UPGRADE PERFORMANCE STUDIES GROUP

STATO DEGLI STUDI DI PERFORMANCE E FISICA PER LA FASE 2 E PIANI PER I TDR

Patrizia Azzi

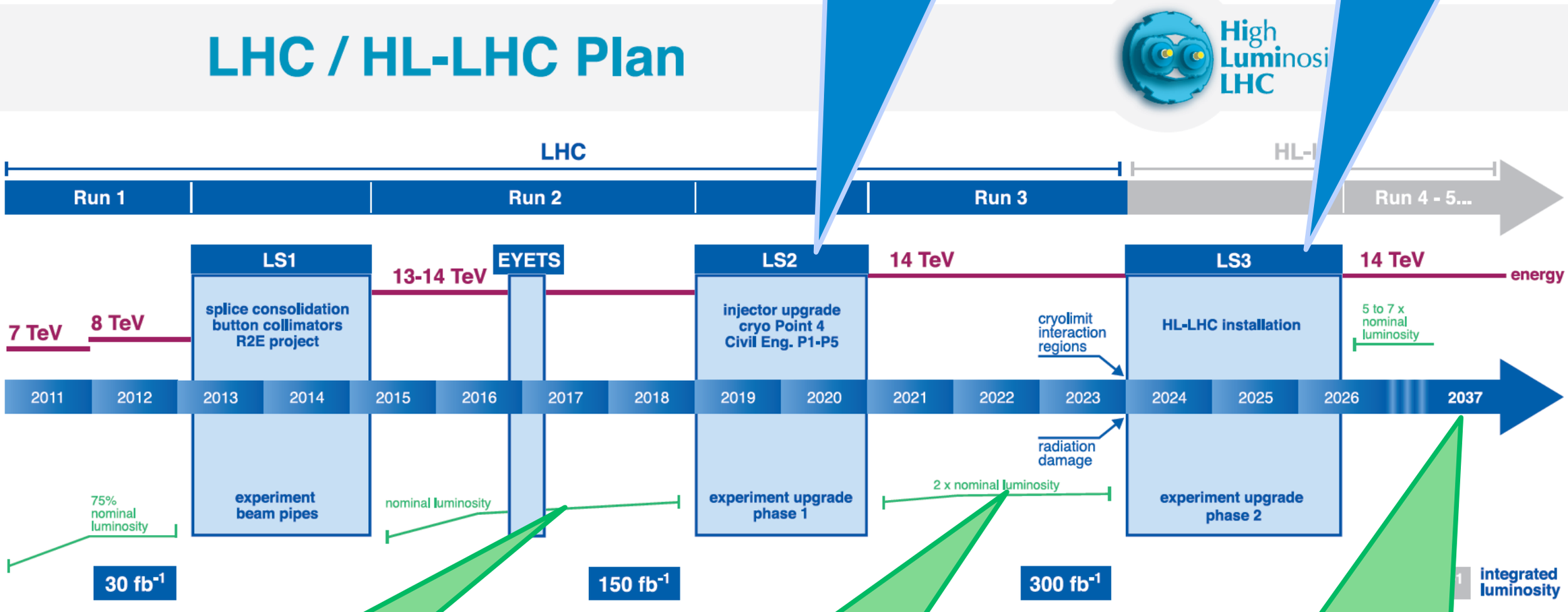
CMS Italia @Spoleto
Dicembre 15, 2016

GRAZIE PER IL FEEDBACK!

LHC schedule

upgrade of injector chain to deliver brighter bunches

new quad triplets to focus beam at ATLAS and CMS decrease β^* to 10-15 cm



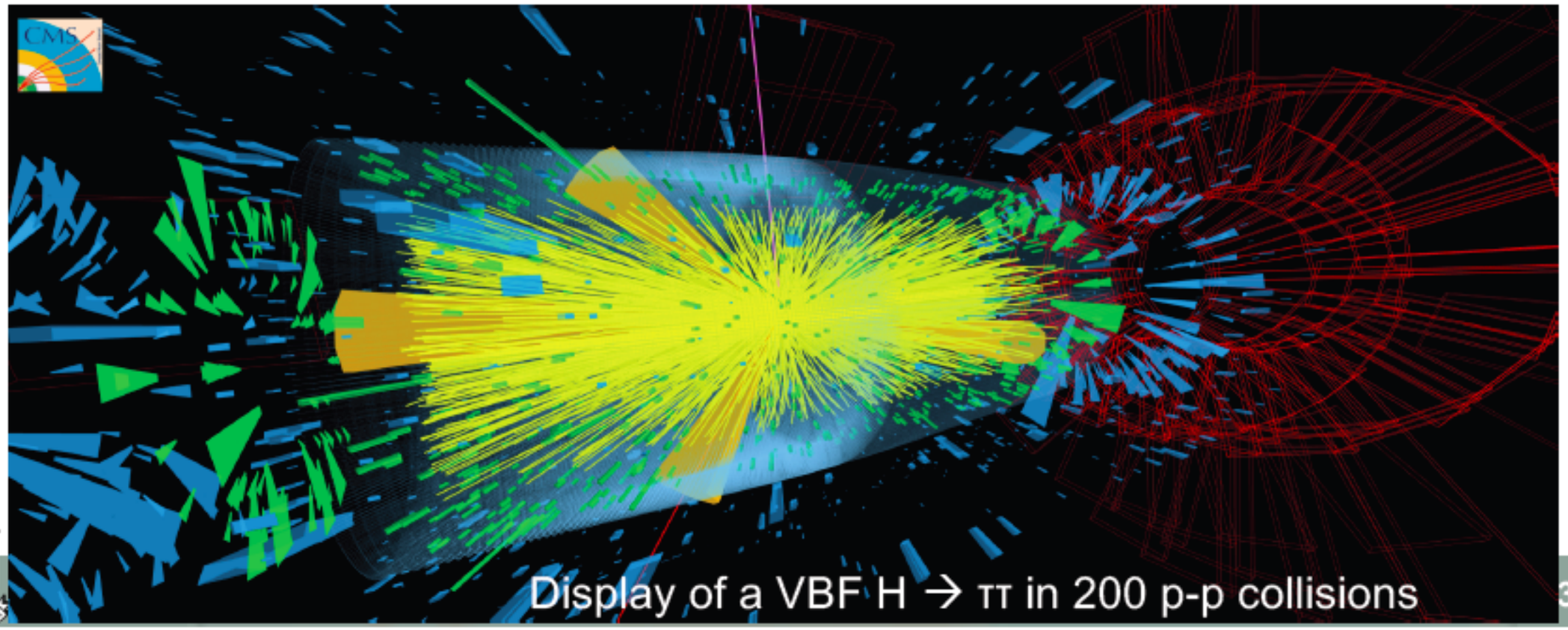
Run 2:
Design $\mathcal{L}=10\uparrow 34$ / $cm\uparrow 2$ /s

Run 3:
$\mathcal{L}=2\times 10\uparrow 34$ /$cm\uparrow 2$ /s for 300

HL-LHC:
Peak $\mathcal{L}=2\times 10\uparrow 35$ /$cm\uparrow 2$ /s
level luminosity to
$\mathcal{L}=5\times 10\uparrow 34$ /$cm\uparrow 2$ /s for 3000/fb or $7.5\times 10\uparrow 34$ / $cm\uparrow 2$ /s for 4000/fb

Main challenges

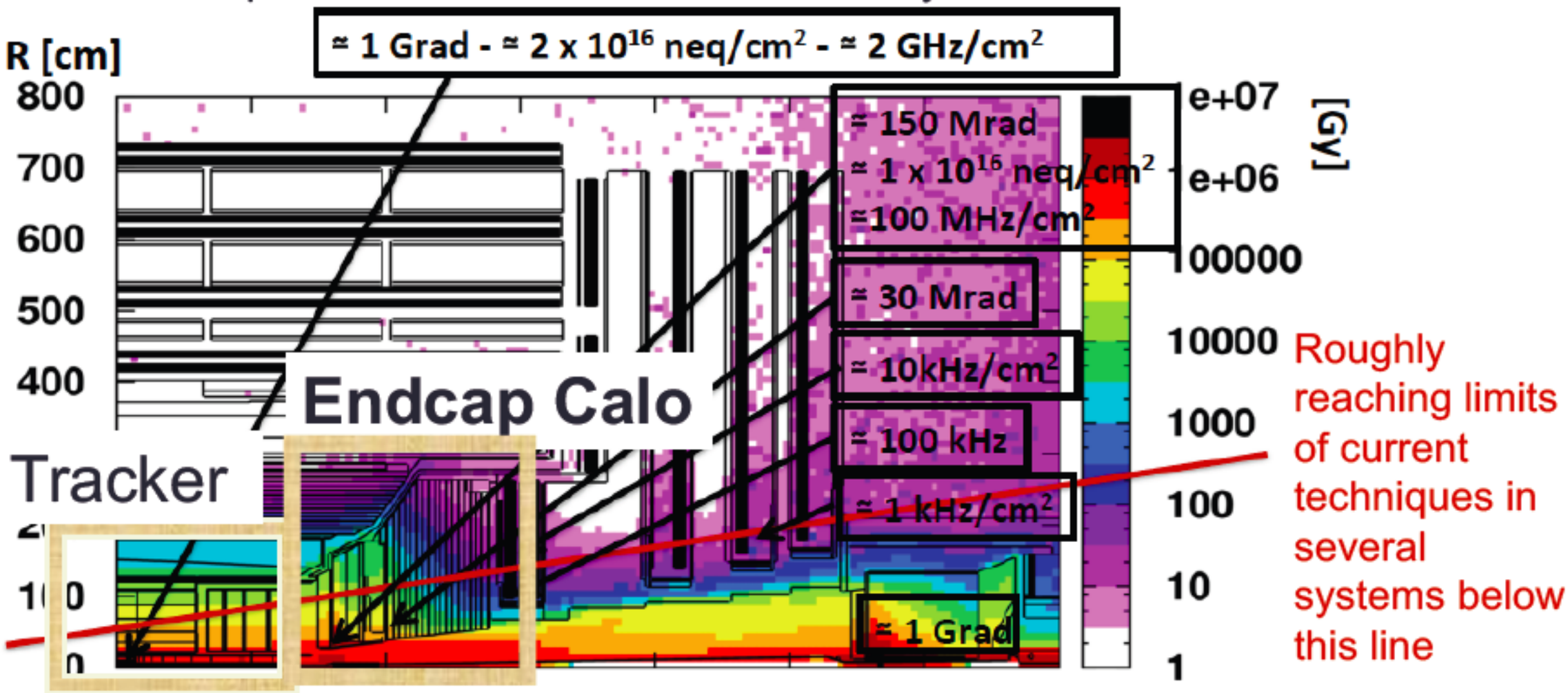
- Pileup
  - Increases the combinatorial complexity and rate of fake tracks
  - Adds extra energy to calorimeter measurements
  - Increases the amount of data that has to be read out in each BX
- Pileup Mitigation
  - High granularity detectors (trackers, calorimeters) needed to identify particles associated with the primary hard scatter collision vertex with high efficiency
  - Precise timing measurement can unambiguously associate both tracks and neutral energy clusters to each vertex, providing ultimate pileup mitigation (under study).



Display of a VBF H → ττ in 200 p-p collisions

Main challenges

- Radiation damage
  - Detector elements and electronics are exposed to high radiation dose
  - Degrades signal, & limits life time of detectors
  - Requires new tracker, and endcap calorimeters, new forward muons
  - And replacement of most of the readout systems



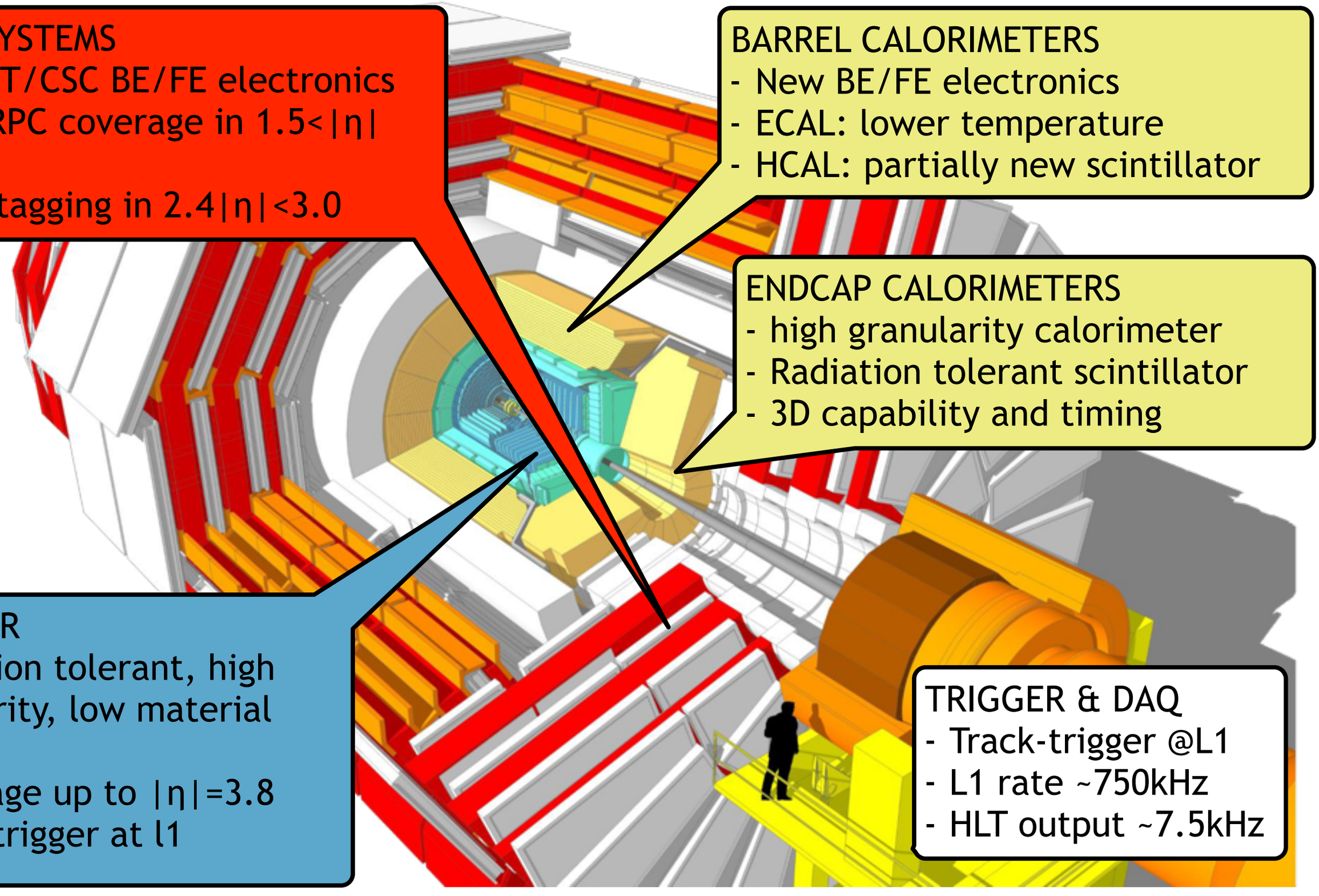
CMS radiation dose map, neutron equivalent fluence and particle rates for luminosities of 3000 fb^{-1} (integrated) and 5 x 10^{34} Hz/cm^2 (instantaneous)

CMS Phase 2 upgrade (2024/26)

MUON SYSTEMS
- New DT/CSC BE/FE electronics
- GEM/RPC coverage in 1.5<|η|<2.4
- Muon-tagging in 2.4|η|<3.0

BARREL CALORIMETERS
- New BE/FE electronics
- ECAL: lower temperature
- HCAL: partially new scintillator

ENDCAP CALORIMETERS
- high granularity calorimeter
- Radiation tolerant scintillator
- 3D capability and timing



TRACKER
- radiation tolerant, high granularity, low material budget
- coverage up to |η|=3.8
- track trigger at l1

TRIGGER & DAQ
- Track-trigger @L1
- L1 rate ~750kHz
- HLT output ~7.5kHz

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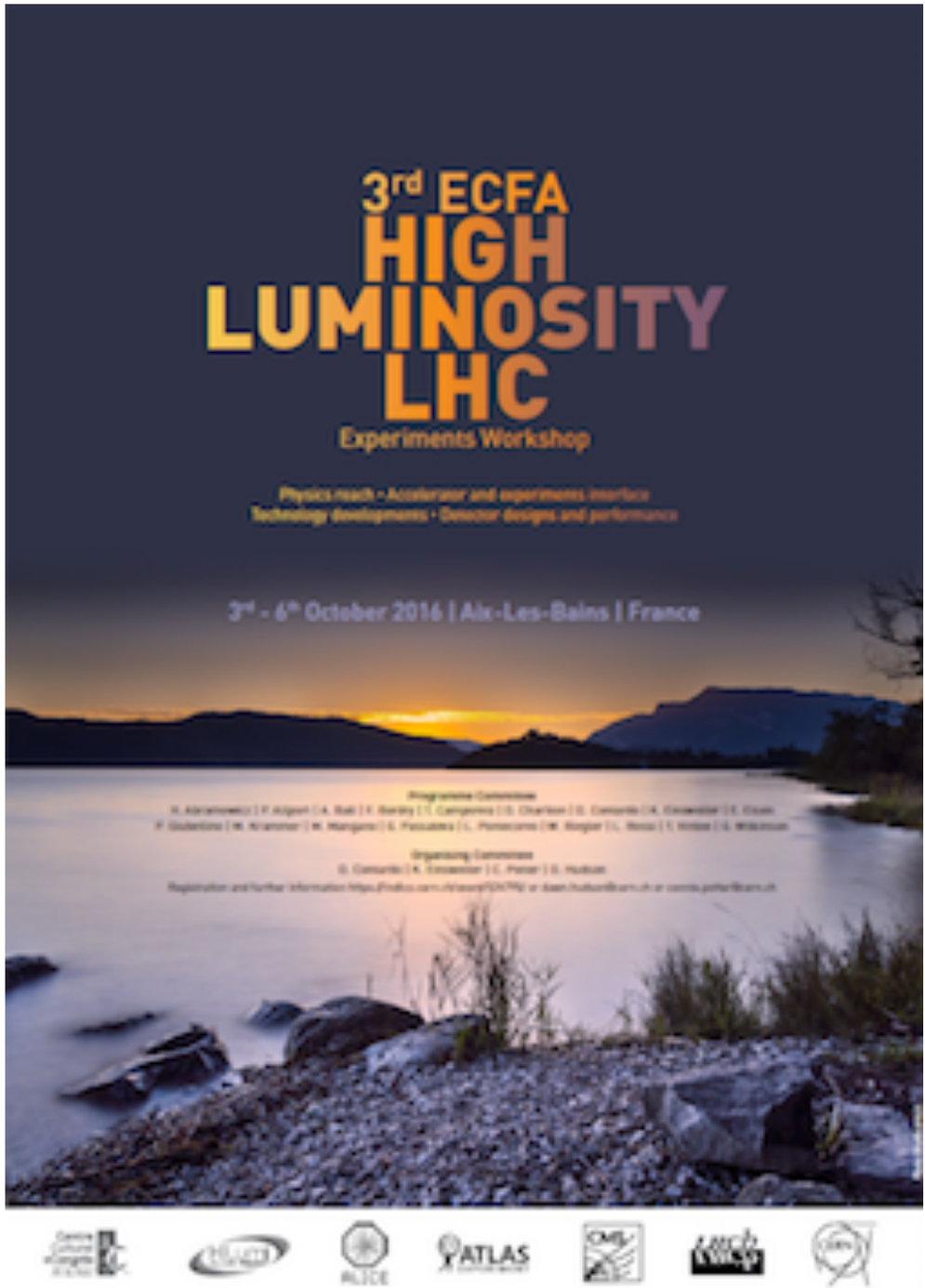
SUMMARY OF STUDIES FOR ECFA WORKSHOP

in 2015
TP CERN-LHCC-2015-010
SD CERN-LHCC-2015-019

- Object performance studies
  - Updated wrt Technical Proposal.
  - Using CMSSW 8_1_X
- Physics Projections/sensitivity studies
  - Higgs properties
  - Searches
  - SM topics
- ECFA 2016 DPS Notes:
  - CMS-DP-2016-064: https://cds.cern.ch/record/2221747?ln=en
  - CMS-DP-2016-065: https://cds.cern.ch/record/2222084?ln=en
- PASs in progress (pre-approval this week and next week UPSG, ARC formed):
  - FTR-16-002 (FHIG)
  - FTR-16-005 (FSM)
  - FTR-16-006 (FNP)



PREPARATION FOR TDRS

- In 2017 CMS is planning to publish the following TDRs:
  - May 9: Tracker; Sep 12: Muon & Barrel Calo; Nov 28: HGCAL
- For each TDR we propose a set of perfomance metrics and analyses which will focus on the improvements due the particular sub-detector.
  - Will use the FullSimulation and Reconstruction of the complete Phase2 detector with PU=200 as a baseline for most of the signal samples and some backgrounds

Tilted OT , Phase2 pixel, Phase1CALO, HGCAL,Timing, all Muon

  - RECO output kept for now. MiniAOD in 2017
  - For large backgrounds and signal scans (DM, SUSY) we will use Delphes retuned with the FullSim performance.
- Special samples will be produced also for trigger studies (L1 and HLT) interim document with a specific event content

PROPOSED TIMELINES & SUMMARY (DETAILS)

- **Tracker TDR**
  - most components in place now (820), pixel with extra disk and optimizer tracking might come in January.
  - This might allow a very fast global validation round and starting production before Xmas break
    - validation of 900pre1 with PU=200 just coming in
  - very likely a 2nd production around Feb/Mar 2017 (bug fixes, higher level objects, additional studies, more RECO functionality)
- **Barrel CALO/MUON TDR**
  - content to cut a release should be ready by March/April 2017
- **HGCAL TDR**
  - full reco planned to be ready by June 2017
  - simClustering reco expected to be ready(validated) by March/April 2017

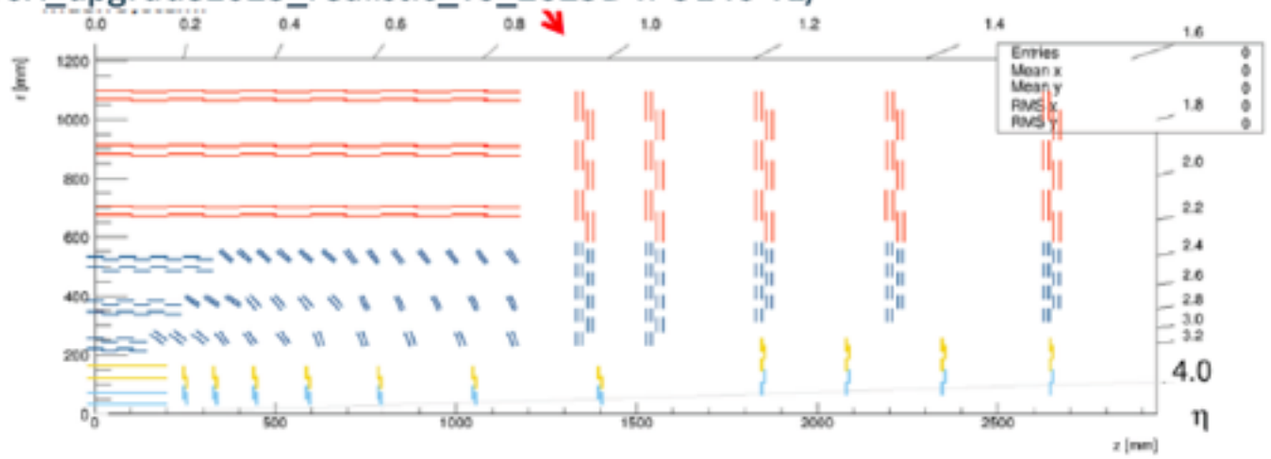
The possibility to have a single production for Muon/Barrel and HGCAL is still open even though not likely if we want to keep flexibility and efficiency.

TRACKER AND PIXELS- 900PRE1

Y^2 Chen,

S. Ahuja

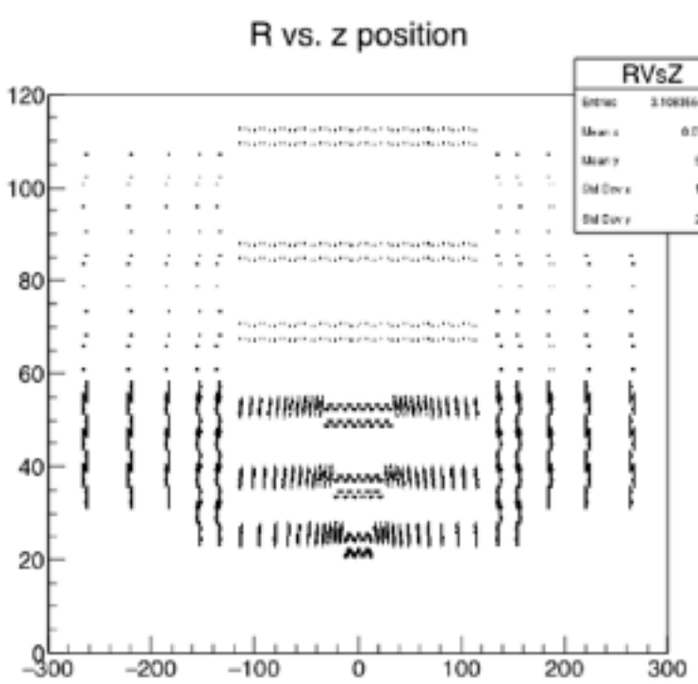
/RelValSingleMuPt100Extended/CMSSW_9_0_0_pre1-PU25ns_90X_upgrade2023_realistic_v0_2023D4PU140-v1/*

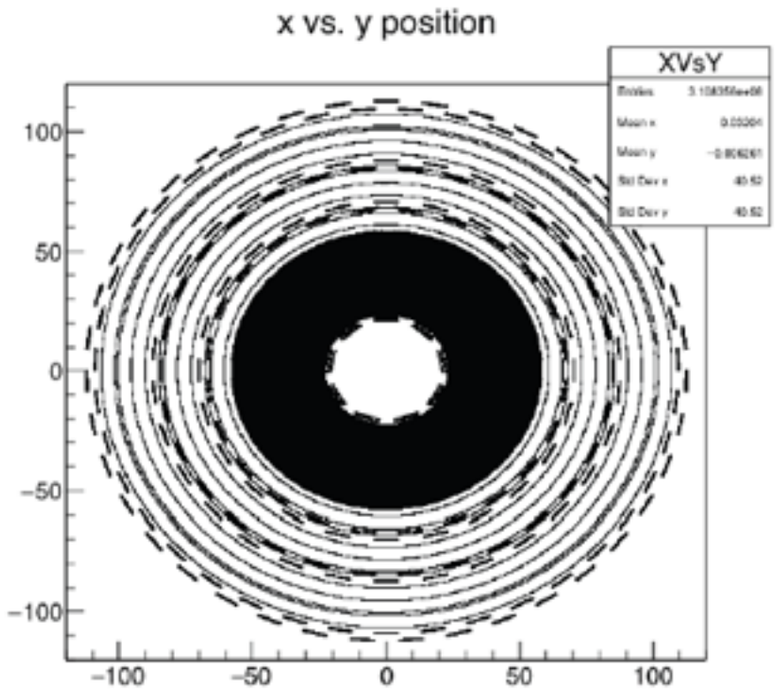


Phase II Pixel simulation and development driven by A. Tricomi & E. Migliore

— Implementation of geometry, simulation, realistic digitizer and local reco

— Optimization and validation studies





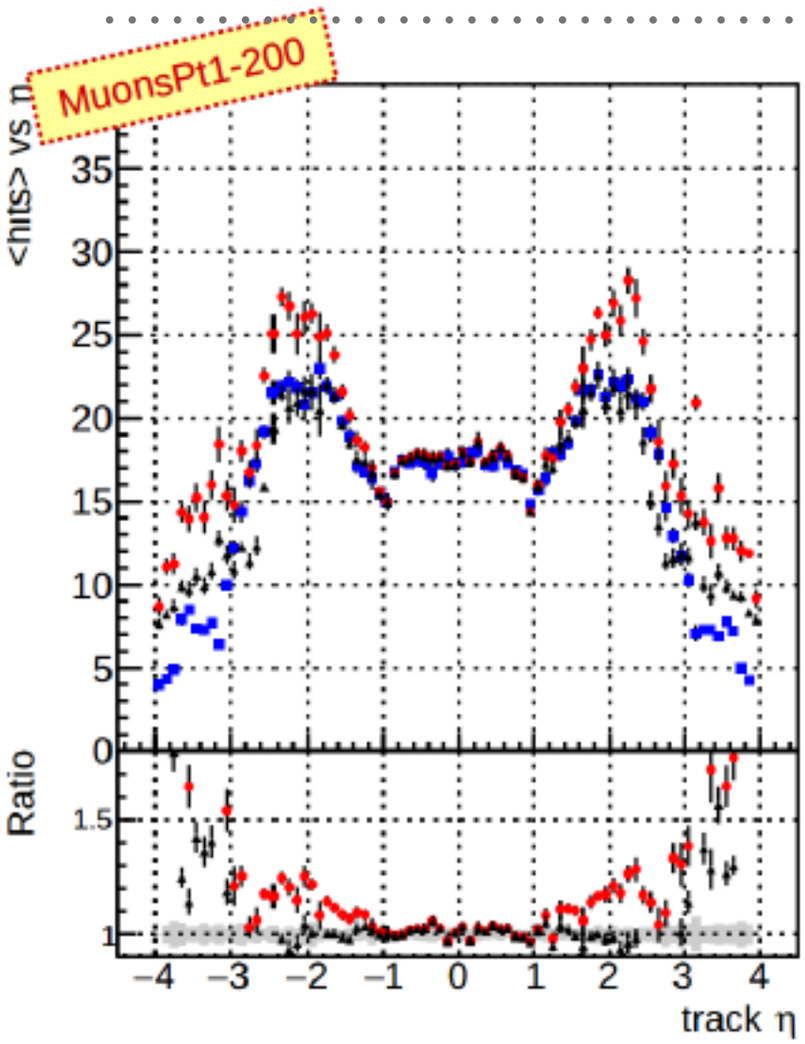
Rechit position map as expected

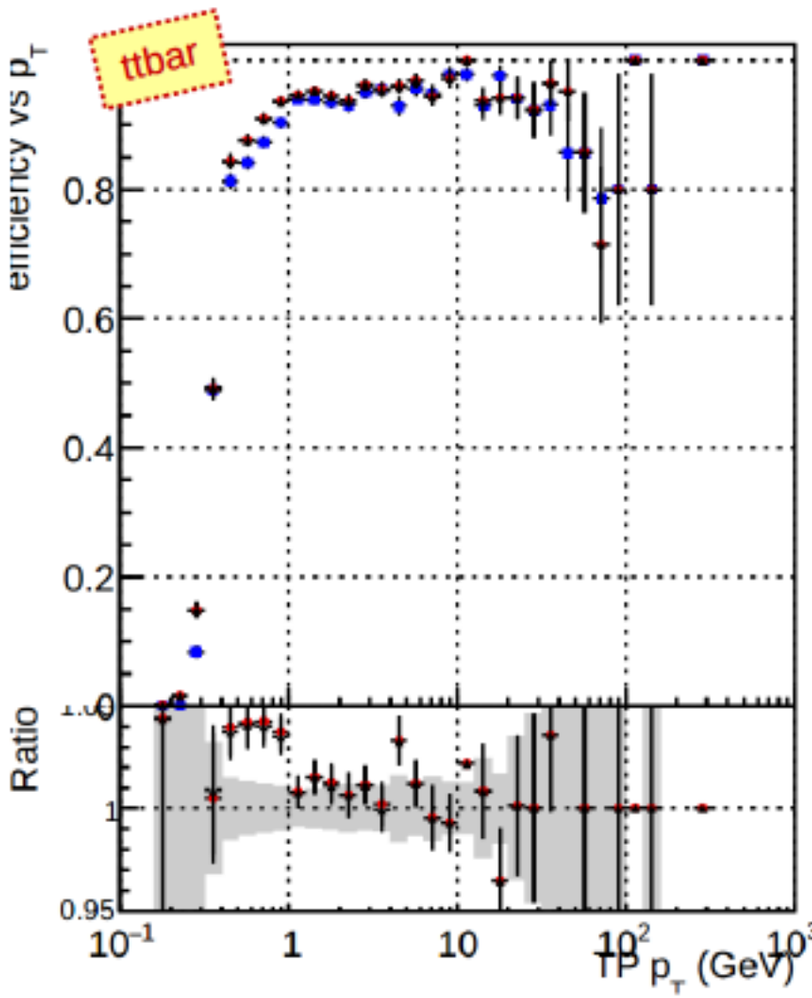
Cleary shows the Phase 2 geometry

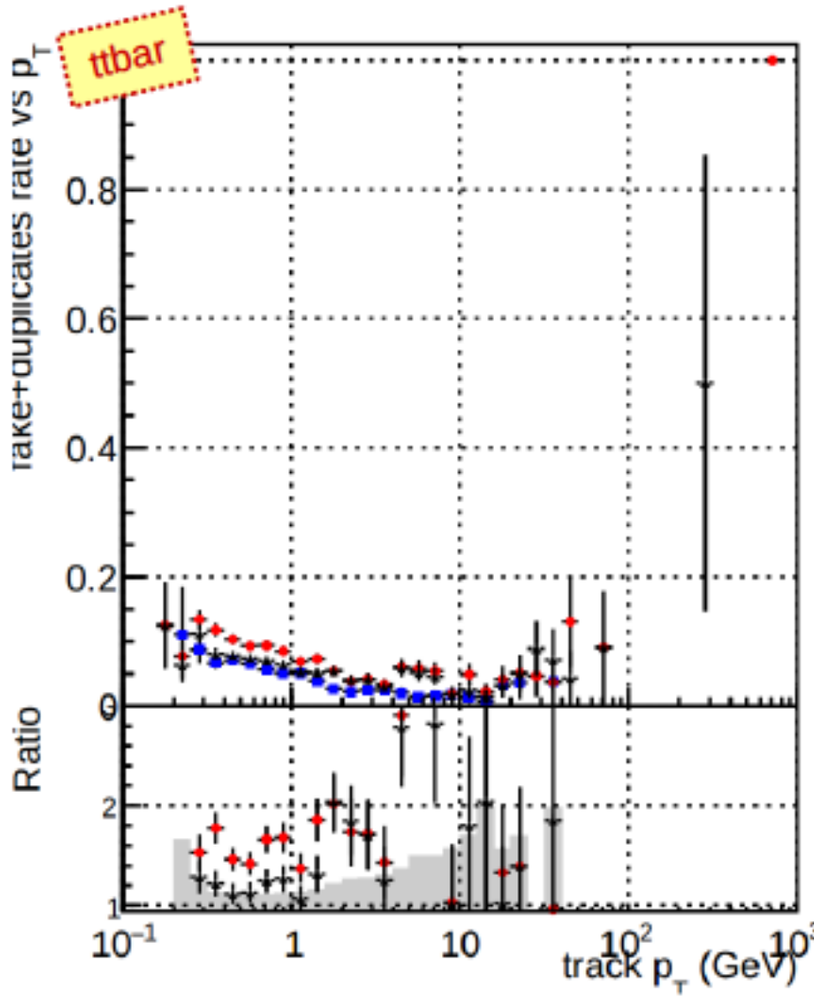
TRACKING – 900PRE1

D1 workflow
D4 workflow
D4 workflow + PR#16470

Erica Brondolin

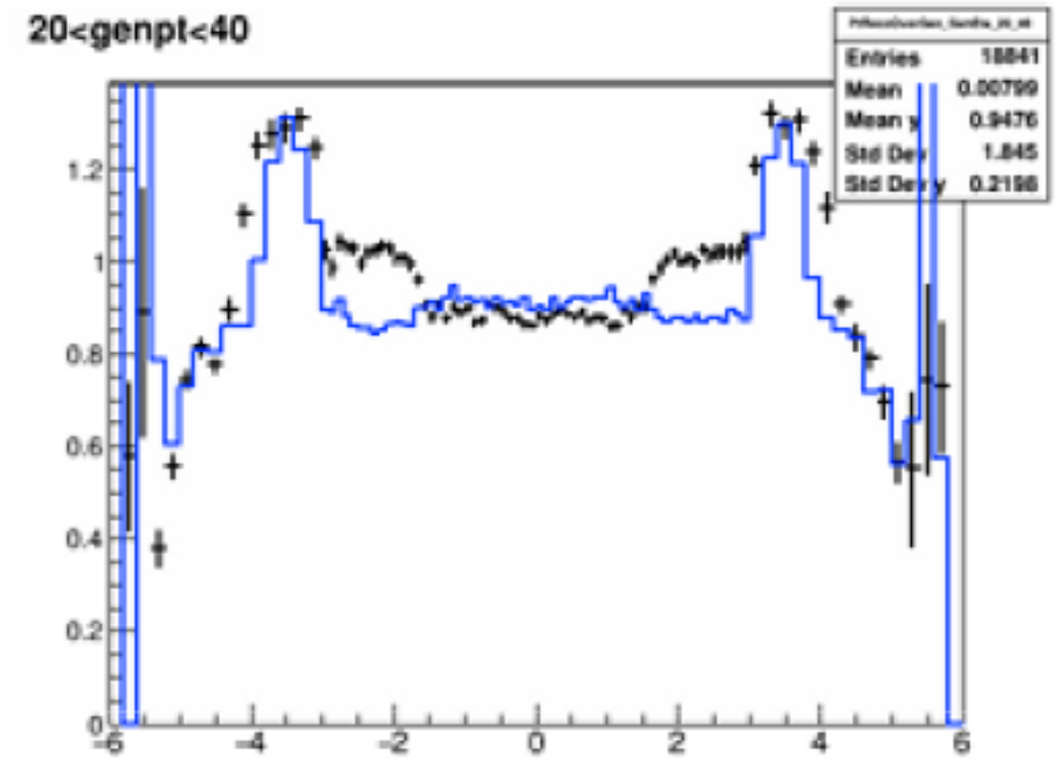






- Tracking has gone through a lot of improvement and fixes both for the material, pixel geometry and to improve the timing.
- Still more optimization especially for the forward region has to happen. This will come later, hopefully in time to have new samples for tracking performance for the TDR.
  - The decision is that Physics studies would not be redone with this, maybe comments can be added in the text if needed.

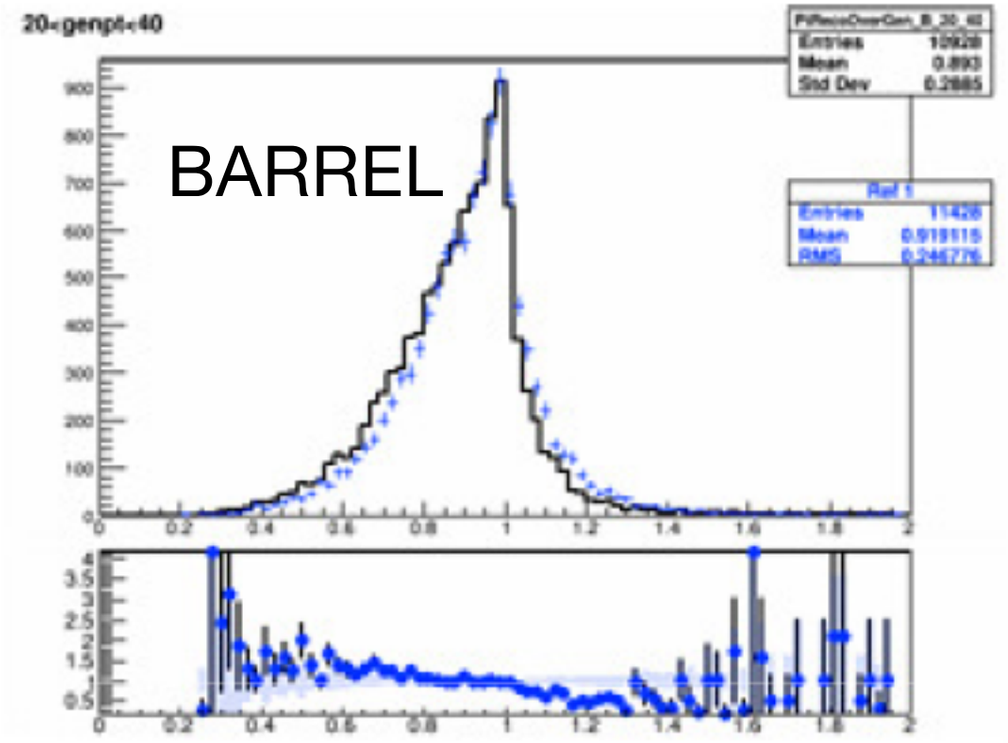
JETS – 900PRE1

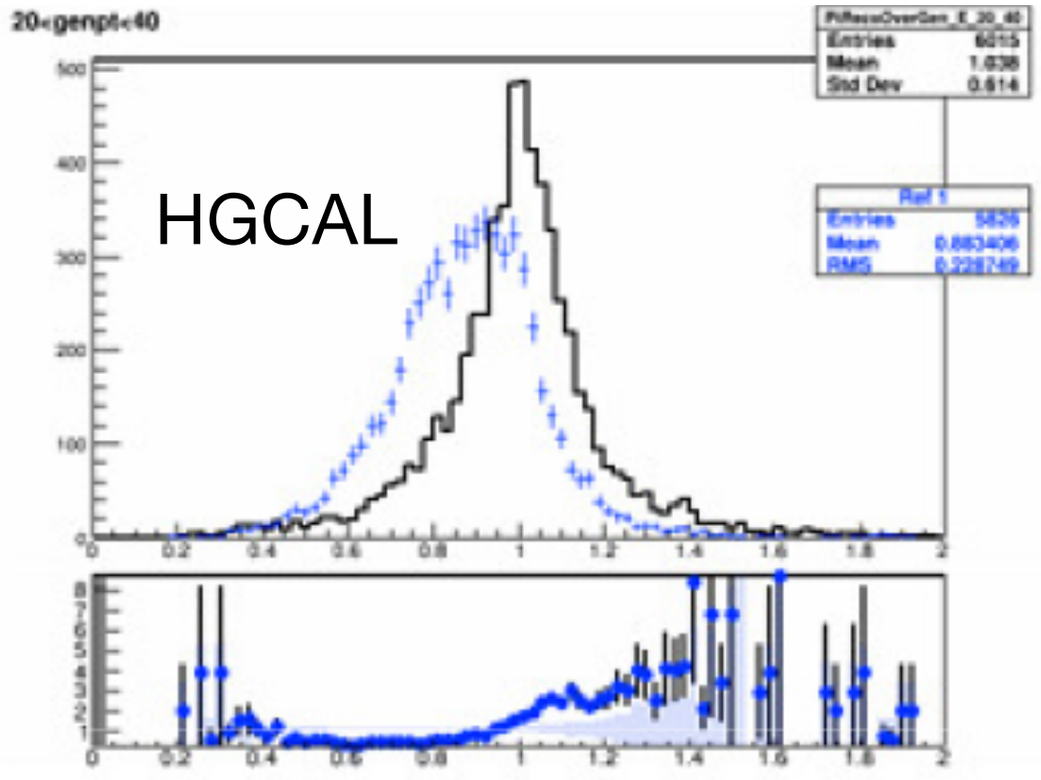


PU=0

RAW Response: (PT_reco/PT_gen) vs genEta for PF AK4 CHS recojets

First PFjets in HGCAL





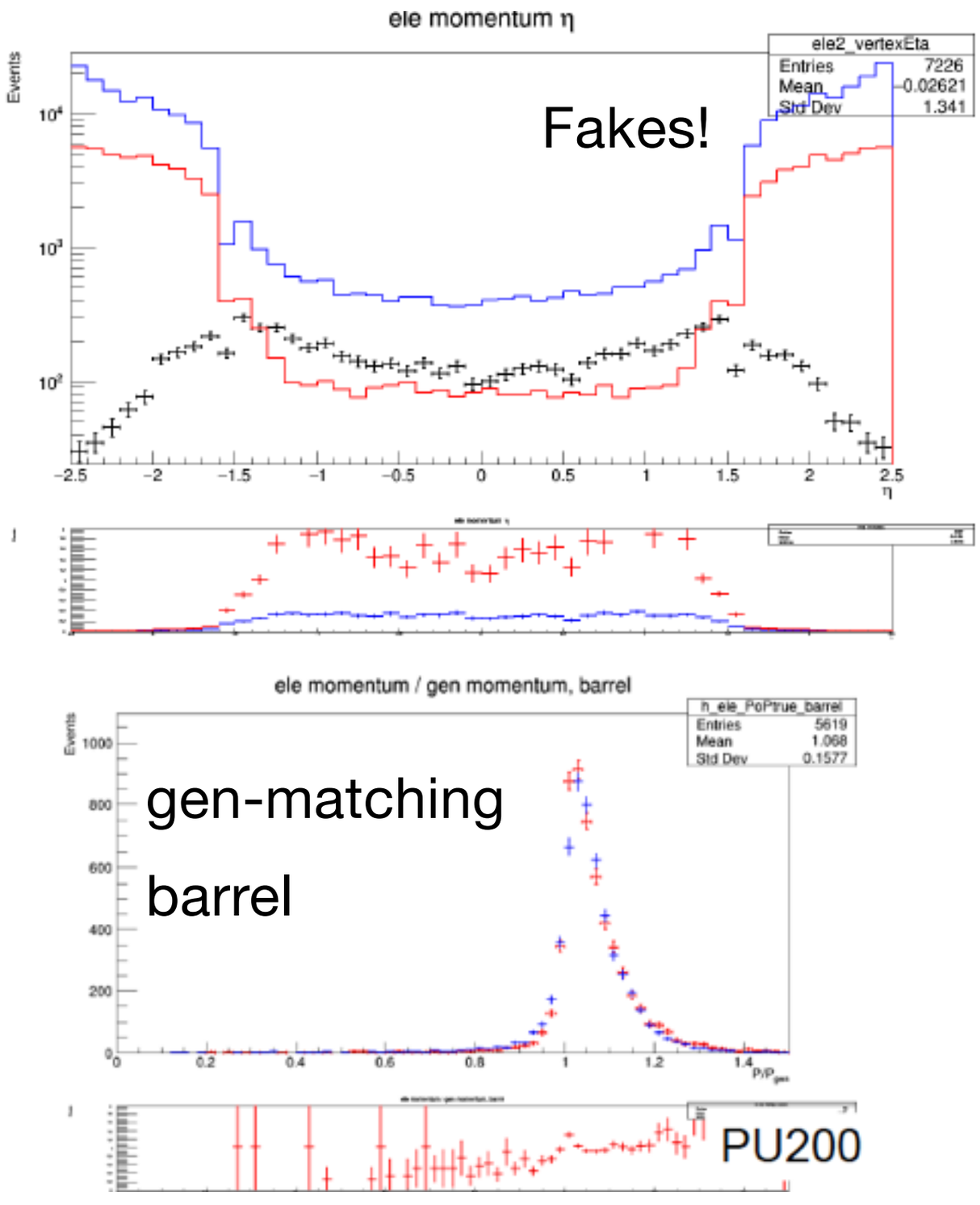
ELECTRONS - 900PRE1

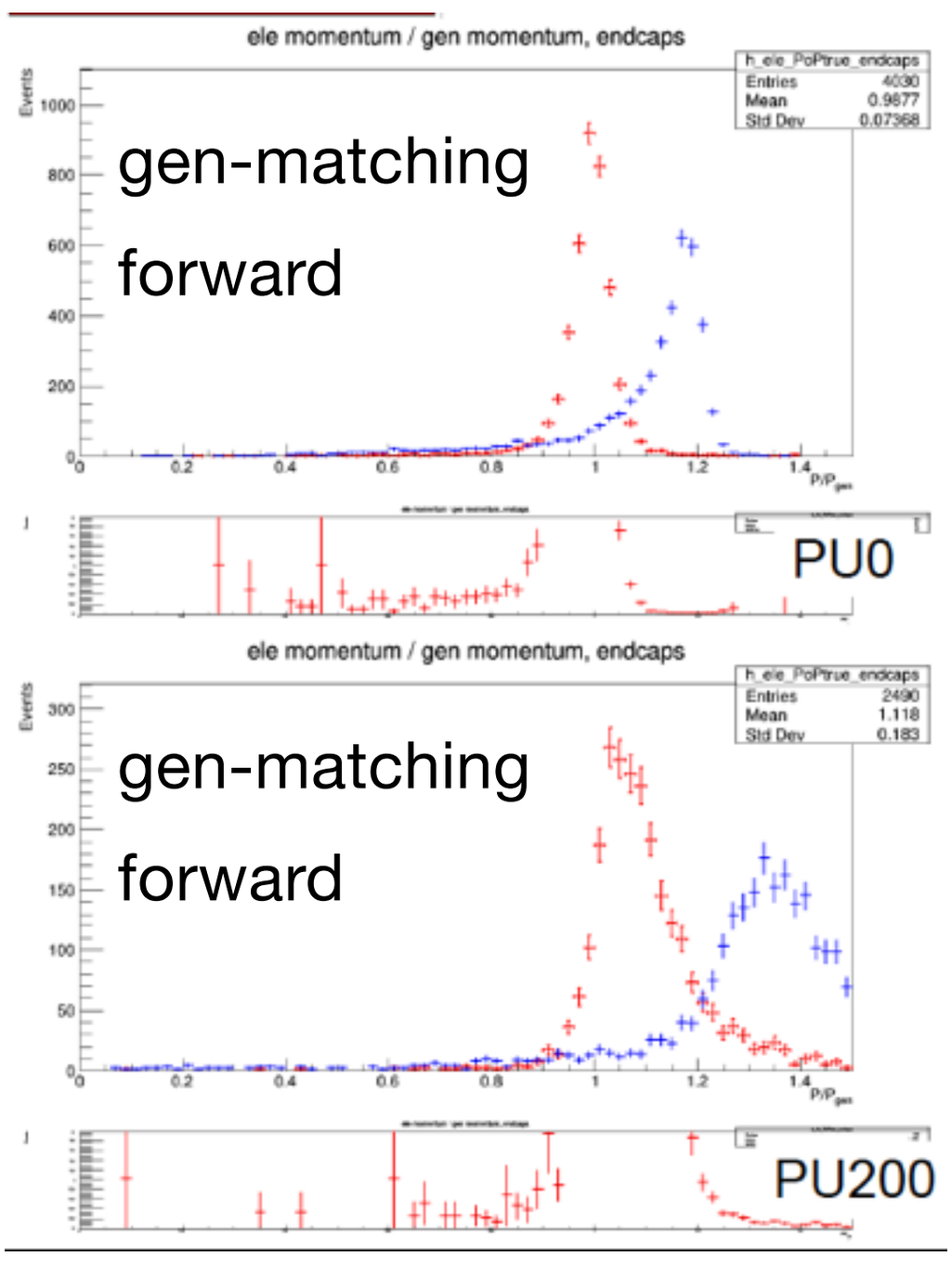
$Z \rightarrow ee$

Dylan Rankin

Nick Smith

D1 | D3 | D4





of course issues in the forward

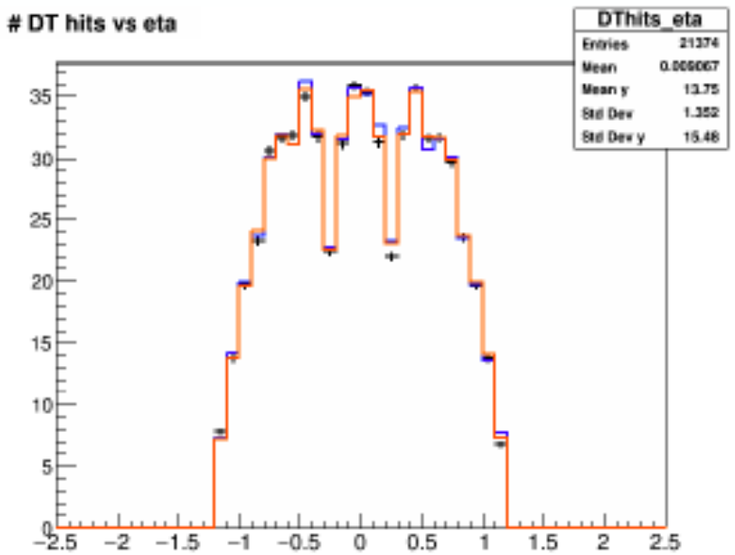
but not bad for a first try!

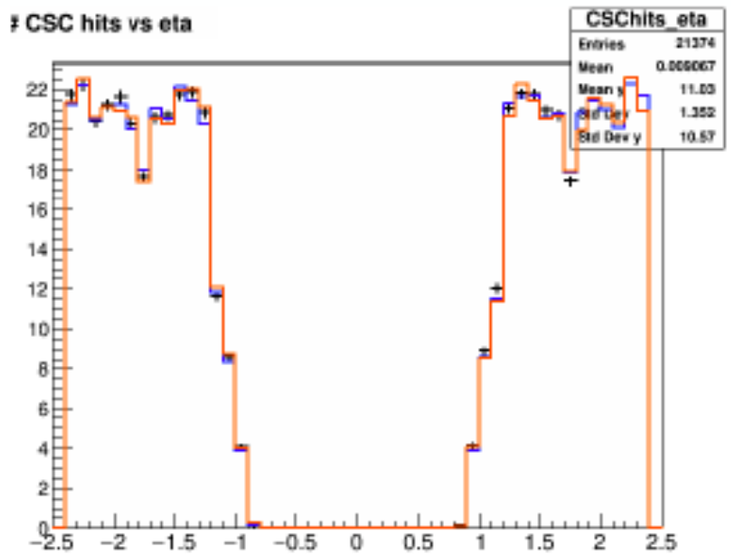
MUONS - 900PRE1 PU=0 GLOBAL MUONS

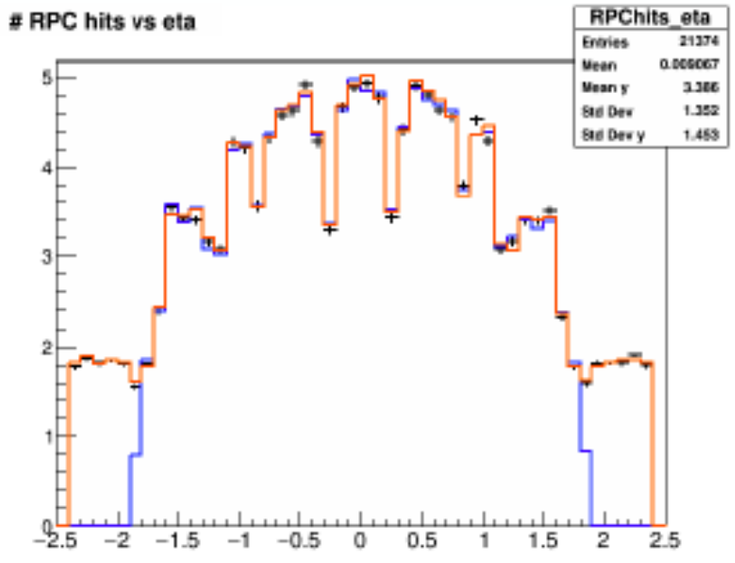
Cesare Calabria

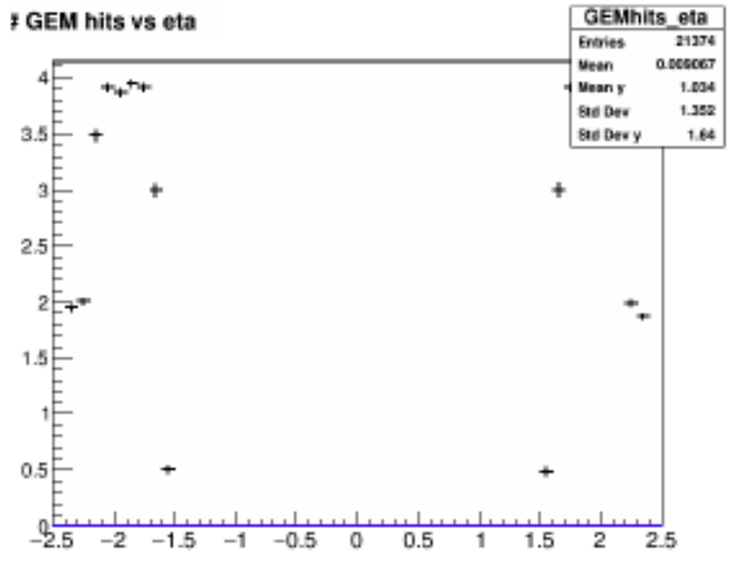
Jason Lee

- BLACK: ZMM events (PU0) in CMSSW_9_0_0_pre1, Extended2023D4
- BLUE: ZMM events (PU0) in CMSSW_8_1_0_pre16, Run2
- ORANGE: ZMM events (PU0) in CMSSW_8_1_0_pre11, Extended2023D1
  - Detectors are working as expected





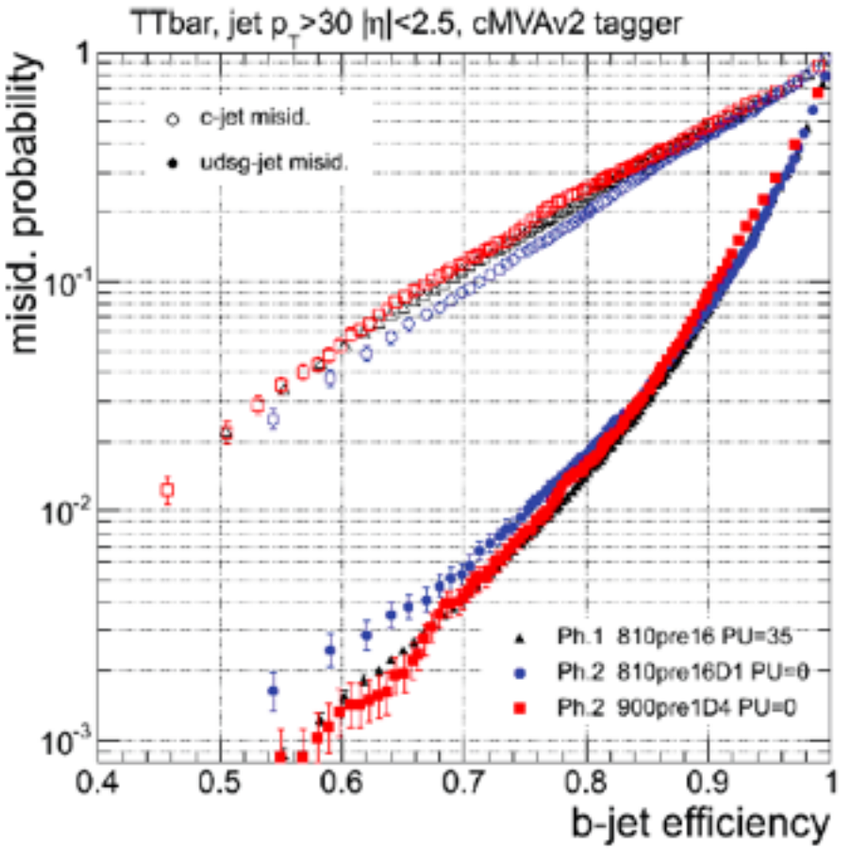




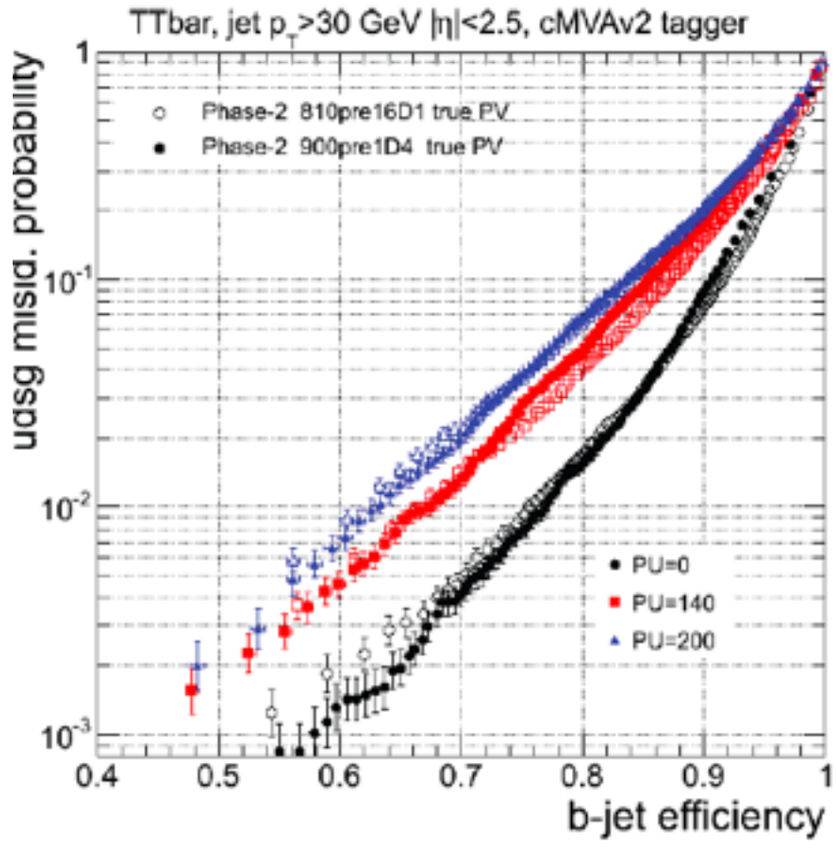
BTAG & TAUS – 900PRE1

D. Bloch

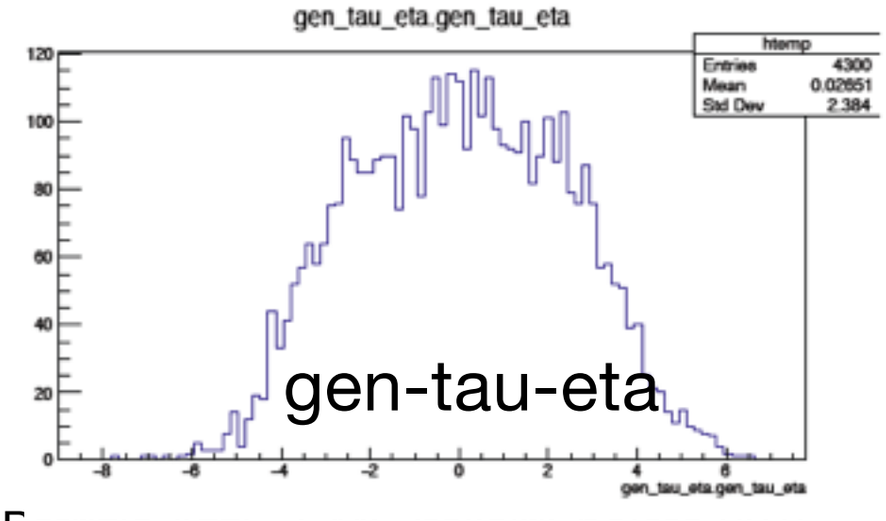
U. Hussein

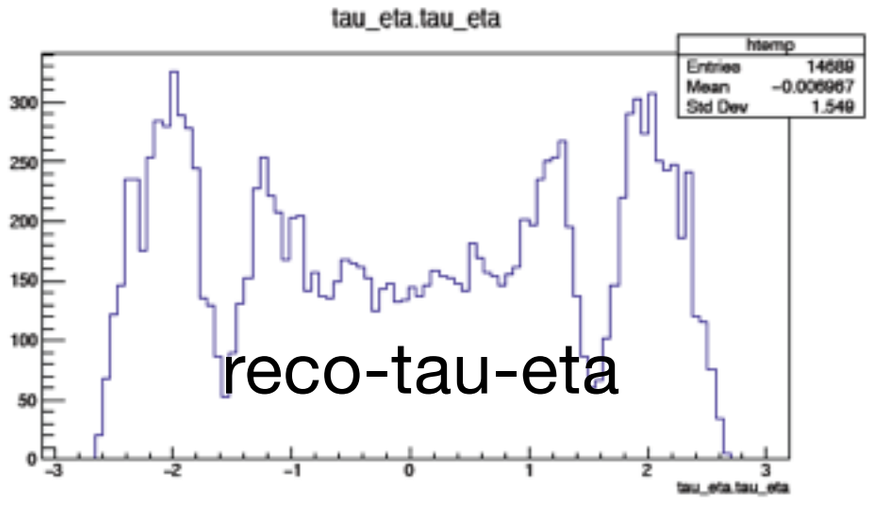


Ph.2 900pre1 at PU=0 is quite close to Ph.1 810pre16 at PU=35 and better than Ph.2 810pre16 at PU=0



for those events with the true PV: 900pre1 is similar to 810pre16 for any PU





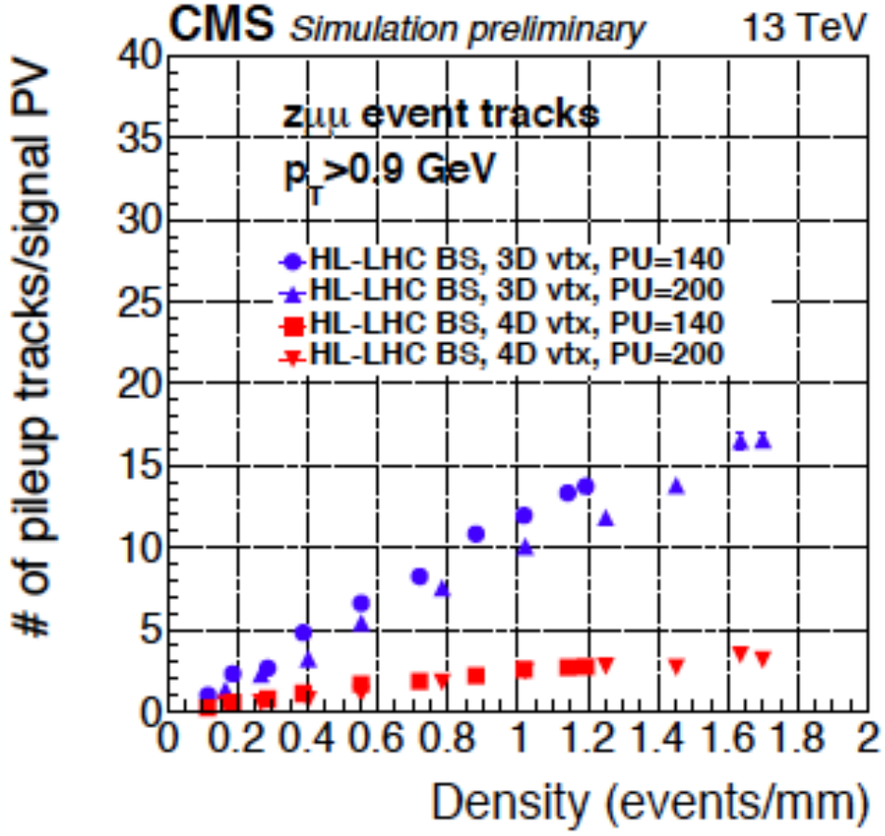
taus not reconstructed above η=2.5 (cut hardwired)
fix in progress. might not get in 820 though

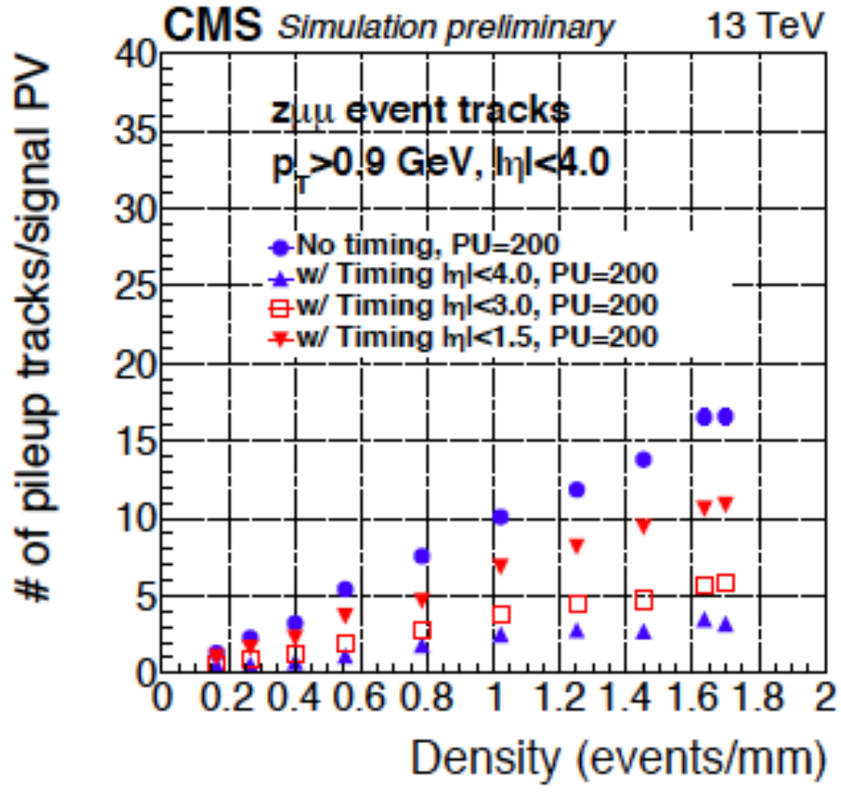
STATUS AND PLANS FOR TIMING

L. Grey

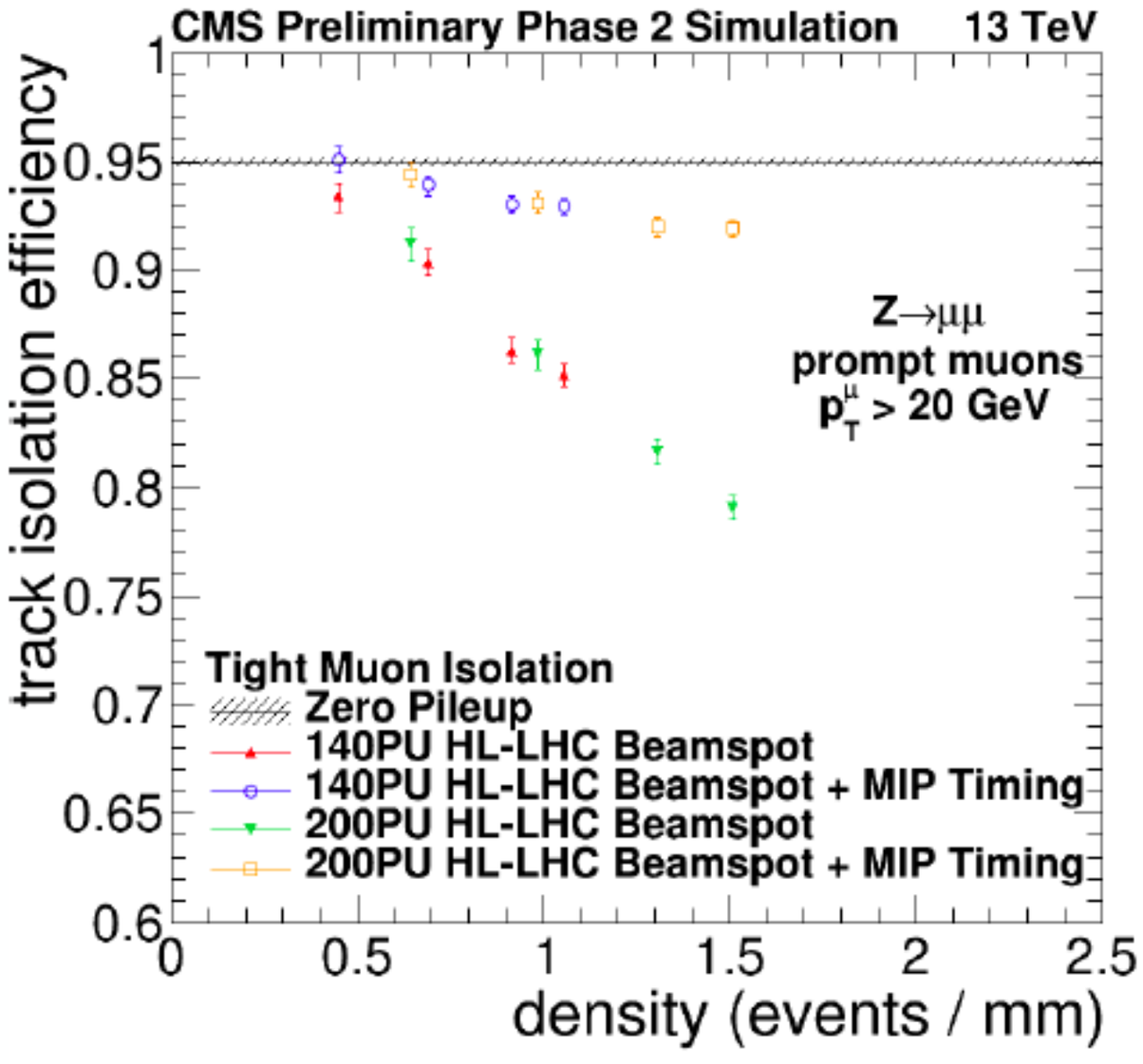
J. Bendavid

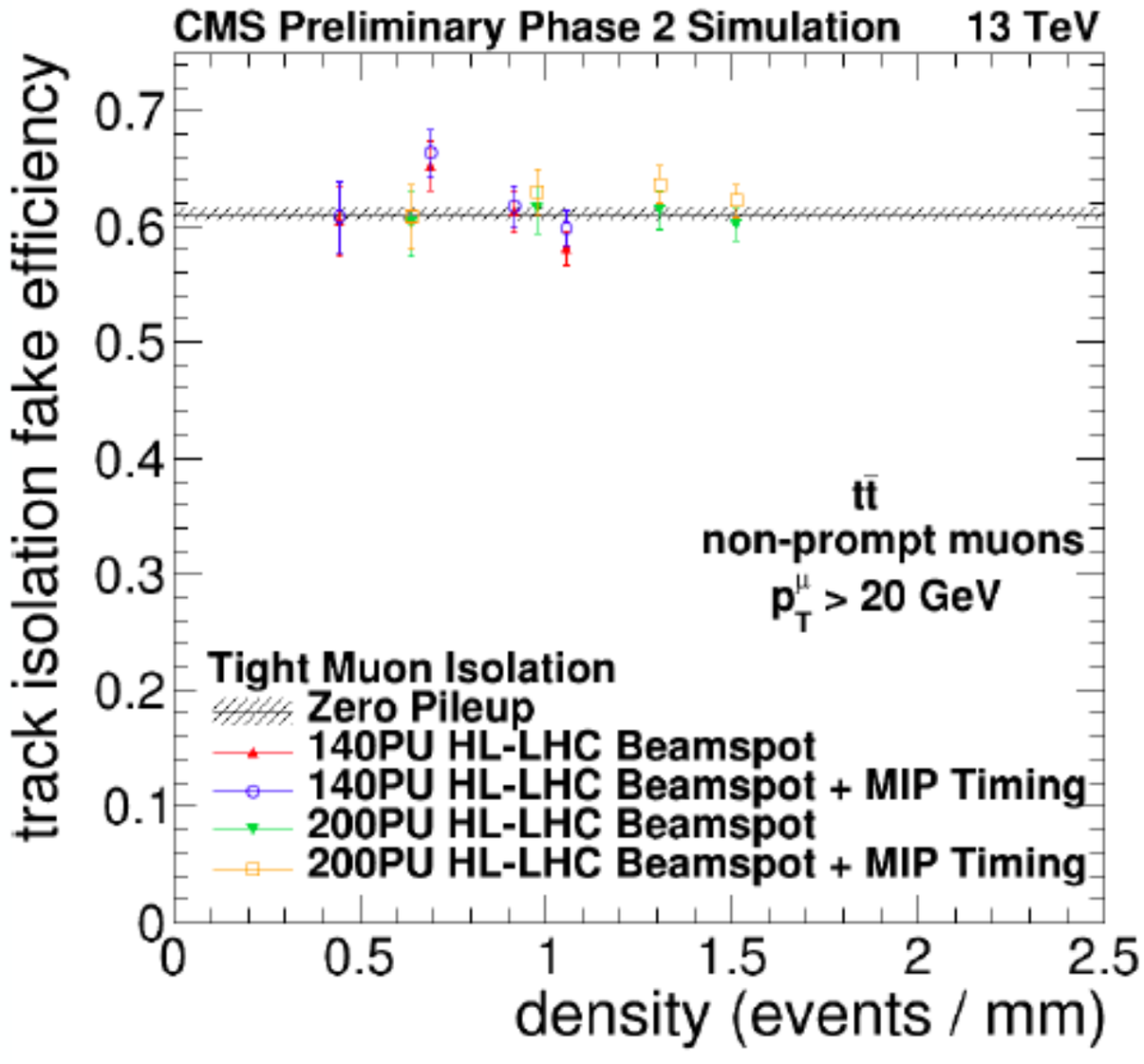
- New! Timing information to Delphes version: useful for Physics studies. Includes 4D vertexing and timing stamps for tracks and photons
- Planned studies with Delphes:
  - start with the study of effects on Jet/Met and isolation
    - use flat resolution (30ps for neutral and 20ps for charged)
    - validate physics impact for low energy photon & tracks (as it has design implications)
- FullSim development: Results from 810pre15timing here





Muon Track Isolation w/ Timing





Muon isolation plots updated with consistent definition of "fakes". Now using non-prompt muons as fakes.

Improvement in prompt-muon signal very clear now. However, this points out that we must be very careful with background definitions in order to get a correct answer in 200PU.

in purple new studies compared to TP

MATRICE DI FISICA

Channel vs TDR/ Studies	H→ZZ →2μ2e, 4μ.4e	H→2μ	H→2γ	H→2τ (VBF)	H→Inv.	Z(ll)H(bb), HH→4b, 2b2τ, bbWW	Long Lived/ displaced	B→$\mu\mu$, B→φφ→ 4K	Top mass with J/ψ	DM (γ,jett)	VBS	Di-boson res.	VLQ (T→th)	FCNC tγ, 4t
Tracker														
Extension	✓	✓		✓		✓	✓		✓					
Resolution	✓	✓						✓						
PU			✓	✓										
B/tau-tag				✓		✓	✓							
Track-trig								✓						
Muon														
Extension	✓	✓					✓	✓	✓					
Trigger							✓	✓						
Barrel Calo														
Reso e/γ/jet	✓		✓			✓				✓	✓			
PU mitig.			✓											
SubStruct.												✓	✓	
Endcap														
Extension	✓		✓	✓	✓	✓								✓
Forward jet				✓						✓	✓		✓	
Resolutions	✓		✓	✓	✓	✓				✓	✓			
PU mitig.			✓							✓				

TRACKER TDR PERFORMANCE CONTENT

- **HIGHLIGHT: Tracker extension, increased object acceptances, momentum resolutions, mass resolutions, pileup mitigation.**
- INTERESTING SIGNALS (Performance plots only)
  - **H→ZZ→2mu2e, 4mu,4e, H→ di-mu** H->leptoni BO, BA
    - lepton acceptance efficiencies, momentum resolutions, mass resolutions
  - **VBF H →2 taus, HH →2b2tau , HH →4b maybe also Z(→ll)H(→bb)**
    - b-tagging & tau-tagging performance in the forward region
  - **Long Lived particles - displaced leptons and b-jets (with $c\tau$ <1m)**
    - performance as a function of decay length, pT, eta
  - **Bs/B0 →2mu (mass resolutions), Bs → phi + phi -> 4K**
    - highlight the need for L1 track trigger and mass resolution, low momentum tracking performance
  - **PU mitigation performance (PUPPI)**
  - Track trigger performance (organized by the L1 Upgrade Trigger Group):
    - include emulation for rates with and without the Track trigger (special samples production)
  - Other possible topics: H→ di-photon, 4D vertexing with MIP timing (subject to timing layer being approved), Top Mass J/psi - increased acceptance

PI, PD
HH->bbττ
Androsov, Bagliesi, Ciocci,Grippo,
HH->4b Dell'Osso, Tosi
Rizzi++(tk, btag)

MUON TDR PERFORMANCE CONTENT

H-4μ, Long Lived, τ->3μ
F. Cavallo, R. Venditti
Coordinano studi fisica per le GEM

- HIGHLIGHT: **Endcap chambers mu reconstruction, L1-trigger, displaced vertices, Extension: Muon and EC mu-tagging**
- INTERESTING SIGNALS:
  - **H→ZZ→4mu, H→ di-mu (full analyses w/ projections)**
    - emphasize lepton acceptance, efficiencies momentum resolutions, mass resolutions
  - **Long Lived particles - HSCP, & displaced leptons (with $c\tau$ >1m)** BA
    - performance as a function of decay length, pT, eta)
    - emphasize trigger capabilities for unusual signatures
    - *possibly would need some reco effort*

HSCP e OOT muons with RCP
F. Primavera, D. Piccolo

  - **Bs/B0 →2mu (full analysis w/ projections)**
  - **τ->3μ**
  - **Top mass - J/psi (full analysis w/projections)**
    - emphasize increase in acceptance
- maybe possible to include SUSY (multileptons or dilepton edge analyses)

BARREL CALORIMETER TDR PERFORMANCE CONTENT

- HIGHLIGHT: **Calorimeter designs, jets, missing Et resolution, jet substructure, Pileup mitigation , EB pointing & possibly timing resolutions,**
- INTERESTING SIGNALS:
  - **H→ZZ→4e, H→ di-photon, HH→bbWW→2e+nu+bb** 
    - emphasize acceptance efficiencies, momentum resolutions, mass resolutions
  - **Dark Matter (mono photon, mono jets)**
    - photon performance, missing Et, jets
  - **Vector Boson Scattering: Same Sign WW, and WZ** 
    - lepton performance. Partial performance in barrel (see EC TDR)
  - **Diboson resonances**
    - W tagging performance, substructure algorithm performance
- Other possible topics: Lepton Flavor violation (multi lepton signatures), SUSY signatures

ENDCAP CALORIMETER TDR

- HIGHLIGHT: **Calorimeter designs, forward jet tagging, missing Et resolution, including EC clustering, pointing & timing resolutions, Pileup mitigation, muon-tagging**
  - **All analyses below will be "full analyses with projections", as overlapping processes in previous TDRs may only show performances.**
- INTERESTING SIGNALS:
  - **H→ZZ→4e, H→ di-photon, HH→bb$\gamma\gamma$, HH→bbWW→2e+nu+bb, Higgs→invisible**
    - emphasize acceptance efficiencies, momentum resolutions, mass resolutions
  - **VBF H→2tau, Vector Like Quarks (single production) T → tH**
    - forward jets, top tagging, Higgs tagging
  - **Dark Matter (mono photon, mono jets)**
    - missing ET, VBF jets, jets and photon performance
  - **Vector Boson Scattering: Same Sign WW, and WZ** ?
    - forward jets, missing Et
  - **PU mitigation performance**
  - **top+gamma FCNC and four tops**
    - show increased acceptance.

TOPICS FOR A PROPOSED WRAP-UP PAPER

- The TDRs are planned to be « slim » documents with only few analyses which emphasize the performance of the detectors. List shown is longer…and still not exaustive
- Interpretations, combinations, and other general studies that pertain to the Physics Case of the Phase2 should be collected and documented in a separate publication/paper (LHCC supports a Yellow Book for now):
  - Higgs Couplings
  - di-Higgs interpretations
  - top physics (mass, FCNC, four tops..)
  - topics in Flavor physics
  - unusual signatures (EXO)
  - SUSY projections
  - Heavy particle productions (W', Z', WW resonances, VLQ.. etc), use of jet substructure
  - Heavy Ion ?

STANDARD MODEL PHYSICS OPPORTUNITIES @HL-LHC

Examine Higgs boson and boundaries of the Standard Model

- precise determination of mass, couplings, decay modes
- searches for New Physics and dark matter

Need to understand SM processes

- production of γ, W, Z, or top quarks + jets
- always appear as irreducible or reducible background

Have their own intrinsic interest, e.g.

- SM electroweak parameters, $t\bar{t}$ cross section, …
  - need improved theoretical understanding and inclusion in event generators
- improved determination of PDF
- searches for anomalous gauge boson couplings
- tests of the unitarity-cancellation mechanism in the SM
- top-quark mass

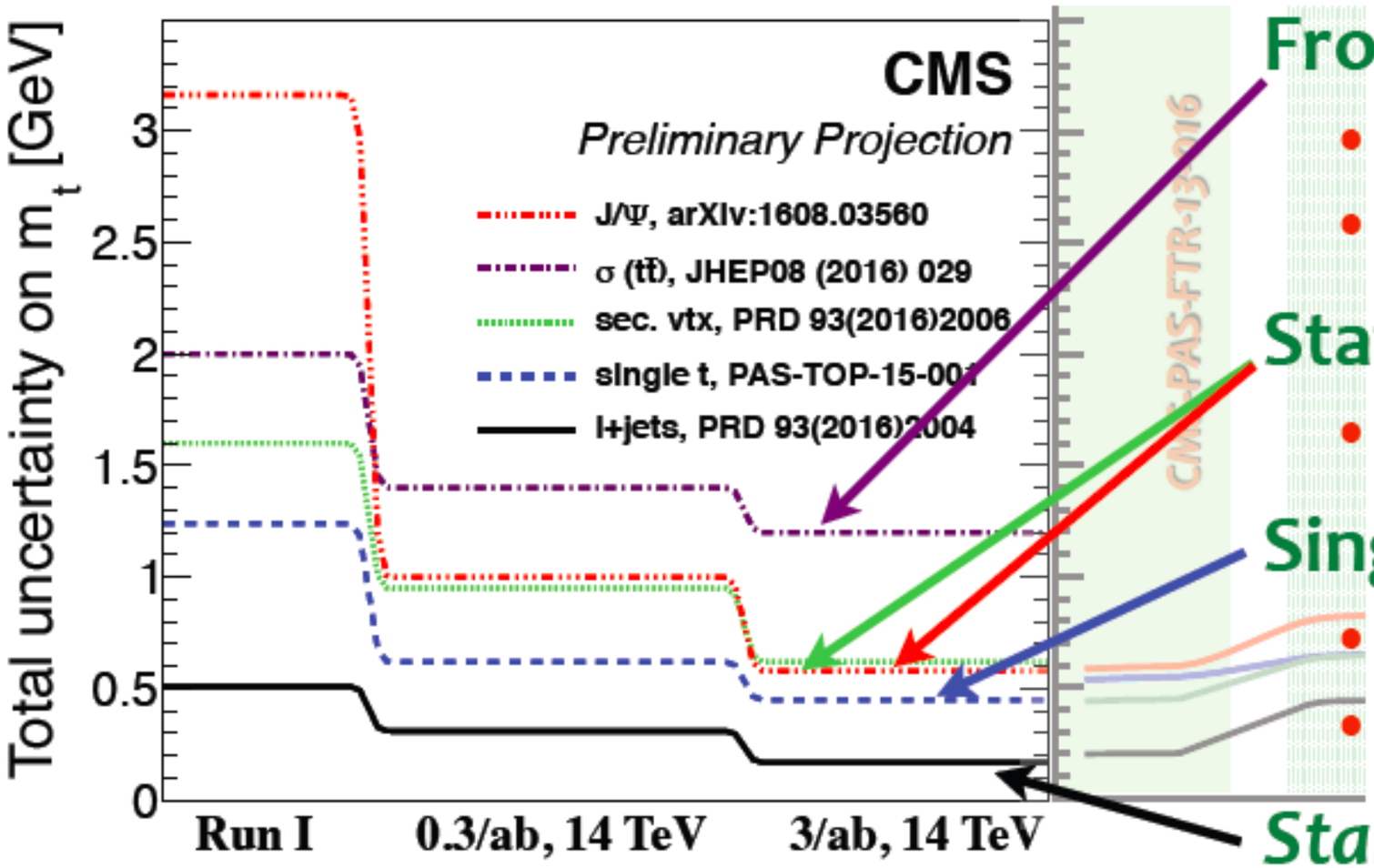
NEW M-TOP EXTRAPOLATIONS FROM CMS

HL-LHC top factory:
3B top pairs
1M single top

Updated projections with 8 TeV analysis experience

PAS FTR-16-006
preapproved yesterday

- additional channels: single top, $\sigma_{t\bar{t}}$, sec. vtx
- pile-up expected to be kept under control



From $t\bar{t}$ cross-section

- limited by theory uncertainty
- and lumi measurement

Stats. dominated channels

- J/ψ and sec. vtx

Single top

- presence of forward jet
- EWK process, different CR, PDF

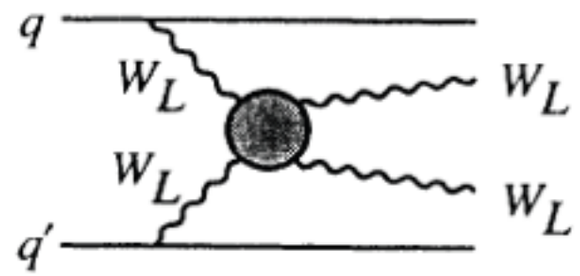
Standard ℓ+jets

- benefit from modeling studies, expect $\Delta m_{top}/m_{top} \sim 0.17$ GeV

m_{top} measurements will be an important element of HL-LHC

MOTIVATION FOR VBS STUDIES

Electroweak $VV \to VVjj$ scattering

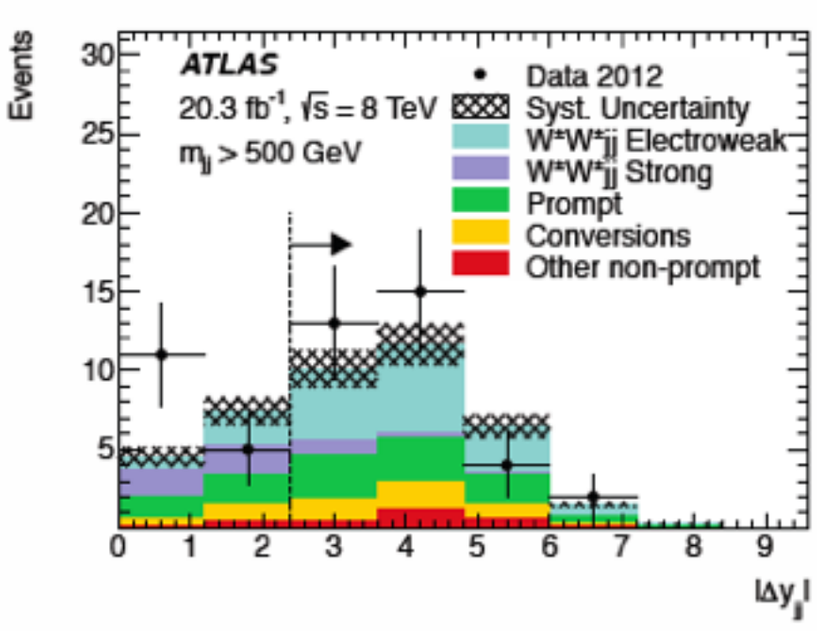


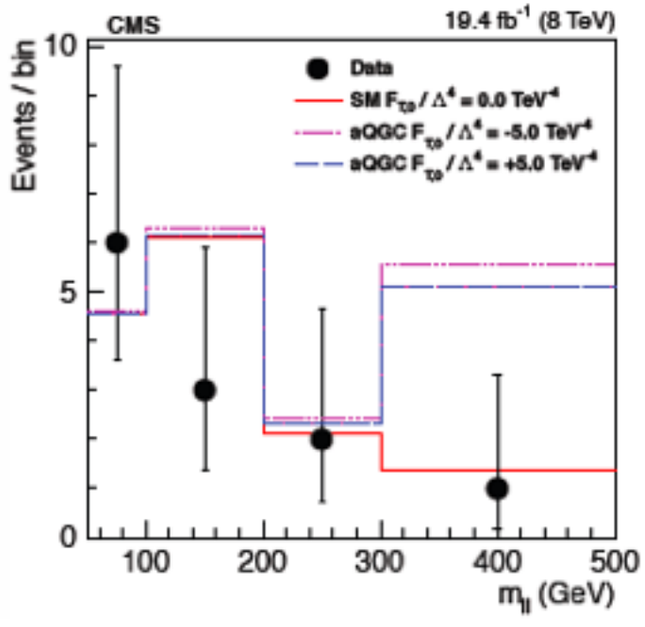
- via TGC, QGC or Higgs boson exchange
- cancellation → sensitive probe of new physics
- distinct signature in detector, good S/B ratio (VV QCD, $t\bar{t}$, V+jets, …)

Run-1

PRL 113 (2014) 141803 PRL 114 (2015) 051801

- fiducial $W^{\pm}W^{\pm}jj \to \ell^{\pm}\ell^{\pm}$ + tag jets + E_T^{miss}
  - evidence of EWK production at 3.6 σ (1.9 σ), with 2.8 σ (2.9 σ) expected by ATLAS (CMS)
  - fiducial cross-sections with $\Delta\sigma/\sigma$ = 30% (60%)
  - interpret as limit on anomalous QGC (or $H^{\pm\pm}$)

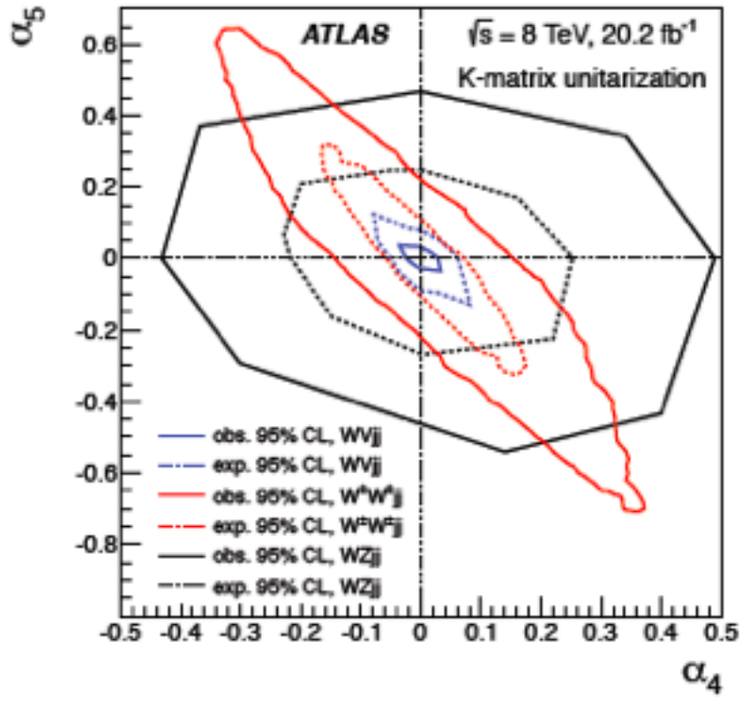




Latest result

1609.05122 subm. to PRD

- $W^{\pm}Vjj \to \ell^{\pm}$ + had + tag jets + E_T^{miss}
  - $V = W, Z$ → decaying hadronically
  - reconstructed as 2 jets or 1 large-R jet
  - interpret as limit on anomalous QGC

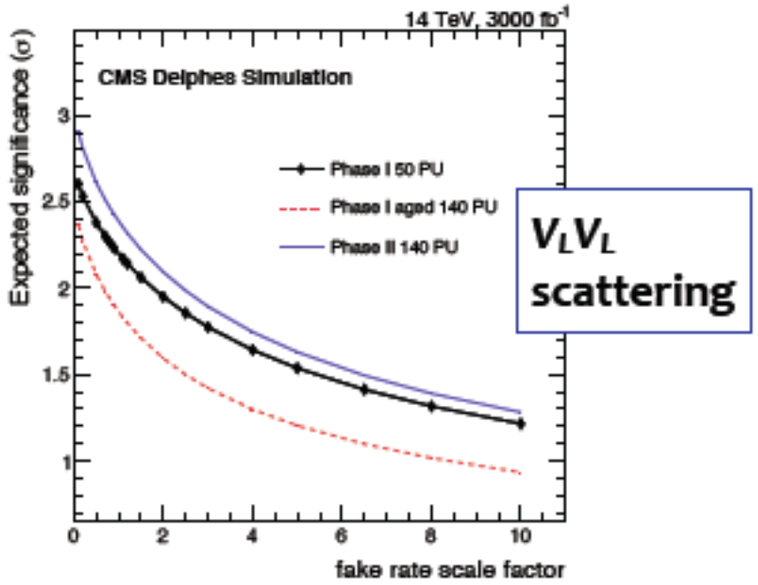


OLD VBS STUDY FROM CMS

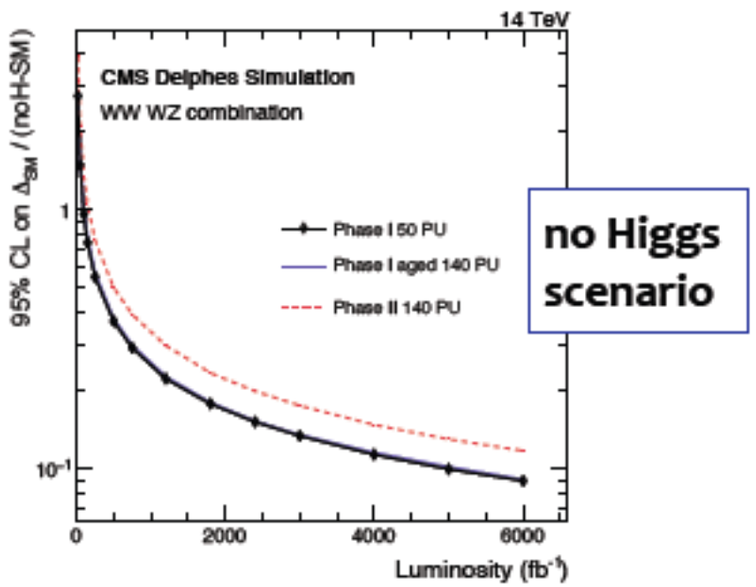
HERE CONSIDER ONLY FULLY LEPTONIC DECAYS OF THE VV

CMS PAS SMP-14-008

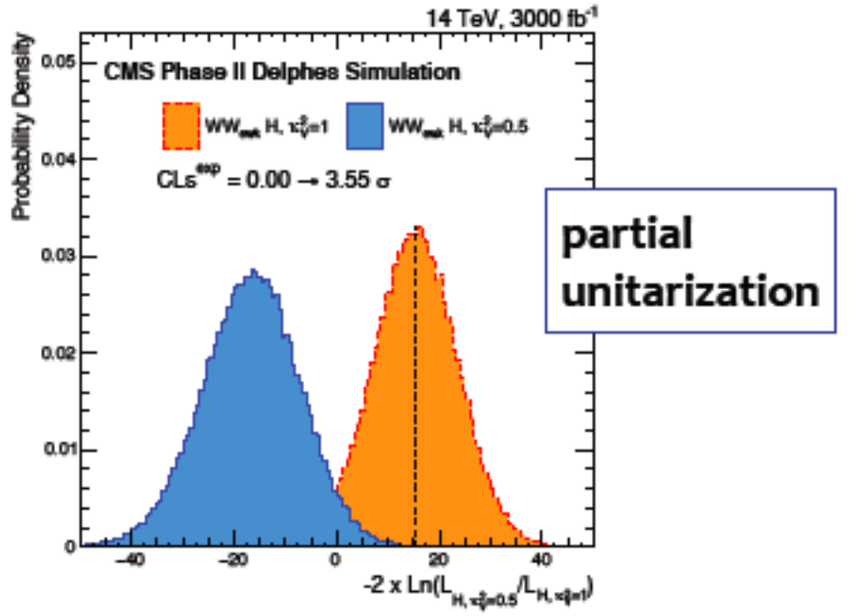
- now including all sources of background, including reducible and fakes
- report results as a function of data/MC fake rate scale factor
- expect $\Delta\sigma/\sigma \leq 10\%$ for WW and WZ VBS and 2.75 σ for V_LV_L scattering



V_LV_L scattering



no Higgs scenario



partial unitarization

Sensitivity to different BSM scenarios

- generic no-Higgs scenario
- presence of additional dim-8 operators in EFT framework
- partial unitarization

Comparing scenarios (current, aged, upgraded)

- detector upgrade recovering performance lost from ageing of CMS detector

OUTLOOK

- Validation of 820 release. XMAS production starting soon.
  - First production ~3M events in RECO format. Useful for developments.
  - need to retune high level objects algorithms. Excellent entry point for new people: work in contact with POGs, enhance synergy, share knowledge (EGM good example).
  - OPENING: Looking for a PPD/PDMV contact person for Relval/production submission and validation coordination (currently Stefan Piperov)
- More productions planned: physics signal content will increase to more complex events by Spring once GED validated.
  - not all physics studies will fit in the TDRs (small documents this time)
  - make sure effort is rewarded with a publication (Yellow Book from LHCC?)
- **Italy contribution is present in crucial aspects of the Performance and Physics studies:**
  - Higgs, di-Higgs, Long lived & HSCP, track trigger, timing
- **could have an even larger impact. Especially on very important topics that have now been abandoned after the TP (my choice, up for discussion):**
  - SM VBS
  - heavy flavor

Channel vs TDR/ Studies	H→ZZ →2μ2e, 4μ.4e	H→2μ	H→2γ	H→2τ (VBF)	H→Inv.	Z(ll)H(bb), HH→4b, 2b2τ, bbWW	Long Lived/ displaced	B→$\mu\mu$, B→φφ→ 4K	Top mass with J/ψ	DM (γ.jett)	VBS	Di-boson res.	VLQ (T→th)	FCNC tγ, 4t
Tracker														
Extension	✓	✓		✓		✓	✓		✓					
Resolution	✓	✓						✓						
PU			✓	✓										
B/tau-tag				✓		✓	✓							
Track-trig								✓						
Muon														
Extension	✓	✓					✓	✓	✓					
Trigger							✓	✓						
Barrel Calo														
Reso e/γ/jet	✓		✓			✓				✓	✓			
PU mitig.			✓											
SubStruct.												✓	✓	
Endcap														
Extension	✓		✓	✓	✓	✓								✓
Forward jet				✓						✓	✓		✓	
Resolutions	✓		✓	✓	✓	✓				✓	✓			
PU mitig.			✓							✓				

TUTORIAL FOR PHASE2 (S. Braibant ,J.Kieseler)

presented in Mumbai https://indico.cern.ch/event/588034/

BACKUP

PHASE2 DETECTOR NAMES AND WORKFLOWS

Calorimeters
- C1: Run2 calo
- C2: HGCal v7 + Phase2 HCAL
- C3†: HGCal v8 + Phase2 HCAL

Tracker
- T1: Phase2 tilted tracker v2016-04-12 w/ Phase1 (extended) pixel
- T2: Phase2 flat tracker v2016-04-12 w/ Phase1 (extended) pixel
- T3†: Phase2 tilted tracker v3.6.2 w/ Phase2 pixel v4.0.2.1

Timing layer
- I1: no timing layer
- I2†: LYSO

Muon
- M1: Phase2 muon system (TP baseline) w/ GE21, ME0, RE3/1, RE4/1
- M2†: Phase2 muon system (for TDR) incl. granularity in ME0

†: in development

- D1 = T1+C1+M1+I1
- D2 = T2+C1+M1+I1
- D3 = T1+C2+M1+I1
- D4 = T3+C2+M1+I1
- D5 = T1+C2+M1+I2
- D6 = T1+C1+M2+I1

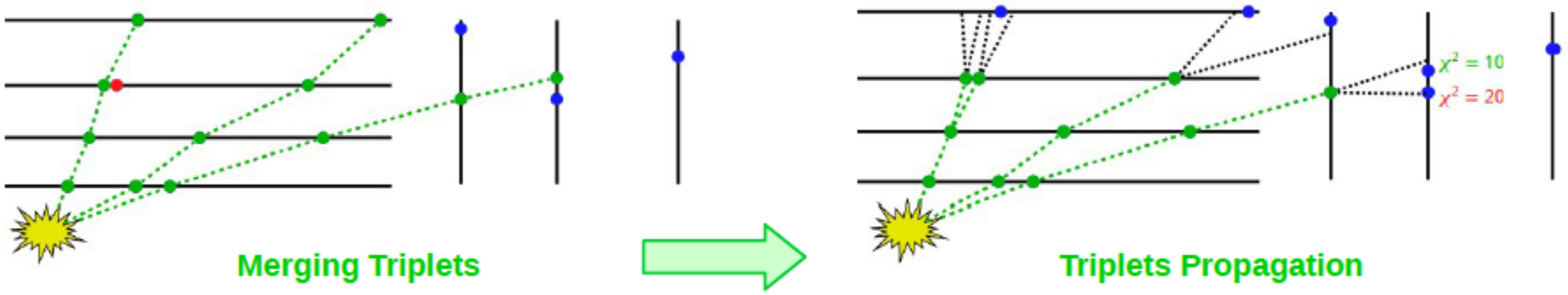
Tilted OT , Latest pixel Phase2 CALO, HGCAL, Timing

- D4(D4_timing) is the default for the Tracker TDR
- D? = T3+C3+M2+I1/I2 will be the default for the HGCAL TDR end of next year

Seeding strategy

- Reviewing the seeding strategy with the goal to improve timing of at least a factor 10

- First step: migration Phase2 seeding to something based on current Phase1
  - TRK-POG PRs are now merged in both 8_1_X and 9_0_X
  - For Phase1 we moved forward from “quadruplets by triplet merging” in last spring



→ Compute the total χ^2 and reject hits above a χ^2 threshold
  - If many found hits, choose the one with smallest χ^2

→ 2X faster than “merging” !!

→ comparison of “quadruplets by triplet propagation” vs. “by triplet merging” for Phase1 presented **here**

- Then: retune and eventually improve efficiency in the forward region.
  - This may require a new iterative strategy to isolate the very-forward region

EXPRESSION OF INTEREST FROM ITALIAN GROUPS

- BO-BA: H->4mu (tracker, muoni)
- BO, BA: H->4mu, tau->3mu con GEM F. Cavallo & Rosma Venditti
- Frascati: HSCP con RCP e muoni OOT Federica Primavera , Davide Piccolo
- PI-PD: HH->4b e HH->bbtautau (track trigger, tracker)
- MI-RM: H->gammagamma (timing)

HH4b – Future plans

NON-RESONANT

HL-LHC

Olivera, D. Majumder, M. Dell'Osso, M. Tosi

High luminosity ⇒ high pileup (200 PU @ 7×10^{34} Hz/cm^2)

New CMS detector

- Tracking at L1 trigger
- Pixel tracking up to η = 4
- Muon systems up to η = 2.9
- High Granularity Calorimeter up to η = 3
- Timing detector (?? not yet approved)
  - Central: thin LYSO+SiPM layer built into the tracker barrel support tube
  - Fwd: Thin layer of deep depleted APD's or LGAD

Brand new experimental scenario -> hard to make guess based on 2016 results. new FullSim required.

Implementation of new sub-detectors in simulation is on-going.
-> Alexandra and Devdetta are producing generation cards for HH4b signals.

First step: ***Tracker TDR*** → study of new tracker on signal efficiency, especially on b-tag efficiency.
Eventual study on ttbar and QCD with comparison with current cut flow.
Goal: quantify improvements due to high luminosity, new btagging- tracking.

Second step: ***Cal TDR*** → 2016 analysis strategy will be reproduced -> bkg estimation is data-driven.
Need to understand how to deal with this. **QCD samples should not be enough due to lack of statistics**, especially for non-resonant analysis flow.

In parallel it would also good to start thinking at new trigger scenarios.

SM HIGGS

➤H → $\tau\tau$

- Experimental uncertainties: lepton, τ_h, and jet energy scales
- how do we project uncertainties to higher luminosities, is Delphes appropriate for say τ_h?
- Theoretical uncertainties: Signal: ggH 1-jet acceptance

➤VH →bb

- Experimental uncertainties dominated by b-tagging
- Theoretical uncertainties: When reaching 10% uncertainty on b, signal systematics will become important (by the end of Run II). Signal (VH) uncertainty in Run I ≤10%

➤ttH, H →bb

- Experimental uncertainties dominated by b-tagging, with a big statistical component
- Theoretical uncertainties: tt + X cross section; especially tt + bb
- **First projection exercise using the current systematic uncertainties.**

➤H → $\gamma\gamma$/ WW/ZZ

- systematics: many of them scale with luminosity; H → ZZ lepton ID/reconstruction
- Theoretical uncertainties: WW differential cross section; FOR $\gamma\gamma$ mode. Largest contribution from ggH cross section; ggH + N jets contributing in VBF and ttH with 30-50 % uncertainty

BSM HIGGS

- DiHiggs (Ongoing for ECFA & longer term):
  - Update of the TP results taking into account Run II analysis improvements
  - Extrapolation of Run I & run II searches: Detector performance in HL-LHC environment needs to be taken into account (eg: PU rejection, btagging, tau performance)
  - Some using full delphes analysis e.g. bbW
  - Revisit background studies for HL-LHC co

Already available:

Final state	Run1	Run2	HL-LHC,TP
bbbb	✔	✔	✗ (*)
bbττ	✔, ✔	✔, ✔	✔
bbγγ	✔, ✔	✗ (*)	✔
bbWW	✗	✔	✔

Blue: resonant, Red: non-resonant (* ongoing)

- MSSM HTauTau
  - Run II analysis ongoing. Possible extrapolation to high luminosity in time for ECFA
  - Model independent limit on cross-section+projections in MSSM benchmark scenarios in the mA-tanβ plane
- Charged Higgs
  - Early Run II searches results in preparation (Large variety of H± decays probed in Run I: tb, cs, τν (etc). Extrapolation planned for ECFA

“Maybe” for ECFA

BSM HIGGS

- H/A→TTbar
  - H,A→ttbar may not display itself as a bump but as a peak-dip structure in mttbar due to the interference of ϕttbar and ttbar background (arXiv:1511.05584). Knowledge of the mttbar differential distribution to 1% necessary
  - Benefit from extended tracker (less dilution in spin correlation variables) and improved btagging
  - Extrapolation from early Run II results (if on time for ECFA) and/or full delphes study later on
- Invisible Higgs searches (connection to DM)
  - CMS-HIG-14-038: trivial assessment of systematic extrapolation (const and sqrt(L) improvement)
  - Update the extrapolations to incorporate Run II analysis
  - improvements (correlated background treatment in VBF, plans for shape analysis)
- LFV Higgs to Lepton Tau
  - Extrapolation of Run 2 search. Assessment of systematics and detector upgrade improvements
  - Ongoing selection optimisation and improvement of background extraction techniques (prior step for a ECFA extrapolation)
  - Longer term: Delphes analysis (beyond ECFA timeline)
- Several other channels under consideration
- Extrapolation vs full analysis depends on the final state, realistic assessment of systematics

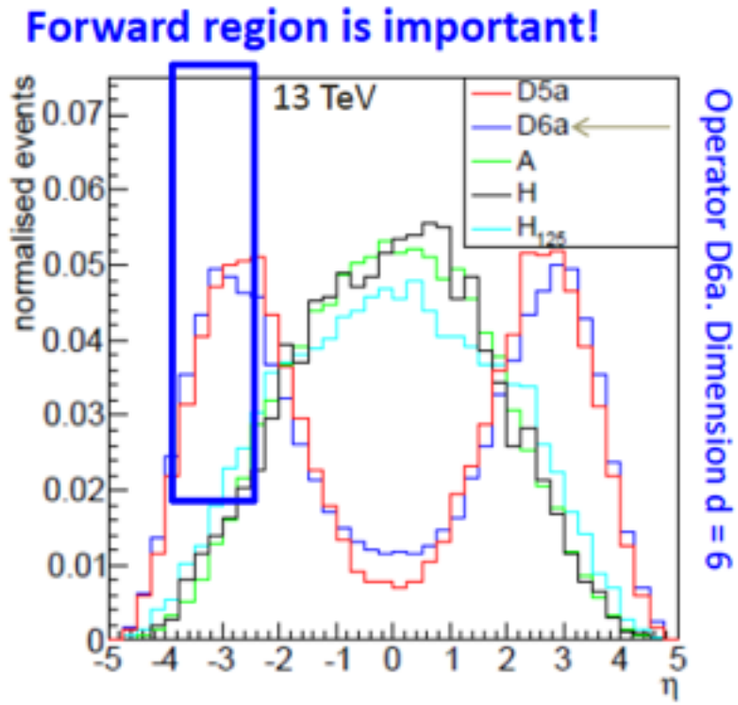
SEARCHES

- Dark Matter

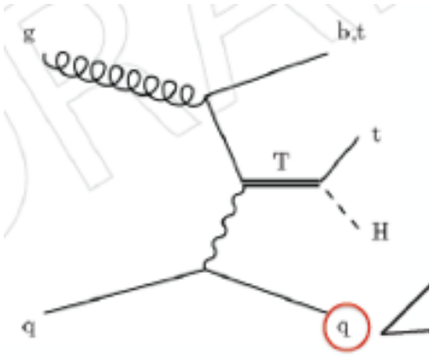
- Classical Missing ET+X=jet channel
  - Monojet is the classical DM „reference model“. Needs a scan of mediator and DM masses (= many samples),

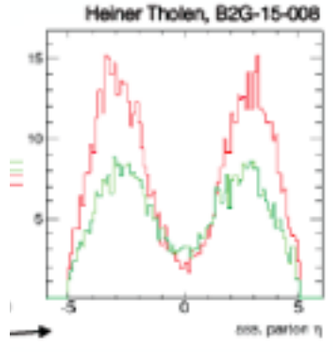
- DM with forward jets:
  - new models
  - Effective operator interactions between Dirac-type DM and W/Z bosons

    ⇒ sensitivity in terms of scale Λ which goes as $\Lambda^{4\text{-d}}$



- Vector Like Quarks
  - Single production of VLQs e.g. T → tH, tag the forward jet
  - all hadronic/leptonic with boosted top, and boosted Higgs





- Multi-Bosons
  - can benefit from W-tagging at low pt (200-500) GeVGeV) and forward jets (VBF, VBS)

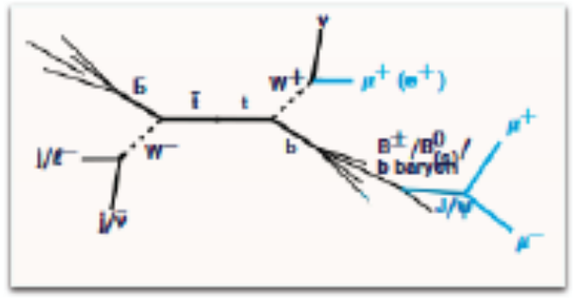
NOT for ECFA

STANDARD MODEL

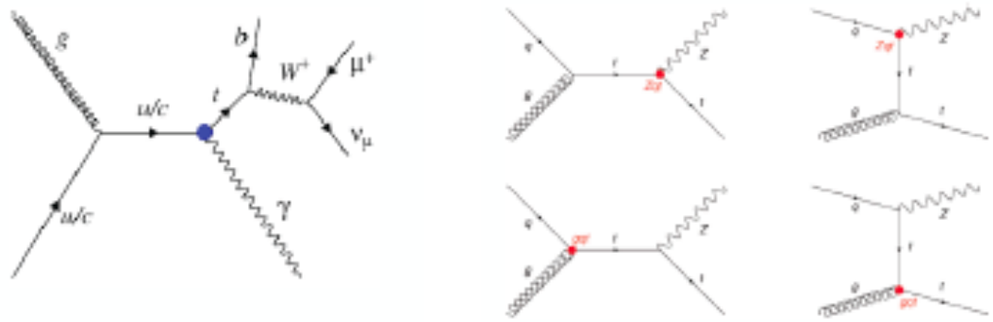
- ➤$\sin\theta_W$ from Z forward-backward asymmetry
- ➤Vector Boson Scattering:
  - ➤ short term: incremental approach
    - ➤ redo the study with the simulation corresponding to the actual expected HGCal performances
    - ➤ add b-tagging up to large eta: this would reduce the ttbar bkg in the WW analysis
  - ➤ long term: new developments
    - ➤ add semi leptonic channels (with boosted technology)
    - ➤ add fully leptonic ZZ final states
    - ➤ rethink longitudinal scattering studies w/ a dedicated approach, as opposed to the signal-search performed so far
- ➤Flavor Physics:
- ➤B→$\mu\mu$
  - ➤ A reprise of the studies done for the TP, baseline plan is to deliver the same results with an updated setup
  - ➤ Spin-of of the current measurement done for run-2 (same group working on both)
- ➤Bs→$\phi\phi$ →KKKK
  - ➤ L1 Track Trigger study and possibly an estimate of the final analysis sensitivity
- ➤ $\tau\rightarrow\mu\mu\mu$
  - ➤ Analysis group currently focused on Run-2 measurement

TOP QUARKS

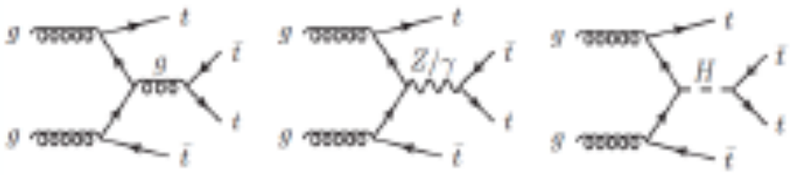
- Top mass using J/Psi endpoint method
  - correlation between Mt and the invariant mass of the J/Psi +lepton combination
  - Extrapolate using the Run 2 result



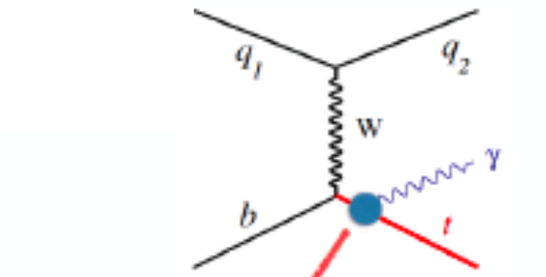
- FCNC in single top + Z/photon production: tqGamma, tqZ, tqg



- Four-top production "Maybe" for ECFA



- Top EW couplings: : Ztt, γtt
  - probe the EW dipole couplings of the top quark with photon.



$$\delta\Gamma_{q'qV} = \bar{q}' \frac{i\sigma^{\mu\nu}k_\nu}{m_t}\left(g_L^V P_L + g_R^V P_R\right) q\, \varepsilon_\mu^V ,$$

NEW PHYSICS TOPICS – QUICK HIGHLIGHT

- Long Lived Particles
  - Extrapolation using Run2 analyses: displaced dijet analysis and the HSCP analysis possible choices
  - dark photons with displaced muon jets is a benchmark analyses for the muon upgrade
    - Neutral naturalness - results in displaced di-Higgs produced via mirror glueballs, leading to two displaced b-bbar pairs as the final state signatures.
    - No need of specific models: can study parameterized performance
- On the detector side:
  - muon trigger studies are ongoing and will be of great benefit for the LL searches.
  - improving tracking resolution and efficiency to reconstruct displaced tracks and vertices beneficial to most LL searches
  - HGC could give more directional information for identifying jets produced at displaced vertices
  - fast timing detector has huge potential for all LL analyses, most obviously displaced photons
- Jet Substructure
  - understand the performance of observables with increased pileup - W/Z/H tagging