The L1 Pixel Trigger for selecting LFV tau->3 mu at Phase 2

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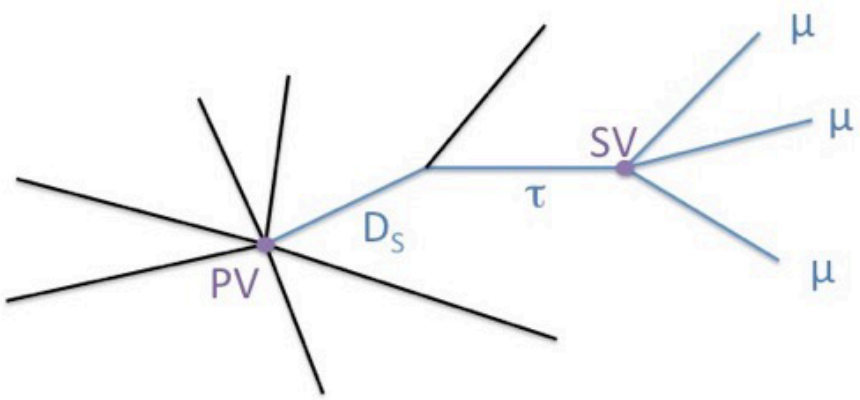
* Supported by the FP7-2012-ITN project 317446, INFIERI

This project has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grand agreement n° 317446

τ -> 3 μ search physics motivations



Three generations of quark, neutrino and charged lepton

Quarks change generation – CKM matrix
Neutrino oscillations
No fundamental law forbids Charged Lepton Flavour Violation

The tau to 3 μ branching fraction in the SM is very small (~10^{-40}), however many scenarios of new physics predict observable levels (~10^{-8})

Experiments have been built for decades to search for CLFV (MEG, COMET, Mu2e, etc)

τ ->3 μ has a clean signature, CLFV τ decay could be studied at colliders

State of the art

World best limit:
Belle ~ $2.1*10^{-8}$ @ 90% CL (LHCb ~ $4.6*10^{-8}$)

CMS estimate sensitivity (Run I) ~$O(10^{-7})$
(two different tau sources : D_s and W)

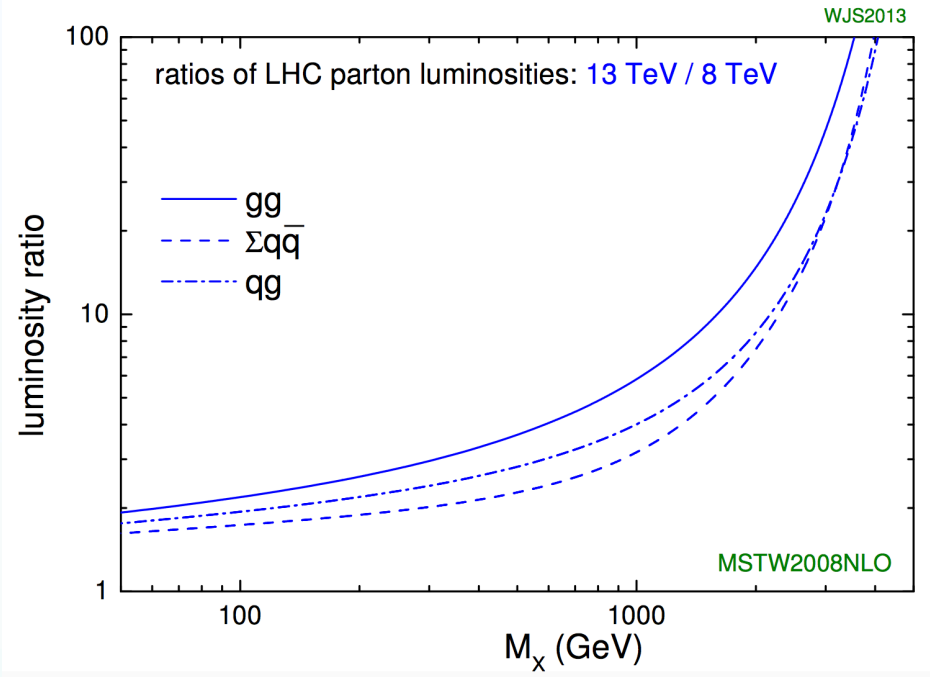
Different tau sources at LHC

- $\sigma(pp \to W \to \tau\nu_\tau) = \mathcal{O}(10\ \text{nb})$
- $\sigma(pp \to Z \to \tau\tau) = \mathcal{O}(1\ \text{nb})$
- $\sigma(pp \to B \to \tau + X) = \mathcal{O}(10\ \mu\text{b})$
- $\sigma(pp \to D_s \to \tau\nu_\tau) = \mathcal{O}(10\ \mu\text{b})$

Improve the sensitivity

Different factors contribute to the limit on the sensitivity:

- ✧ Cross section
- ✧ Integrated luminosity
- ✧ Trigger efficiency
- ✧ Background rejection



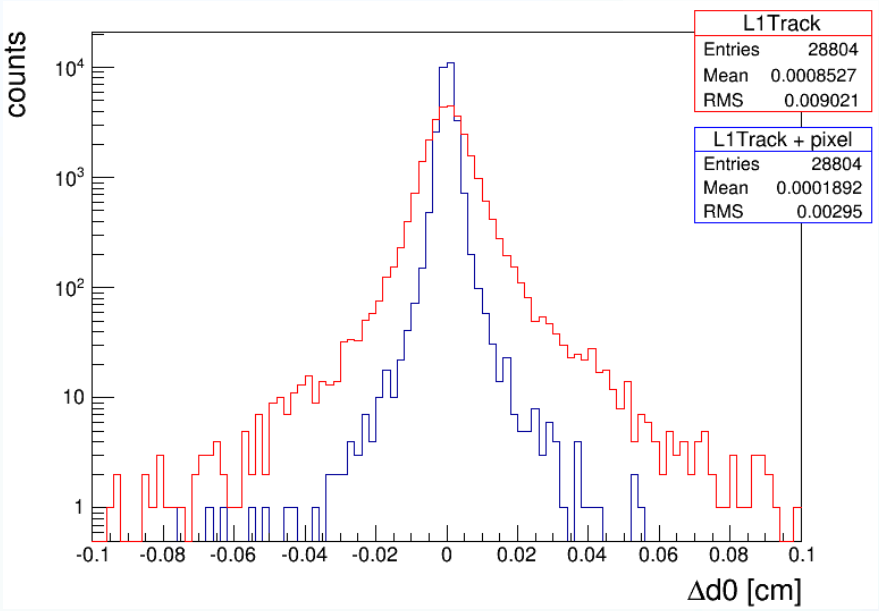
In Run II will gain an order of magnitude with respect to Run I because of the expected integrated luminosity

At 13 TeV the production cross section will be a factor ~2 higher

L1 Pixel trigger

A pixel trigger will improve the resolution on the secondary vertex position

- ✧ Less background
- ✧ Higher efficiency
- ✧ Reduce the needed bandwith

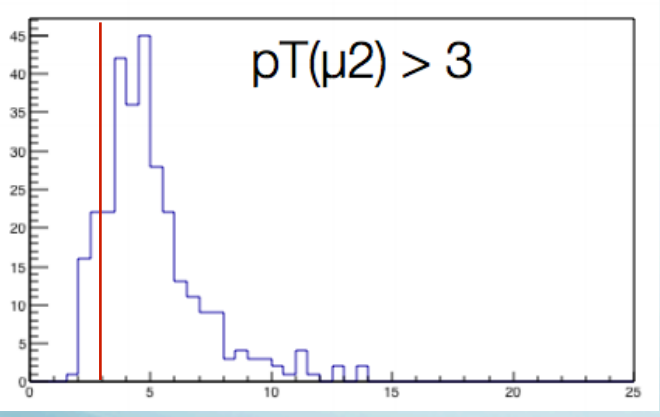


Plans

- ✧ Simulation studies will be performed to demonstrate the crucial role of a L1 pixel trigger for an exciting physics case
- ✧ The analysis on Run II data will complement the work and will give the necessary expertise and knowledge to study a rare decay channel

Trigger

- CMS has already shown its robustness in triggering muons
- To enhance the trigger efficiency to very rare decays, additional objects have been added
- **The key to improve the efficiency is to add tracks to the trigger path**
  - 2 muons + 1 track ... *HLT_DoubleMu3_Trk_tau3mu*



- Coming from the same displaced vertex
- Invariant mass window required
- total p_T over threshold
- kinematic constraints
- quality cuts on muon ID and track parameters
- etc..

HLT_DoubleMu3_Trk_tau3mu @ Run II

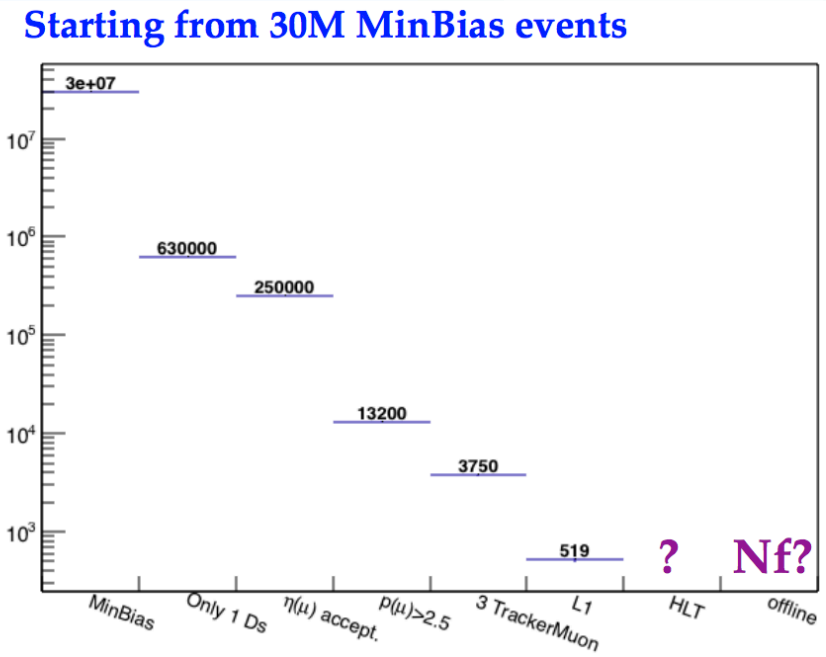
✧ **Efficiency studies**

wrt. “offline reconstructable” events
wrt. “offline reconstructable & L1 triggered” events

✧ **Sensitivity studies**

Usable tau rate in CMS (based on PYTHIA)

Nf × 1.2 × 1.3 × 80mb × 0.05 / 30M =
Nf × 2 × 10^5 fb



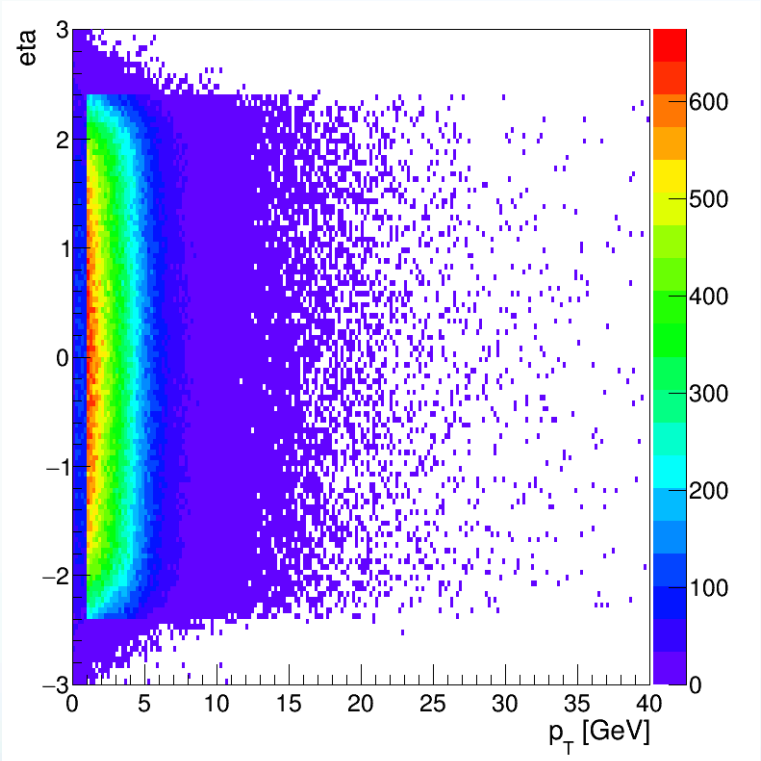
Nf - final number of events, **80mb** - cross section of MinBias
0.05 - Br(Ds->tau), **1.2** - taking into account events with 2 or more Ds
1.3 - taking into account tau from other B,D mesons decay

Bottom-line of CMS Run 2 is to collect ≳ 2.5x10^9 tau

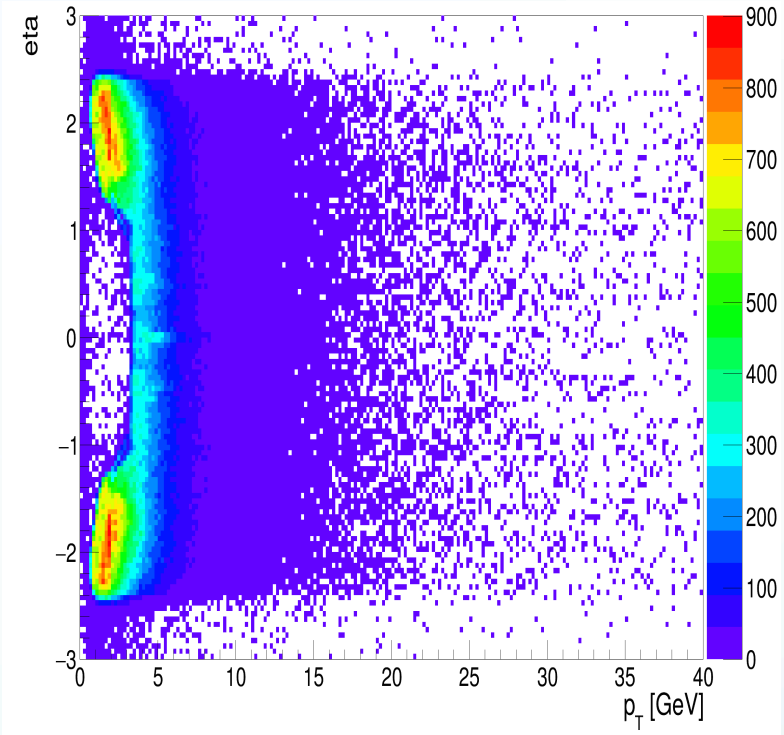
Assume 100/fb in Run2 -> **Nf ≳ 130**

Acceptance limits @ Run II

All muons at GEN level



All muons at RECO level

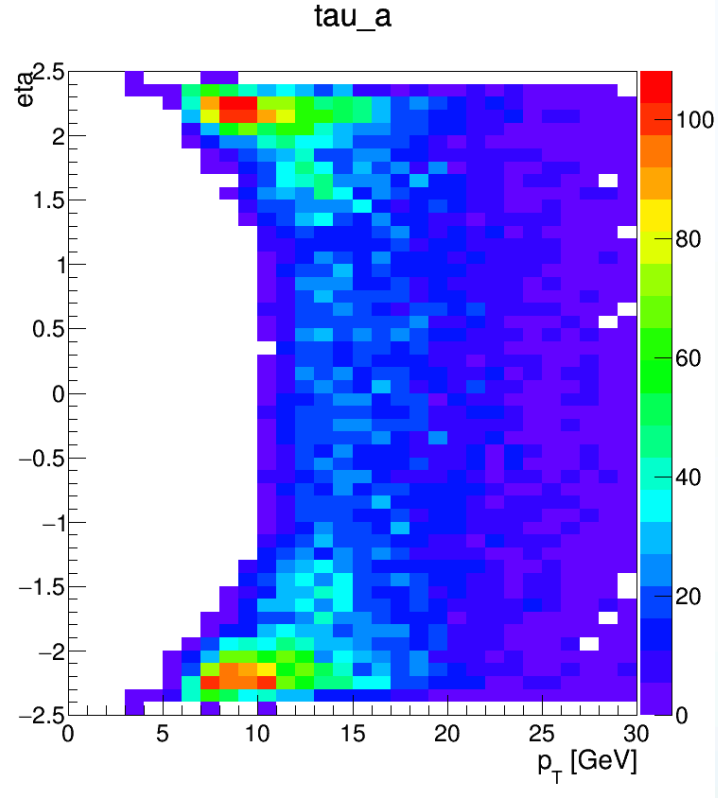


Acceptance limits (CMS standard)

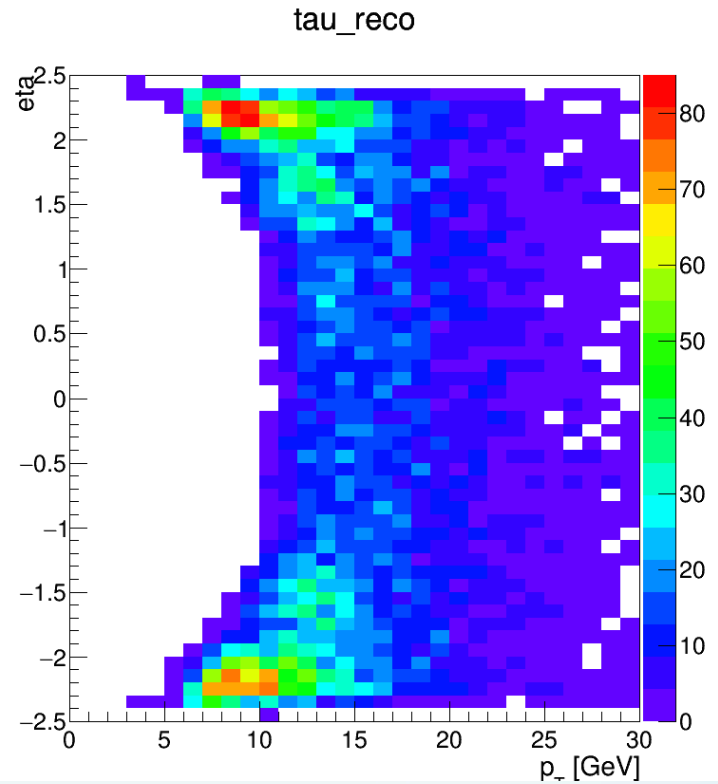
- $\eta < 1.3$; $p_T > 3.3$
- $1.3 < \eta < 2.2$; $p_T > 2.9$
- $2.2 < \eta < 2.4$; $p_T > 0.8$
- **accepted events (2 muons within the limits)**

Reconstruction studies @ Run II

tau in acceptance

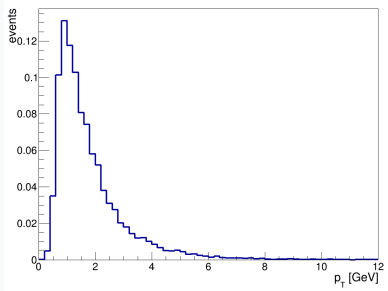


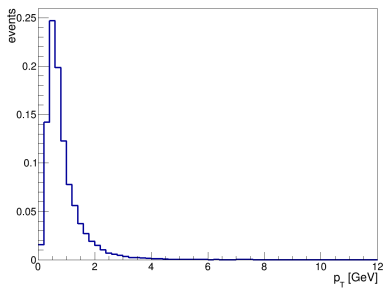
reconstructed tau

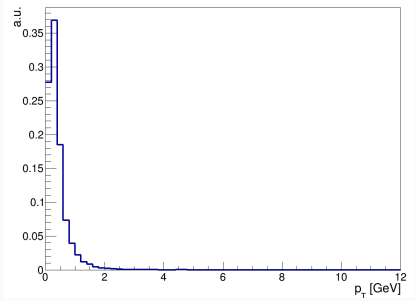


Required match between RECO muons and GEN muons

Simulation @ HL-LHC (Phase II)

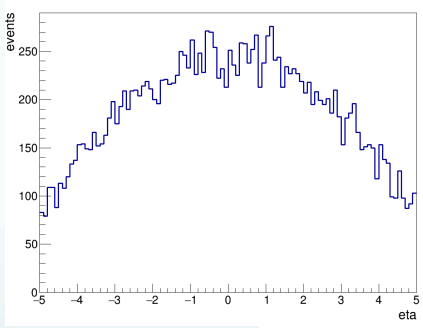


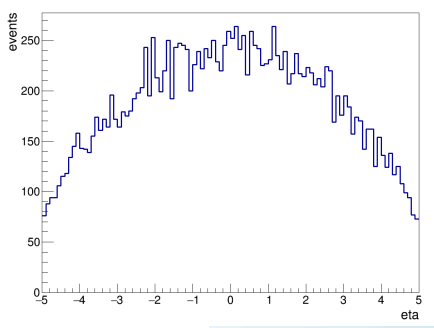


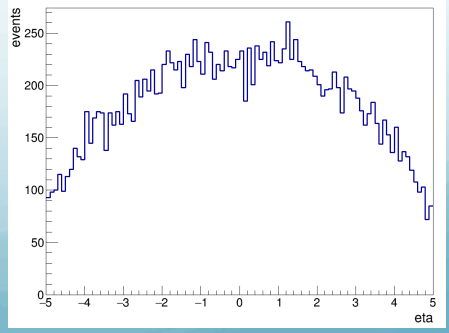


muons p_T spectrum

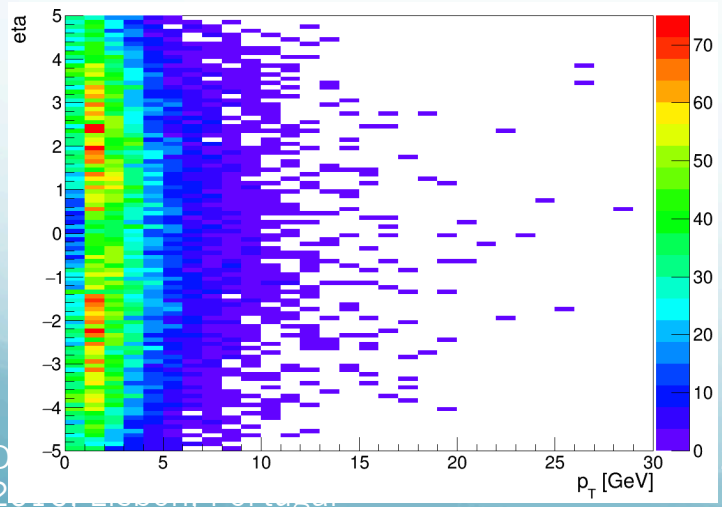
muons η spectrum





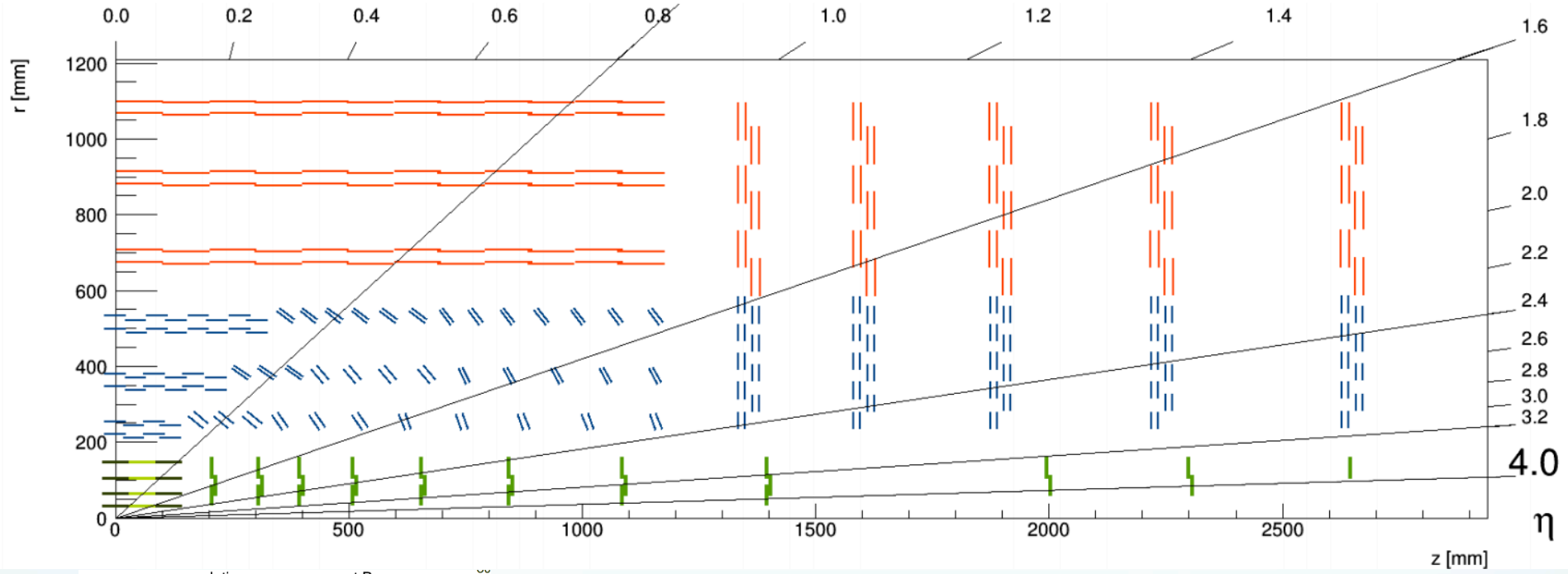


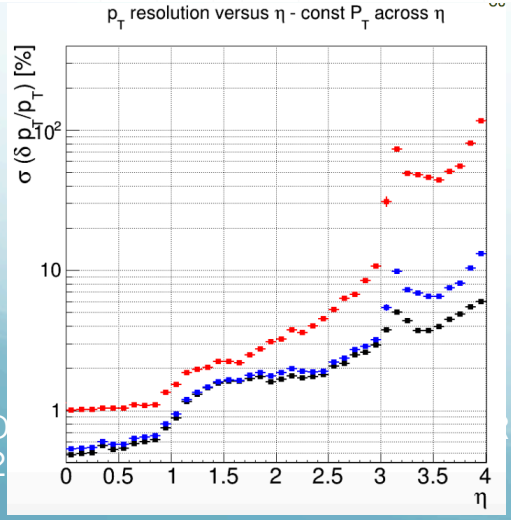
tau p_T/ η spectrum



Simulation @ HL-LHC (Phase II)

Pixel detector high eta extension (up to 4.0)

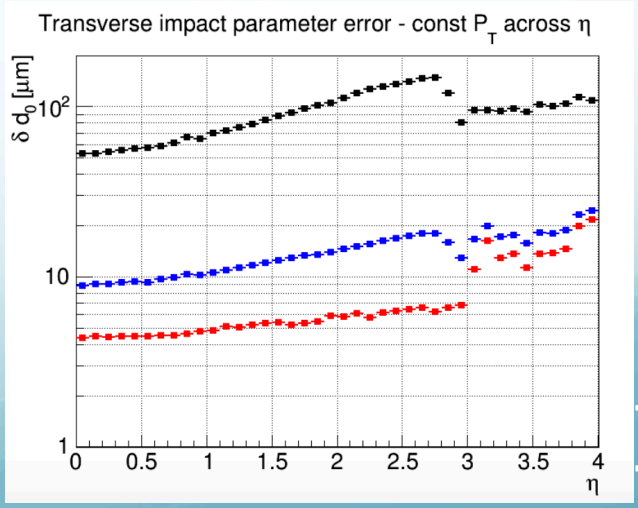




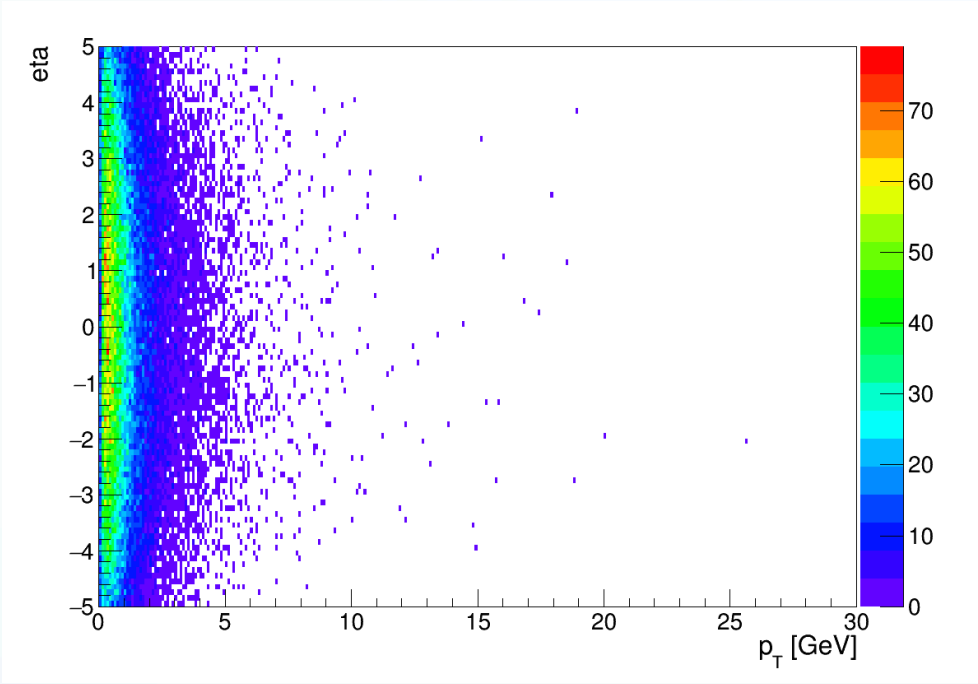
p_T = 1 GeV/c

p_T = 10 GeV/c

p_T = 100 GeV/c

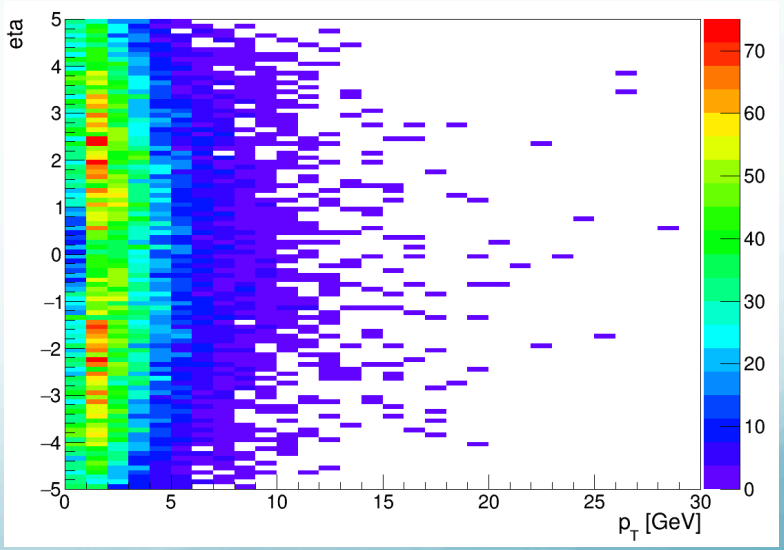


Simulation @ HL-LHC (Phase II)

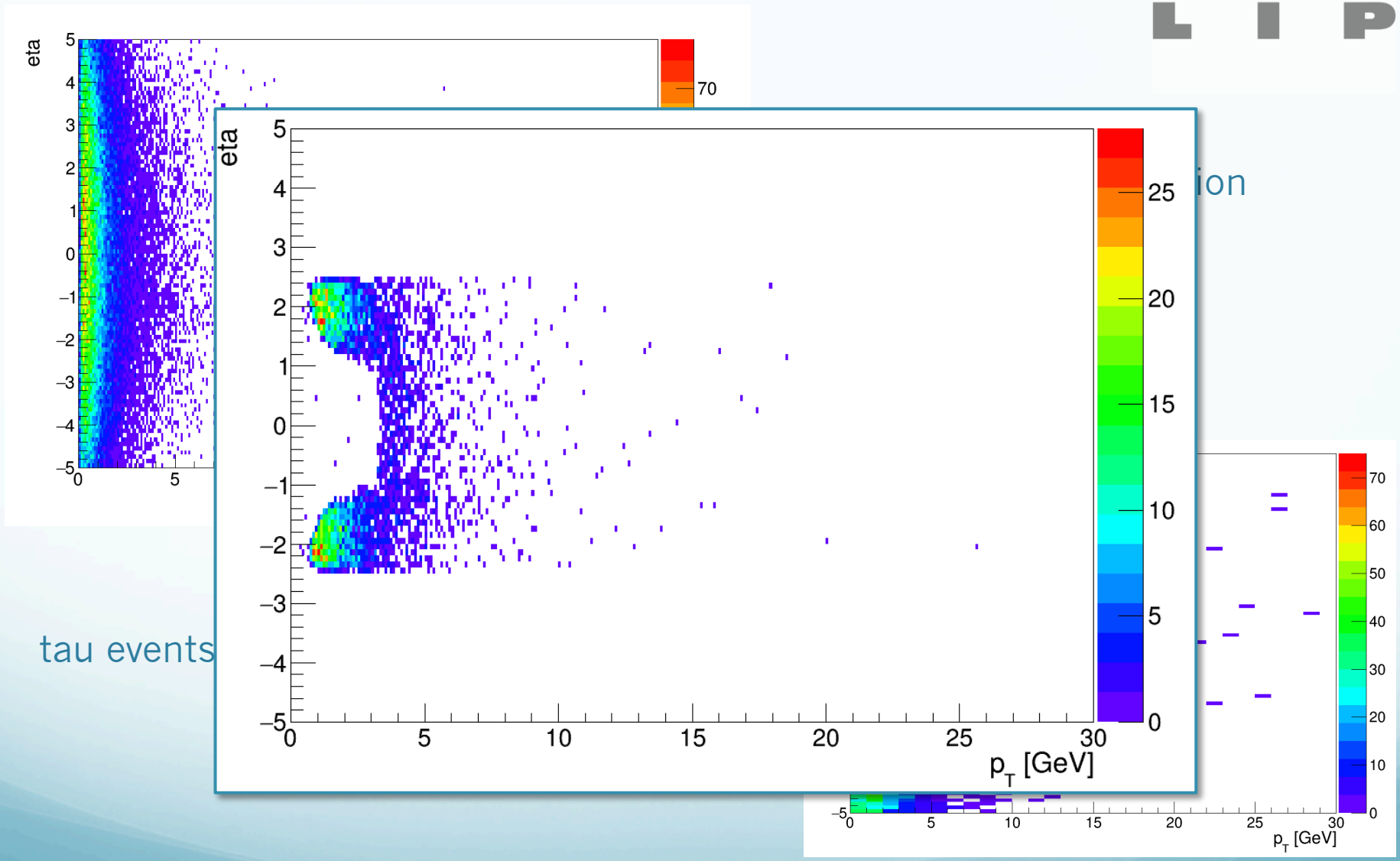


muons distribution almost rapidity indipendent

tau events at high rapidity range

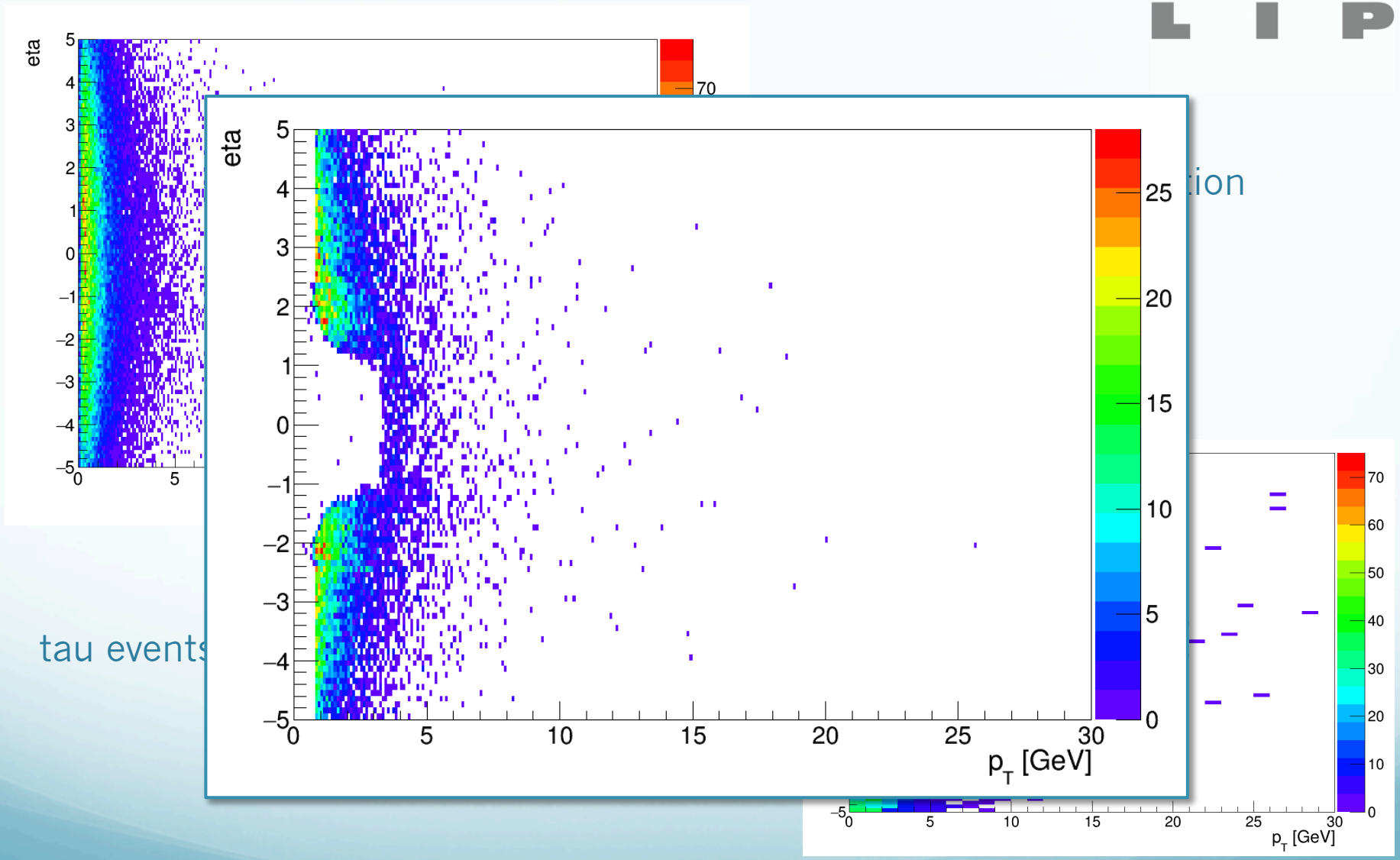


Simulation @ HL-LHC (Phase II)



tau events

Simulation @ HL-LHC (Phase II)



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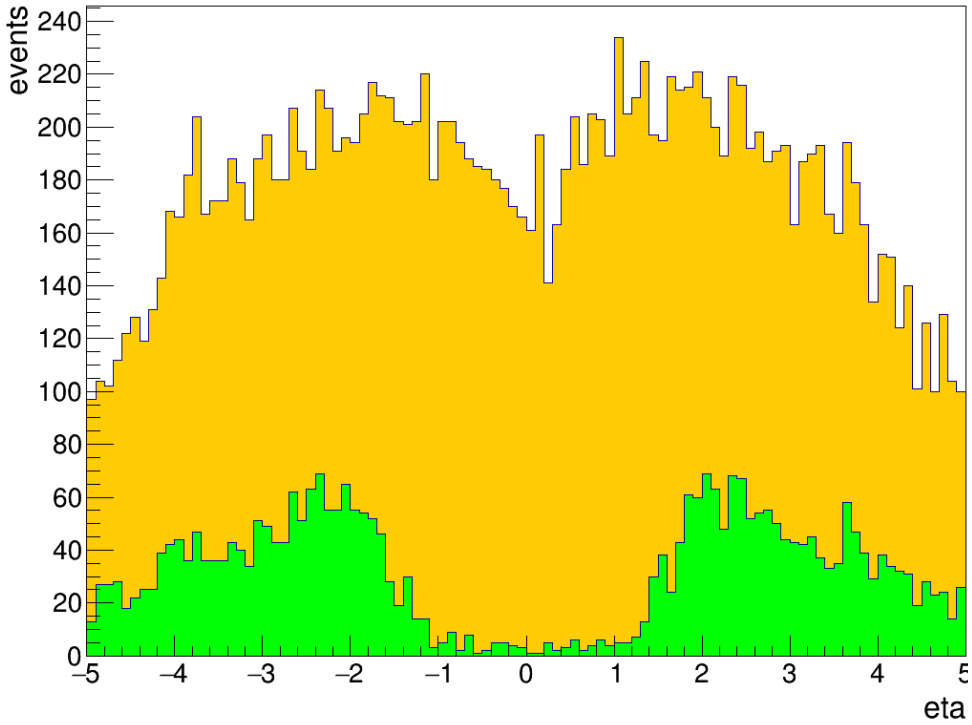
tau events

Simulation @ HL-LHC (Phase II)



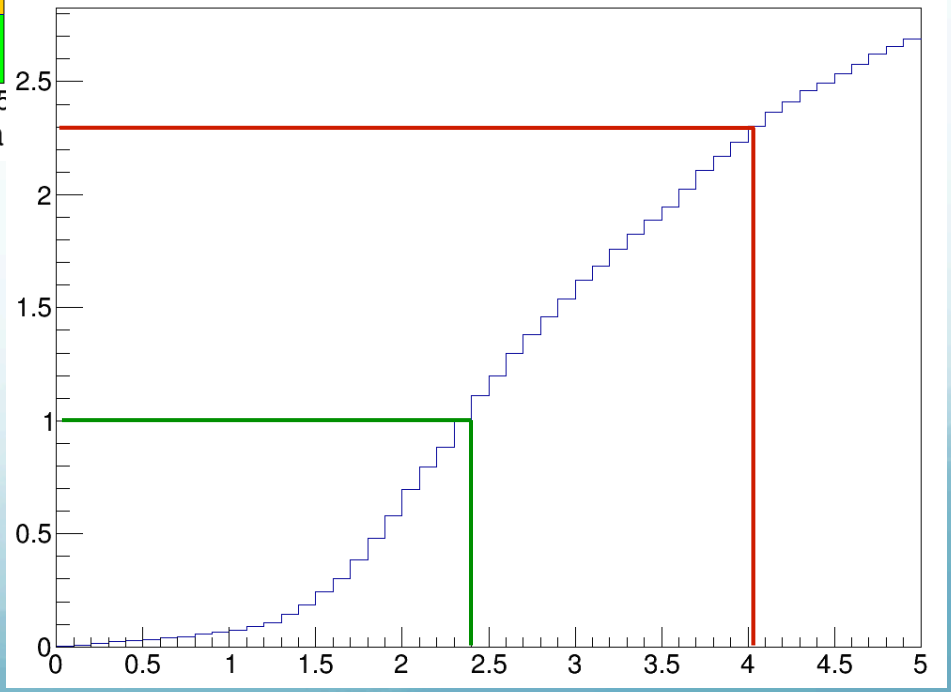
tau events

less than 2 RECO muons

at least 2 RECO muons

pixel extension up to η 4.0 would allow to collect more tau events

numbers very preliminary, reconstruction efficiency extrapolated, to be computed precisely



Conclusions

- **Developed the HLT path** within Run II
- Plan to run the path on **real data** (and eventually refine it)
- Perform the **complete analysis** search to get the new world best limit and get the necessary expertise to **include** efficiently **the pixel** in the game
- Perform sensitivity and resolution studies in **HL-LHC conditions**
- Apply the HLT path as **L1 trigger** path on simulations for HL-LHC Phase-II, expecially requiring TrackerMuons to be reconstructed with the **L1PixelTracks**
- (Eventually) show the difference in rate and efficiency and sensitivity with and without pixels