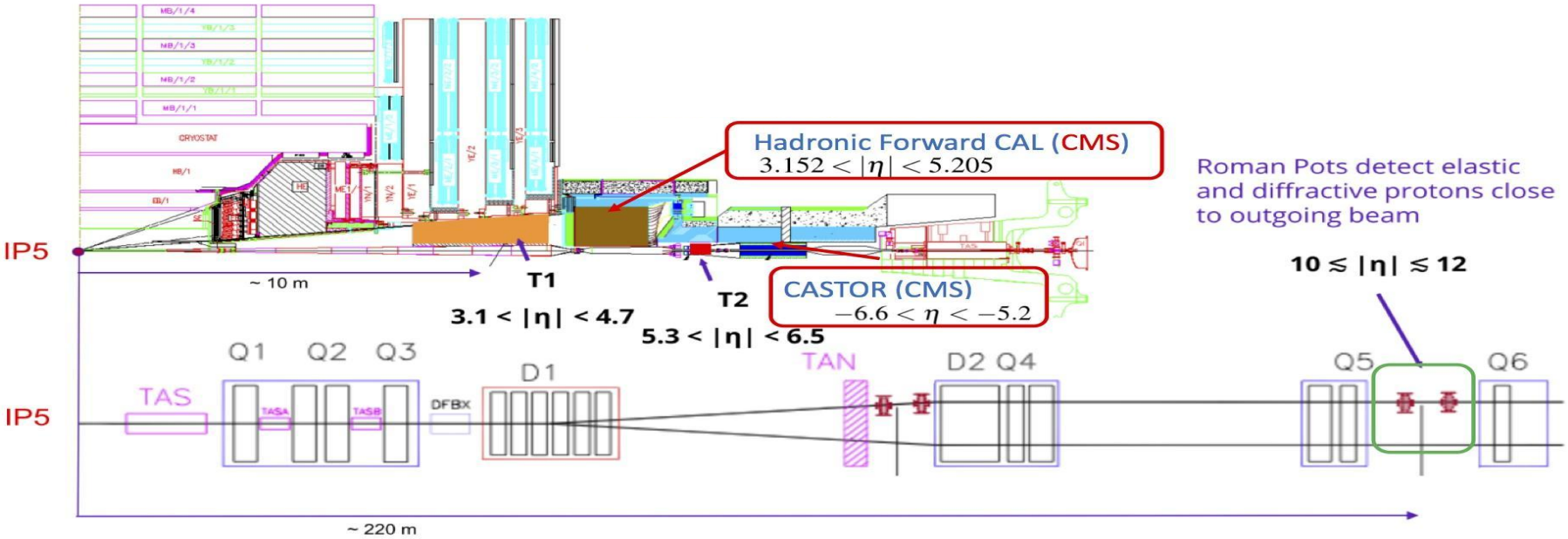
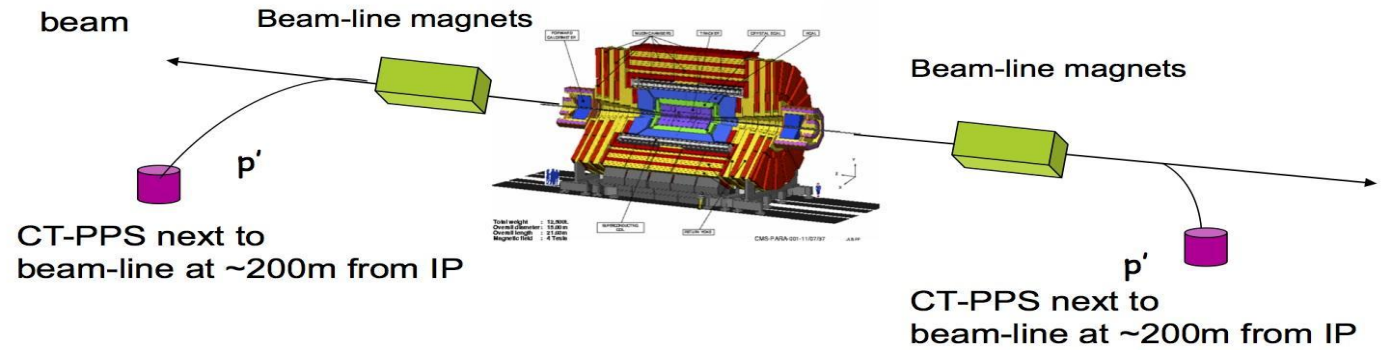
Forward physics with CMS: “initial thoughts” on 2017-18 data-taking

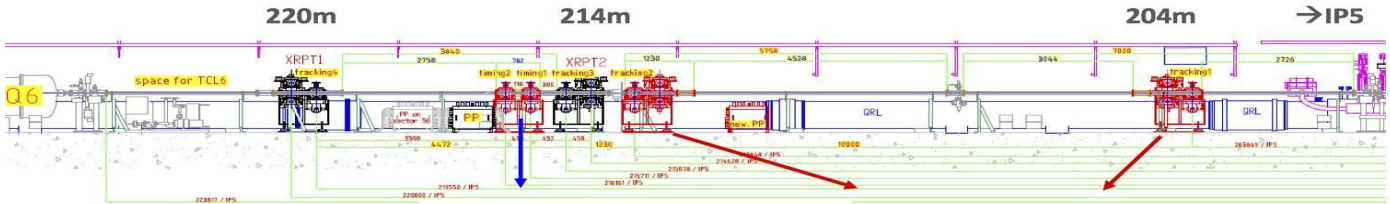
A. Moraes, H. Van Haevermaet
on behalf of the CMS Collaboration

The CMS detector: forward subsystems



CMS-TOTEM
Precision Proton Spectrometer (CT-PPS)





NB one arm shown only!

1 new horizontal cylindrical RP

Equipped with timing detectors, for PU rejection

2 horizontal box-shaped RPs

Equipped with tracking detectors to measure the displacement of the scattered protons w.r.t. the beam

Measure proton fractional momentum loss ξ between 2% and 20%

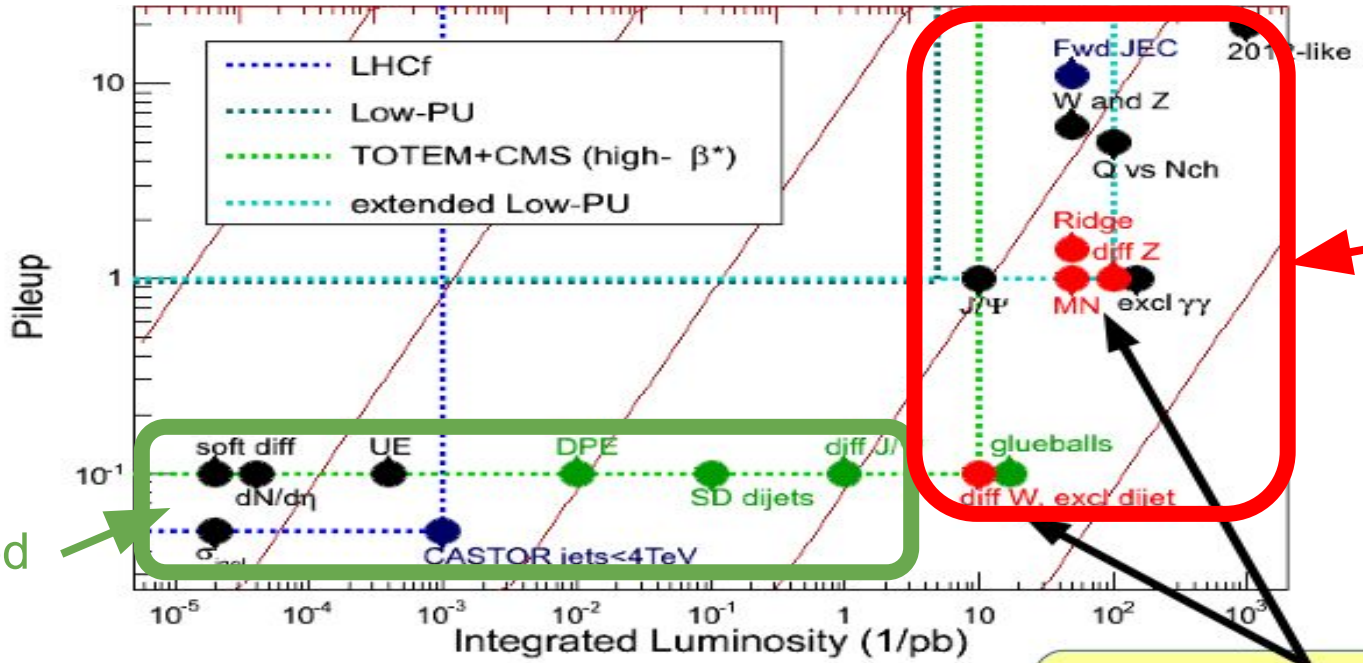
Overview of low pile-up data collected at 13 TeV in 2015 - 2016

- Low pile-up in 2015:
  - Run2015A at **0T**: 85.6 /nb PU ~0.1 (with CASTOR)
  - Run2015B at 3.8T: 229 /nb PU ~1.6
  - Run2015C at 3.8T: 22 /nb (VdM) PU ~0.5
  - Run2015D at 3.8T: **663 /nb** PU ~0.1 (with TOTEM)
  - *pp at 5 TeV + AA at 5 TeV* *(with CASTOR)*

- Low pile-up in 2016:
  - Run2016B at 3.8T: 43 /nb (VdM) PU ~0.6
  - mini ramp-up after MD: ~1.3 /pb PU ~0.5-1.0

- Total available: **~2 /pb CMS data**
  663 /nb CMS+TOTEM data

Soft QCD, small-x and forward physics: pile-up & luminosity



There is a considerable part of the small-x / forward physics programme that depends on new data!

Preliminary LHC running schedule in 2017

➢ **Only ~22 weeks of pp running (~20 weeks if we exclude the special physics runs in this plan). Not much level arm to add more low pileup running**

Soft QCD, Small-x & Forward physics: possibilities for data taking for the rest of Run 2

Scenario 1 (baseline):
Nominal conditions for high pile-up pp collisions

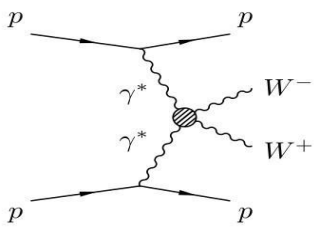
➢ During regular high-luminosity pp run, CT-PPS will be able to collect significant amounts of data

Physics motivations: central exclusive production

1) LHC as tagged photon-photon collider

EWK

- Measure $\gamma\gamma \rightarrow W^+W^-$, e^+e^-, $\mu^+\mu^-$, $\tau^+\tau^-$
- Search for AQGC with high sensitivity
- Search for SM forbidden $ZZ\gamma\gamma$, $\gamma\gamma\gamma\gamma$ couplings



Scenario 1 (baseline):
Nominal conditions for high pile-up pp collisions

2) LHC as tagged gluon-gluon collider

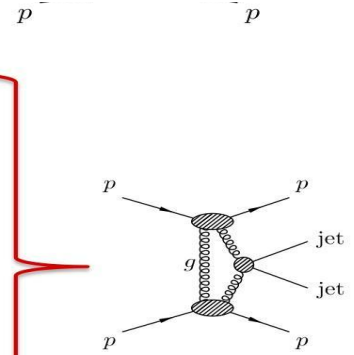
QCD

- Exclusive two and three jet events, M up to ~ 700-800 GeV
- Test of pQCD mechanisms of exclusive production
- Gluon jet samples with small quark jet component
- Proton structure (GPDs)

BSM

Search for new resonances in CEP

- Clean events (no underlying pp event)
- Independent mass measurement from pp system
- J^{PC} quantum numbers 0^{++}, 2^{++}



6

NB mass of centrally produced system measured from scattered protons momenta

- The main objective is to enlarge the mass acceptance interval. Based on physics considerations this interval should be from ≈100 GeV to >2 TeV.
- The lower limit is set by the Higgs mass and the upper limit by naturalness arguments.
  - The lower limit is also important to guarantee acceptance for standard model processes which are used as control data.
- This mass acceptance interval implies exploring the following options:
  - TCL4 collimator settings that give at least the same or larger upper mass limit with the 2017 optics.
  - Dispersion (D) and beam size (S) at XRPs location such that minimum $\xi = 15 * S/D \sim 0.008$.
- **Obviously, there is a limitation to what we can accept as modifications in the optics in case this has negative effects in normal pp running, so these options must be considered as settings to be explored, and not as a formal or explicit request from CMS**

Scenario 1 (baseline):
Nominal conditions for high pile-up pp running

❑ VdM scans

➢ Similarly to the operation in 2015/2016, we expect (short) periods when VdM scans are performed.

➢ CMS continues to be interested in collecting data during VdM scans (with low pile-up conditions: PU ~0.5 – 0.6) in 2017-18

❑ Mini ramp-up

➢ Also in 2016, we collected low pile-up data (PU ~ 1) during mini ramp-up periods after MD's

➢ CMS continues to be interested in collecting data during these mini ramp-up periods in 2017-18. This can provide us with O(pb-1) of data.

Soft QCD, Small-x & Forward physics: possibilities for data taking for the rest of Run 2

Scenario 2 (feasible if LHC running time is optimized):

Special run conditions: dedicated low pile-up pp collisions with usual optics (i.e. no beta* 90 m run)

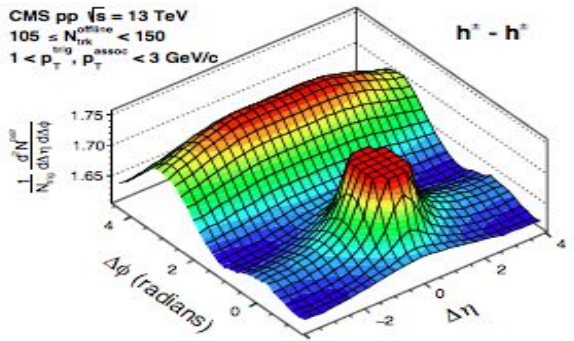
- Many studies in our forward physics programme still require larger samples of low PU data (~25-50 pb^{-1})
- Examples:
  - Central/forward jet final states
  - Mueller-Navelet jets
  - DPS 4-jet production
  - High-multiplicity studies: multiparticle correlations
- Need fully working CMS detector (including new pixel upgrade), → take data after Commissioning phase

- **These measurements can be done with CMS alone and could require less LHC running time**

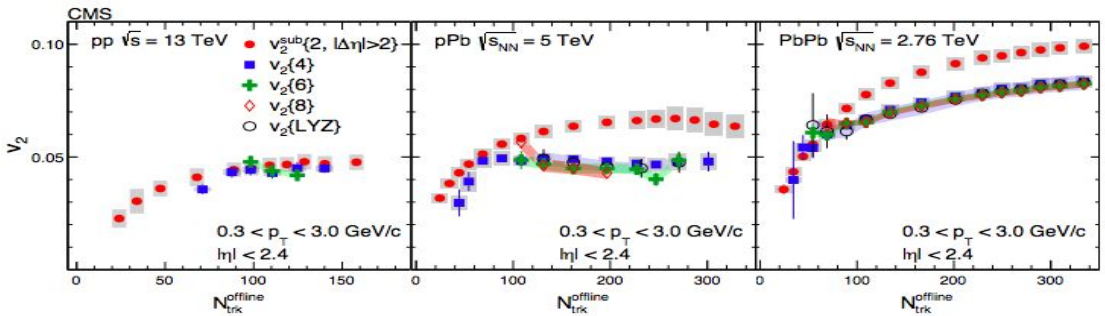
Low-PU pp collisions: implications for HI physics

Studies of QGP in high-multiplicity pp

Data from 2015 β*=90m run



multi-particle correlations: v2{m}



arXiv:1606.06198

v2{2} ≈ v2{4} ≈ v2{6}

Evidence of collectivity and QGP in pp

Use 25 to 50 pb^{-1} with PU <= 1 for detailed investigations of: higher order vn, jet quenching, heavy flavor, quarkonia etc.

Scenario 3 (not baseline):

Special run conditions: dedicated low pile-up pp collisions with beta* = 90 m

➢ **Detectors:**

- Combining CMS and TOTEM: this would extend the range of physics we can explore
- If CMS+TOTEM: need special beam optics with **β* = 90m** and bunch separation (eg. 50ns)
- Potentially expensive in terms of running time in 2017 if ~50 pb^{-1} are required

➢ **Physics examples with >~ 5 pb^{-1}:**

Single Diffractive Processes
Exclusive dijet production
Low mass resonances in Central Diffraction
Exclusive χ_c

Scenario 4 (more complicated, not in 2017):
Special run conditions: dedicated low pile-up pp collisions

(CMS with CASTOR & TOTEM T2):

Data with extended forward tracking/calorimetry: installation of CASTOR and/or TOTEM T2

Able to study correlations between central low-pt track jets & energy/jets in CASTOR.
Perform e.g.:

- Underlying event measurements in forward region
  (e.g. Run1 paper: JHEP 04 (2013) 072)
- Measurements of central - forward multi-jet final states in CASTOR

⇒ This will yield unique information on QCD in a regime .

No pp data at 13 TeV exists yet with CASTOR and CMS solenoid at B=3.8T yet

➢ **Caveats with detector installations: can only run with low intensities: need TS's to install/remove**

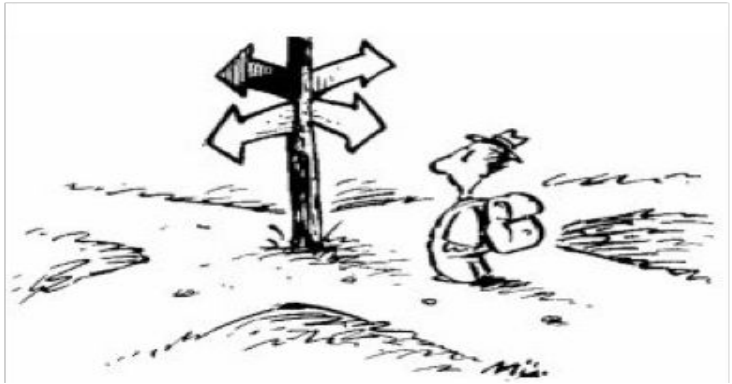
Summary

- During **high intensity/pile-up pp** run periods:
  - Take data with **CT-PPS**: probe mass acceptance interval 100 GeV - 2 TeV or higher
    ⇒ Requires special optics and settings: to be explored, provided it is not disruptive with normal pp running

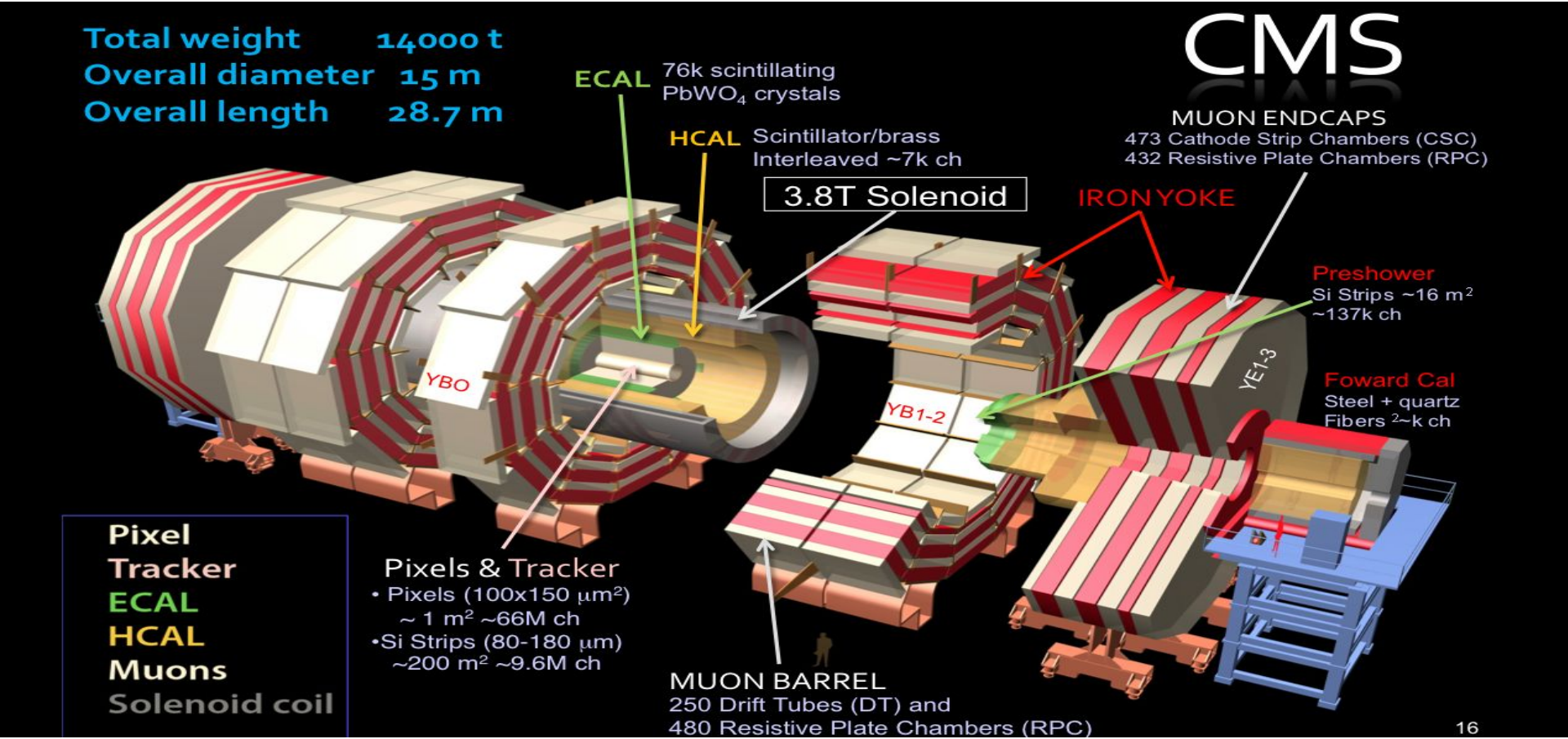
- Continue **VdM scan + mini ramp-up** low pile-up data taking

- Special **dedicated low pile-up run would** significantly extend forward physics programme:
  - study forward QCD physics:
    (diffractive, exclusive, multi-jet, high multiplicity topologies etc...)
  - 2017: collect 25 to 50 /pb at PU ~1 with no special optic conditions, somewhere in 2017 after commissioning phase, assuming minimal impact on high pileup pp running

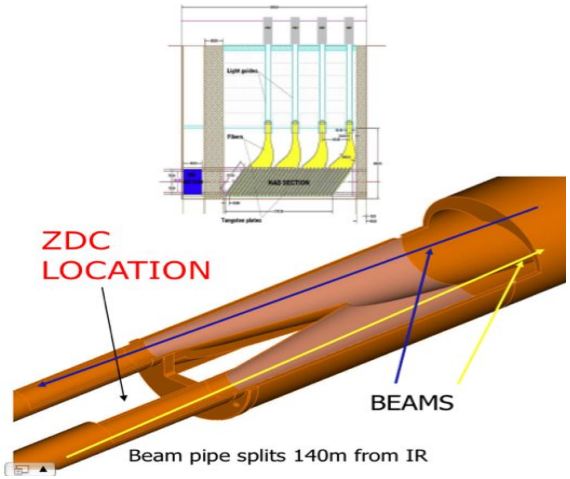
Extras...



The CMS Detector

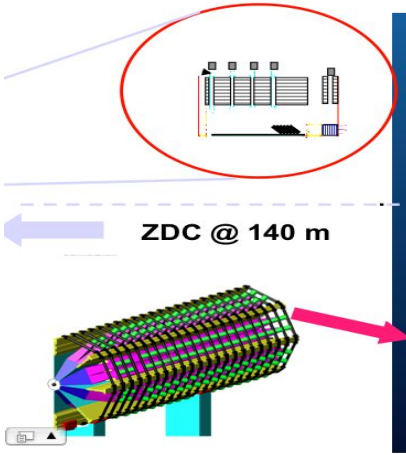


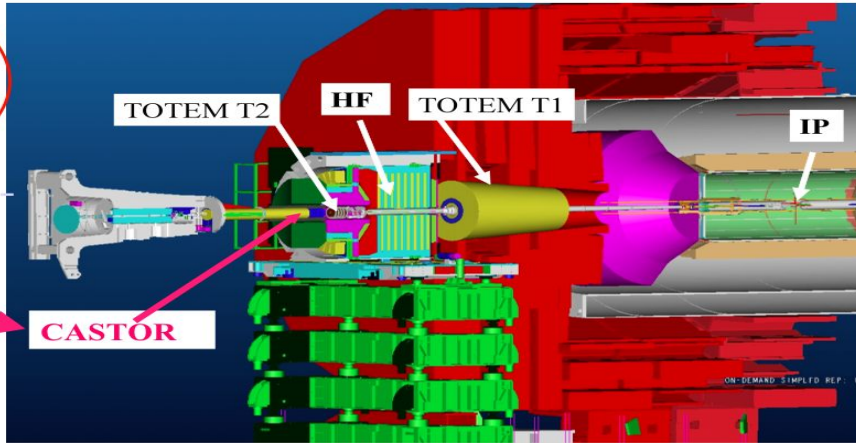
Forward detectors in CMS

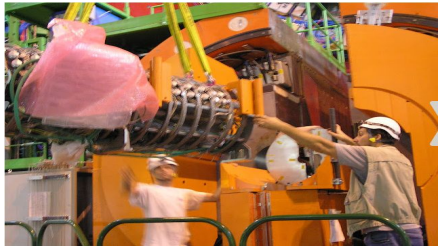


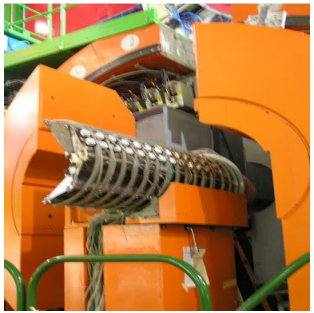
T1 3.1< η <4.7
T2 5.3<η <6.7
Castor 5.25<η <6.5

Extend the reach in η from |η|<5
to |η| <6.7
+ neutral energy at zero degrees







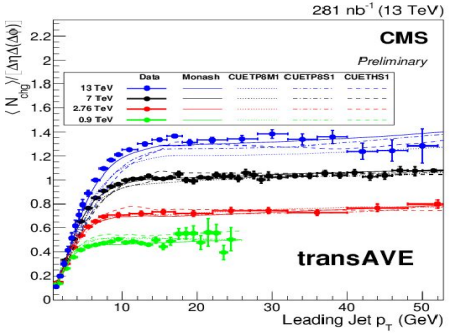


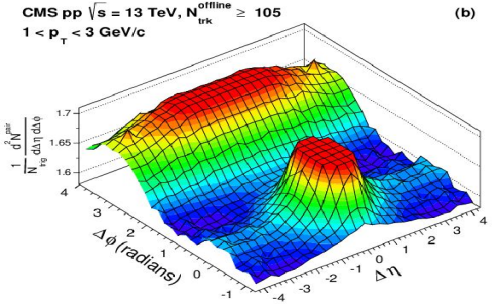
Coverage: down to η= 6.6 and
neutral particles to zero degrees

Scenario 1:
Nominal conditions for high pile-up pp running

❑ VdM and mini ramp-up physics studies (some…) :

➢ Physics studies that typically will benefit from data collected during VdM scans and/or mini ramp-ups





Minimum-bias
(particle spectra, hadronization,,,…)

UE
(tracks, track-jets, full jets)

If sufficient statistics accumulated:
inclusive low-p_T jets

Particle multiplicities

Correlations
(2pc, BEC, …)

DPS studies

Possibilities for data collected during VdM scans (assuming CMS+TOTEM)

CMS-TOTEM charged multiplicity at √s=13TeV (important extension on our previous measurements)

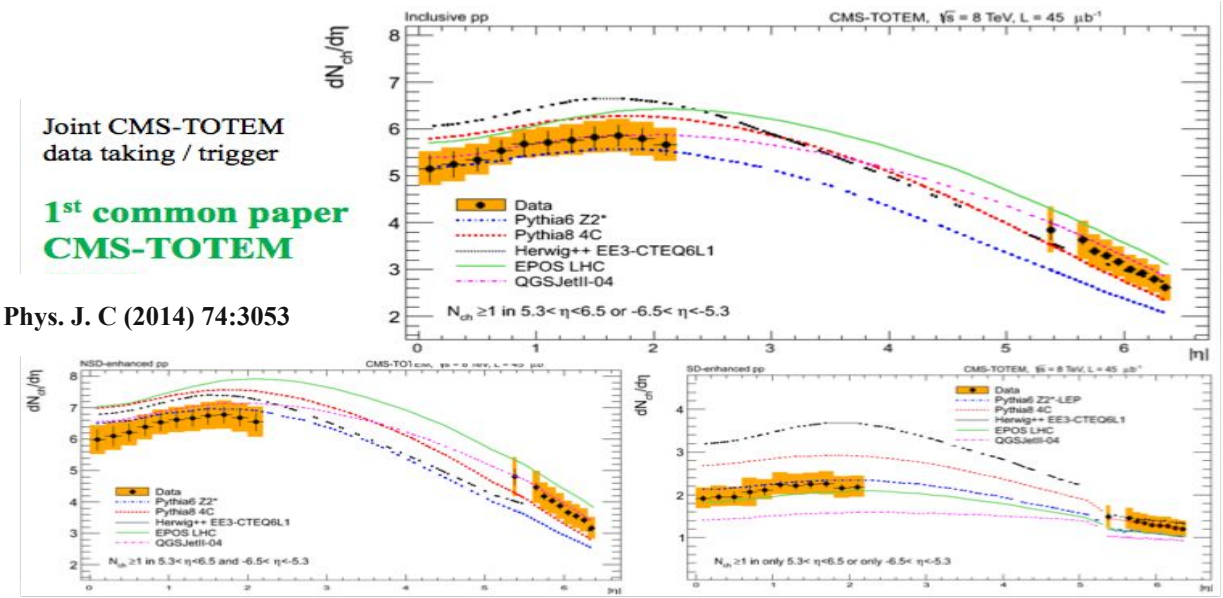
Event selection is considerably improved with forward triggers.

Particle density at high η needed to improve understanding/modeling of diffraction

Joint CMS-TOTEM
data taking / trigger

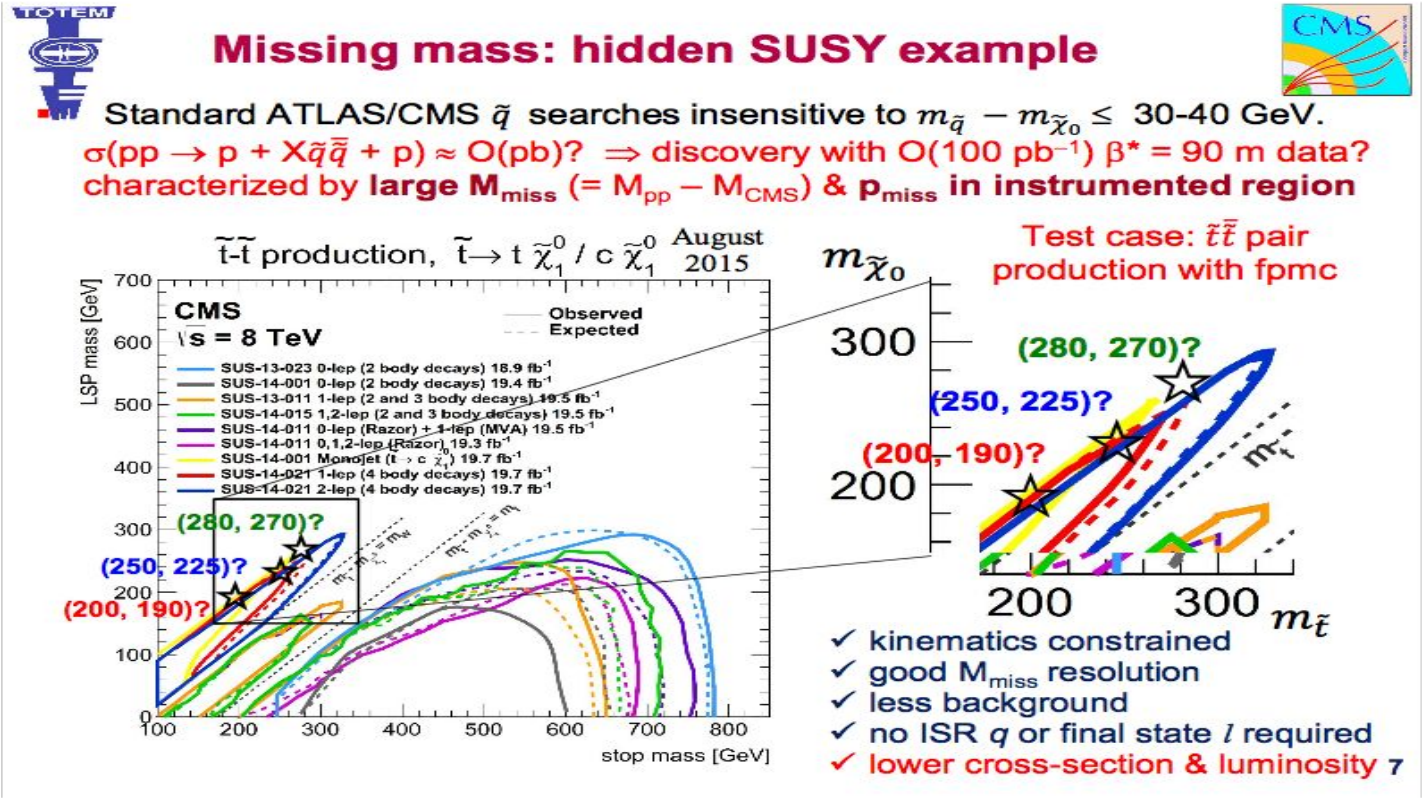
1st common paper
CMS-TOTEM

Eur. Phys. J. C (2014) 74:3053



Possibilities for data collected during special runs - beta=90m*

(assuming we collect ~50-100 pb-1)



https://indico.cern.ch/event/450914/contribution/15/attachments/1165717/1680487/KO_susy_CMS_PAG_oct15.pdf