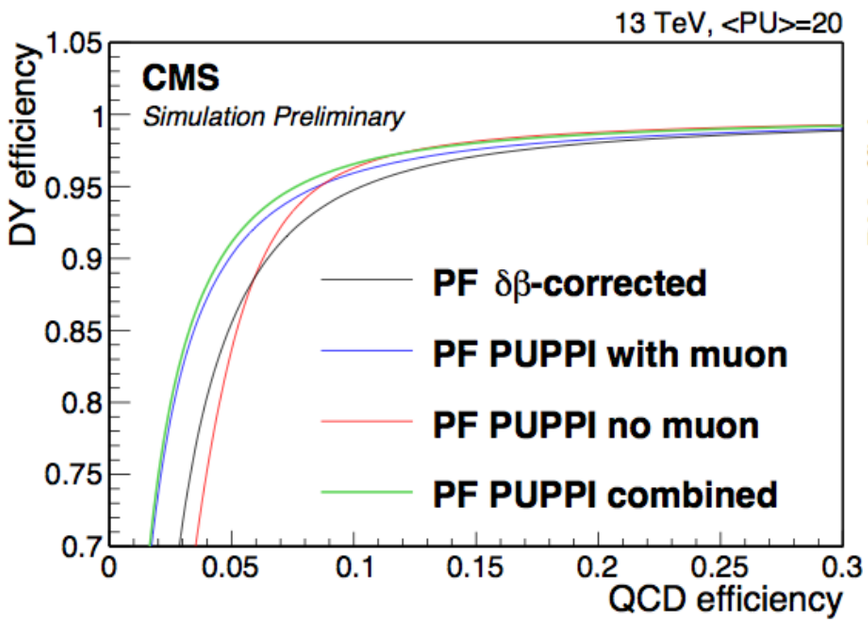
# Muon isolation status and plans for 2017

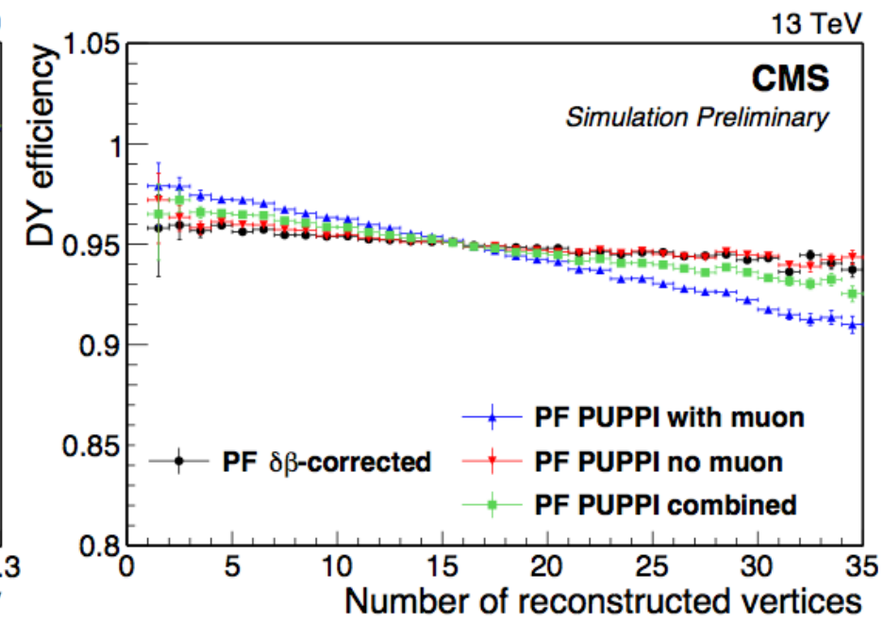
More intense roadmap for isolation tuning. A brief recap of the workflow:

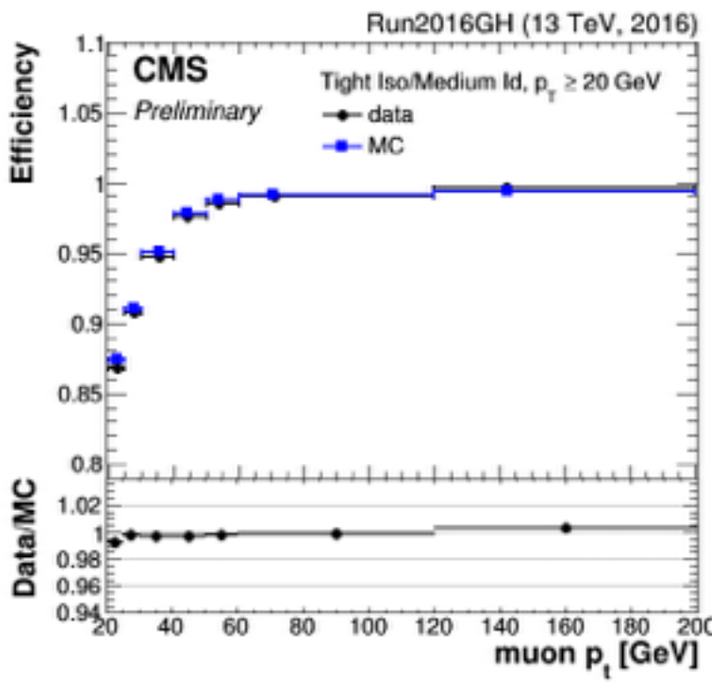
- Present tuning performed in 2015 *(L. Benato, S. Hasegawa)* and cross checked at 2016 startup *(J. Brochero)*
  - For PF isolation tested different strategies (Δβ / ρ *corrections, PF weights, PUPPI) and cone sizes.*
  - Outcome: though slightly worse in performance, central w.p. Δβ based*: simpler / implies less maintenance*
    - Tight w.p. *(Δβ)* : ~95%(~11%) efficiency on DY(QCD) for Tight muons *($p_T$ > 20 GeV/c)*
    - For <PU> slightly above $1 \cdot 10^{34}$ $cm^{-2}$ $s^{-1}$
- Very good data/MC agreement *(performance monitored along both runs)*

All this need to be repeated for 2017

- Firstly exploiting high-PU corner from 2016 dataset *(activity restarting)*
- Then repeat studies regularly with coming datasets *(81X, 90X)* even if exact strategy not cleat *(to me)*
  - *Though partly covered, a task where additional person-power would be welcome*



# Monitoring and analysis tools overview

*[X] == recent updates for Moriond17*

Summary of workflows presently used to provide recommendations

- Tag-and-probe efficiency measurements
  - Z: ID *(G. Perrin [1])*, isolation *(G. Perrin, P. F. Manteca [2])*, Single Muon Trigger *(K.P. Lee [3])*
  - JPsi: ID *(L. Cristella, T. Madlener)*
- Double muon trigger efficiency:
  - Reference trigger method *(H. Brun, Q. Wang L. Favart )*
- Muon scale/resolution corrections *(low, intermediate $p_T$)*
  - Rochester Method *(A. Bodek, A. Khukhunaishvili)*
  - Kalman Filter Based Method *(G. Rolandi, M. Bachtis, E. Manca)*
- Muon scale/resolution measurement *(high-$p_T$)*
  - Resolution: by comparison of top and bottom legs in cosmics *(J. Chaves, J. Tucker)*
  - Scale: generalized endpoint method with collisions *(R. Radogna, A. Escalante, R. Castello)*
  - Cosmics endpoint method *(J. Sturdy, P. Karchin, S. Zaleski) [presently under development]*

Plus DQM, dedicated commissioning tools and analyses not run on regular bases, to name a few:

- Common ntuple based
  - Data/MC comparison, commissioning of ID/Isolation variables *(L. Li)*
  - APE Validation *(G. Abbiendi, S. Chhibra)*
- TnP trees based
  - High-$p_T$ triggers cut and count efficiency measurements *(S. Chhibra)*
  - Hadron mis identification analysis *(J. Goh)*

# Monitoring and analysis tools milestones achieved and next steps

Large effort n 2016 in terms centralization of "private" workflow into common frameworks and automatization of existing workflows

- E.g. porting of generalized end-point method to central ntuples *(R. Radogna)*
- Extension of TnP "additional" utilities *(for skimming, automatized publication of plot and fit results … S. Wusch)*

*Also significant reduction of memory footprint of TnP fitting code*

- *From code architecture, not simply a bug*
- *Limiting factor for the analysis of large volume of data*
- *Achieved in two "significant steps" (M. Calderon - M. Marionneau)*
- ***A third one missing** to ultimate technical performance optimization*

*General "decent task coverage" (AFAIK), but there are spots where additional person-power is desirable*

- *Right now, or, more likely, as part of the usual set of EOY task transitions*
- *Please contact directly Hugues and Alicia to get a more up-to-date overview*

# Summary

- Brief of summary of present MUO performance results and plans for 2017 was presented

- Most significant activity on the trigger side
  - Major changes planned and started in advance, whenever possible
  - Some delays on the initial timeline, for now not “critic”

- But also relevant developments for offline reconstruction, isolation and analysis tools

- Very strong Italian contribution to MUO
  - Even if could be improved in terms links with PAGs

- Except few holes, many tasks are “decently covered” *for POG standard*, anyhow additional person-power is highly desirable in some fronts
  - Status of tasks coverage presented at the best of my knowledge, but I’m not fully aware of recent updates
  - In case of interest better to iterate directly with *cms-phys-conveners-MUO@cern.ch*

# Backup

# Trigger inefficiencies "at high $p_T$" (1)



## EMTF ISSUES [WAS: HIGH PT INEFFICIENCY]

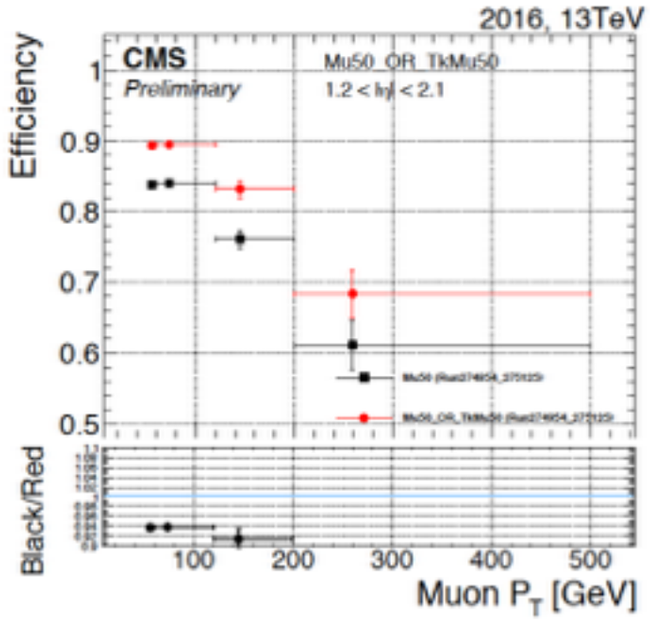
S. Wunsch

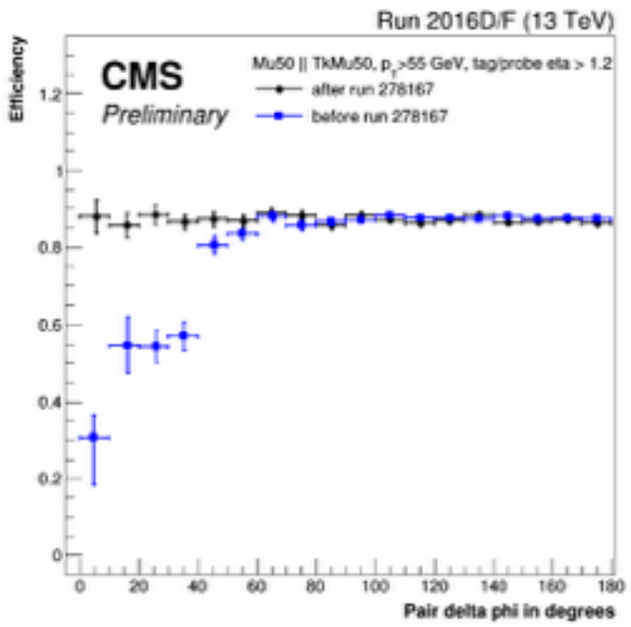
- Efficiency decreasing with pT for L1 muons in the endcap/overlap region

- Three issues found in EMTF, affecting especially high pT muons

  1. Configuration error: EMTF only assigned pT to highest-quality track in a 60° sector - others got pT = 0
  2. Firmware error: track in BX=0 was sometimes mis-assigned the pT from a track in the same sector in BX=-1
  3. Algorithm tuning: showering muons can produce tracks with three LCTs in a straight line, plus one outlier LCT - EMTF assigns low pT

- All the issues have been fixed by L1 side from Run 278167



# Trigger inefficiencies "at high $p_T$" (2)



## PHI ISSUE AND HIGH PT INEFFICIENCY

S. Wunsch

- S. Wunsch performed some more studies on HLT_Mu50 OR HLT_TkMu50 efficiency, to understand the effects of the fix to the EMTF misconfiguration (bullet B.2 of the previous slide)
  - all details from Stefan here
  - the geometrical issue shows up especially for high pt muons due to their kinematic distribution
- **this geometrical issue was actually introducing a correlation between the tag and the probe muons used in the single muon efficiency calculation**
  - single muon efficiency for analyses using one single muon should be evaluated by neglecting those events where the tag and probe muons cross the same endcap
  - in the plot on the left, neglecting same-endcap muon pairs if their offline phi difference dPhi is > 70 degrees
- **this issue was actually found to be the dominant one**