First CMS results at 13.6 TeV

Detector performance and measurements with 2022 data
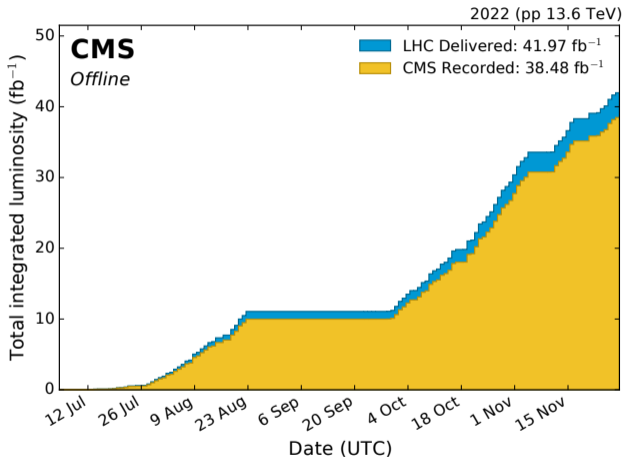
Joscha Knolle
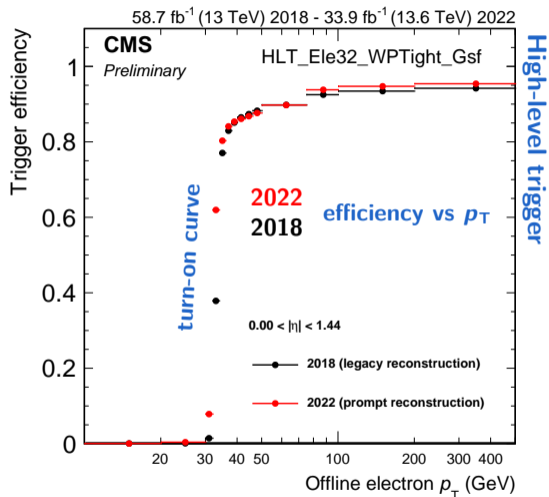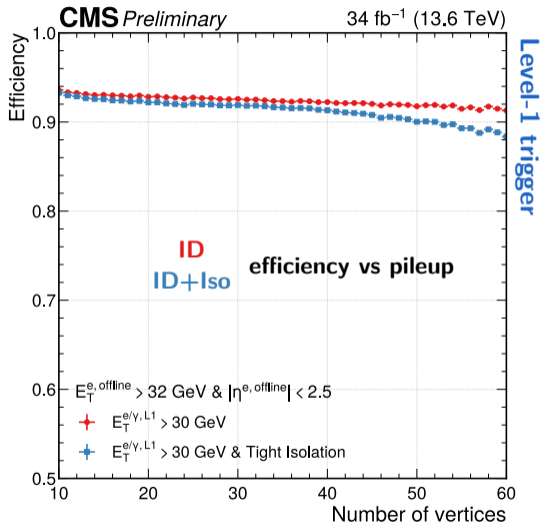on behalf of the CMS Collaboration

Introduction

- 2022 pp @ 13.6 TeV
  - delivered 42.0 fb^{-1}
  - recorded 92%
  - certified 89%
  - ⇒ excellent start of Run-3!

- this talk:
  - electron trigger
  - jet energy scale
  - muon tracking
  - luminosity
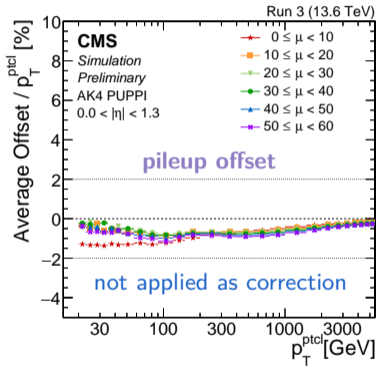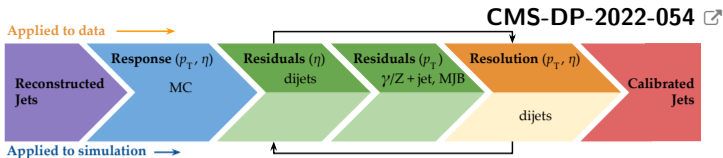 - $t\bar{t}$ cross section

2022 (pp 13.6 TeV)

CMS
Offline

LHC Delivered: 41.97 fb^{-1}
CMS Recorded: 38.48 fb^{-1}
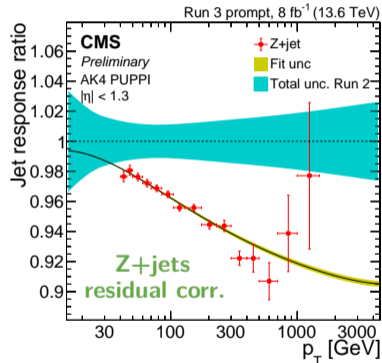
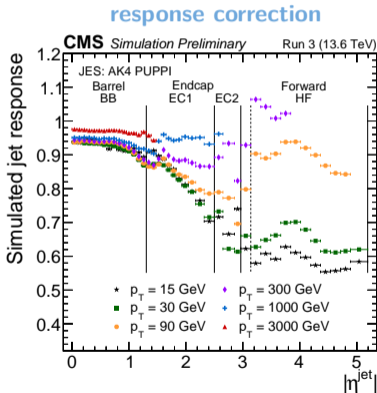Total integrated luminosity (fb^{-1})

Date (UTC)

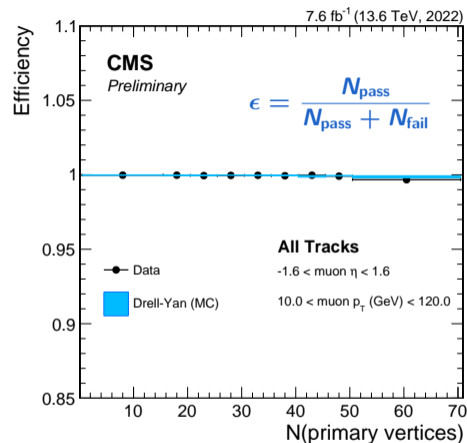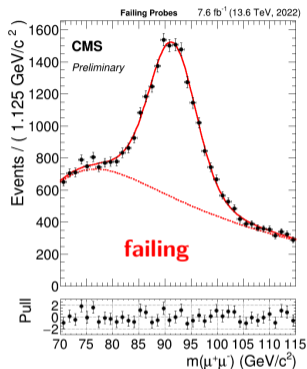# Electron trigger performance

Jet energy calibration

AK4 PUPPI jets

⇒ much larger for CHS!

response correction

⇒ mismatch from
HB scale shift

# Muon tracking performance: tag & probe

- **tag muon**: tight ID, $p_T > 27$ GeV, trigered
- **probe muon**: good muon track, $|\eta| < 1.6$
- **passing**: matched to track with $p_T > 10$ GeV
- events with OS T&P muons, $70 < m_{\mu\mu} < 115$ GeV, data until 23 Aug 2022, MC reweighted to match N_{vtx}

$$\epsilon = \frac{N_{pass}}{N_{pass} + N_{fail}}$$
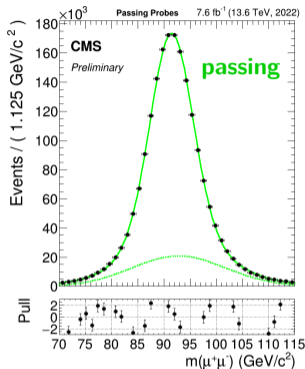
⇒ excellent efficiency vs pileup

Z counting: setup

- $Z \to \mu\mu$ rate measurement in intervals of $20 \, \text{pb}^{-1}$ $\Rightarrow$ luminosity measurement!
- in-situ tag-&-probe measurement of efficiencies: HLT, tracking, reconstruction, ID
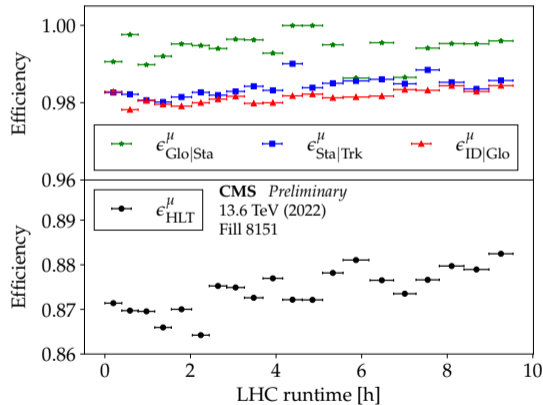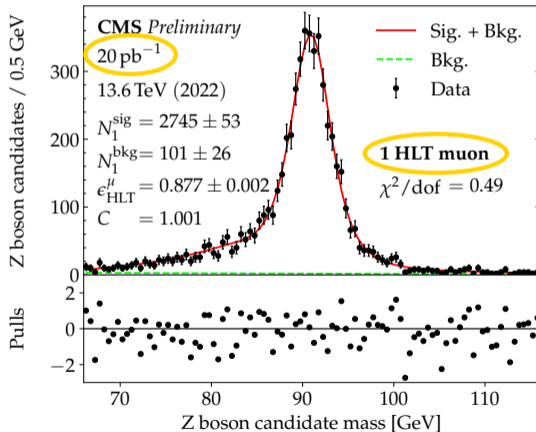
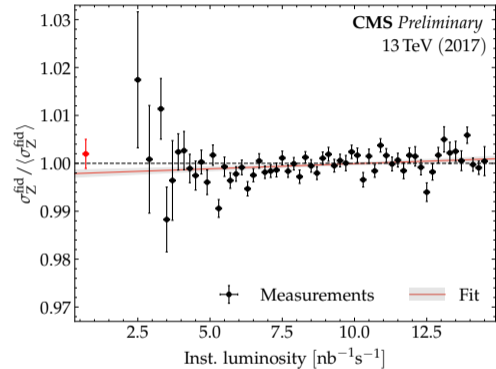# Z counting: validation @ 13 TeV

- performed with 2017 data
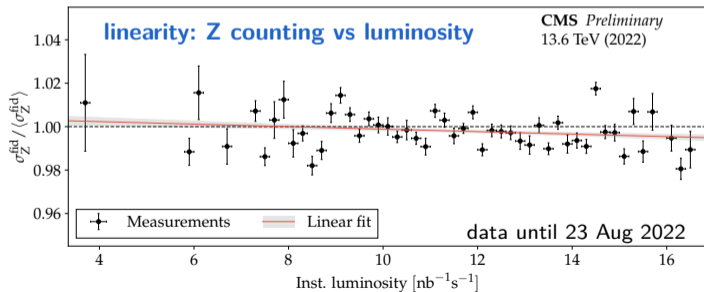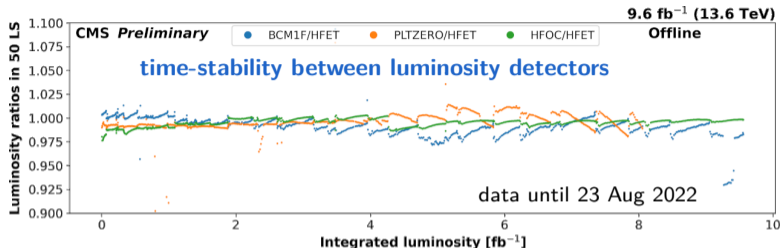- first complete estimate of systematic uncertainties
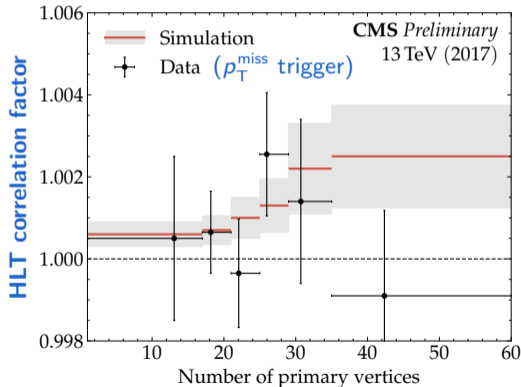
linearity: Z counting vs luminosity

- use low-pileup data for normalization
  ⇒ results in backup

Luminosity measurement

- multiple independent luminosity detectors
- initial calibration with emittance scans ($\pm 6\%$)
- interim results VdM calibration: $\pm 2.3\%$

CMS *Preliminary* — 9.6 fb^{-1} (13.6 TeV) Offline
BCM1F/HFET · PLTZERO/HFET · HFOC/HFET
time-stability between luminosity detectors
data until 23 Aug 2022

linearity: Z counting vs luminosity — CMS *Preliminary* 13.6 TeV (2022)
Measurements — Linear fit
data until 23 Aug 2022

- evaluate **linearity** and **time-stability** with Z counting comparison
- $\Rightarrow$ good agreement!

t̄t measurement: analysis setup
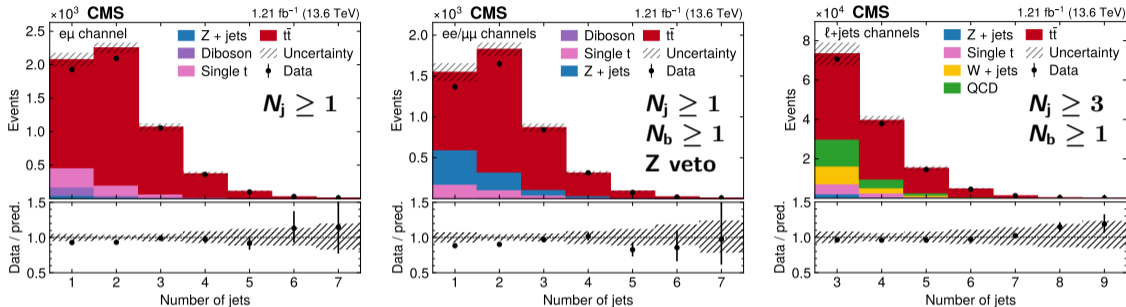
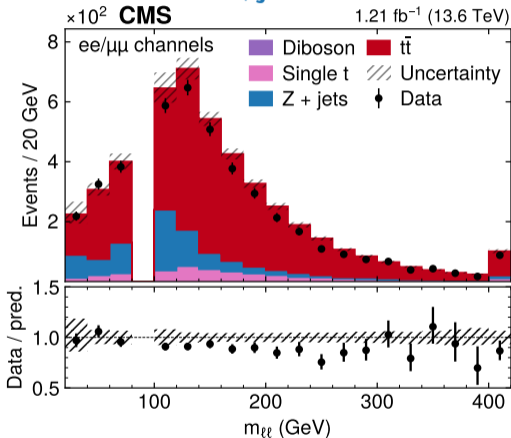- combined analysis: dilepton (eμ, ee, μμ) and lepton+jets (e+jets, μ+jets) channels
- event categories: lepton number & flavor, N_j, N_b
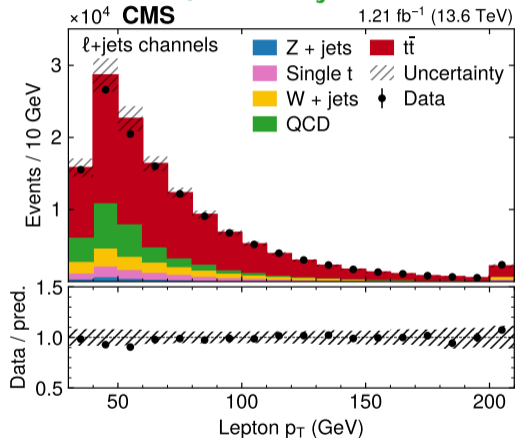- data from 27 Jul to 03 Aug 2022 ⟹ 1.21 fb^{-1}

t$\bar{\text{t}}$ measurement: background corrections

normalization from on-Z sideband   from sidebands with non-isolated ℓ / $N_j = 1$
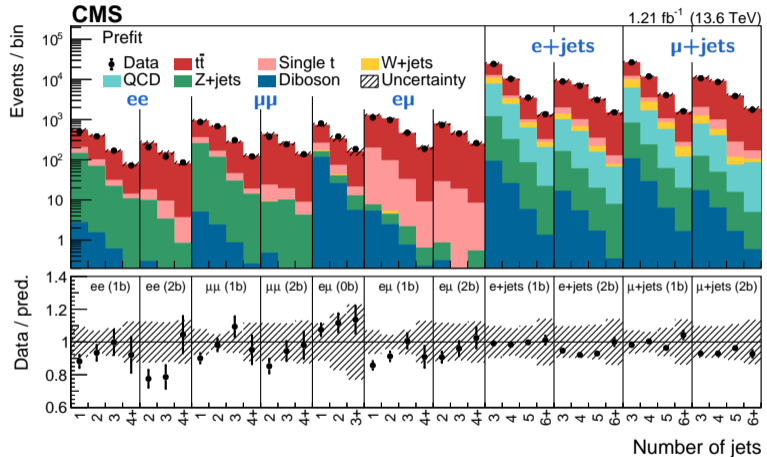
t̄t measurement: prefit

Lepton ID efficiencies

- with T&P from Z+jets events in bins of p_T, $|\eta|$
- extrapolation uncertainty
- cross-check: scale factors as free fit parameters
  $\Rightarrow$ agree within unc. (2%)

Jet energy calibration

- cross-check: scale factors from W mass fit in ℓ+jets

b tagging efficiencies

- free fit parameter
- constrained from using $N_b = 0$, 1, 2 categories

t̄t measurement: postfit

Source	Uncertainty (%)	
Lepton ID efficiencies	1.6	⬅
Trigger efficiency	0.3	
JES	0.7	
b tagging efficiency	1.1	⬅
Pileup reweighting	0.5	
ME scale, t̄t	0.6	
ME scale, backgrounds	0.1	
ME/PS matching	0.1	
PS scales	0.3	
PDF and α_S	0.3	
Single t background	1.0	
Z+jets background	0.3	
W+jets background	0.0	
Diboson background	0.5	
QCD multijet background	0.3	
Statistical uncertainty	0.5	
Combined uncertainty	2.6	
Integrated luminosity	2.3	⬅
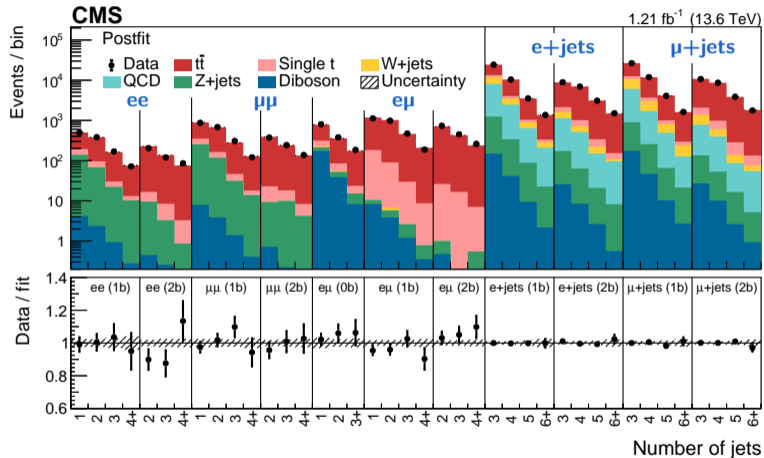
result: $\sigma_{t\bar{t}} = 882 \pm 23\,(\text{stat+syst}) \pm 20\,(\text{lumi})\,\text{pb}$

Summary

- successful start of Run-3 data taking

- jet energy calibration with PUPPI jets

- excellent tracking performance

- luminosity measurement: Z counting and interim VdM results

- first $t\bar{t}$ cross section measurement at 13.6 TeV
  - now available at arXiv:2303.10680 (submitted to JHEP) ⌐
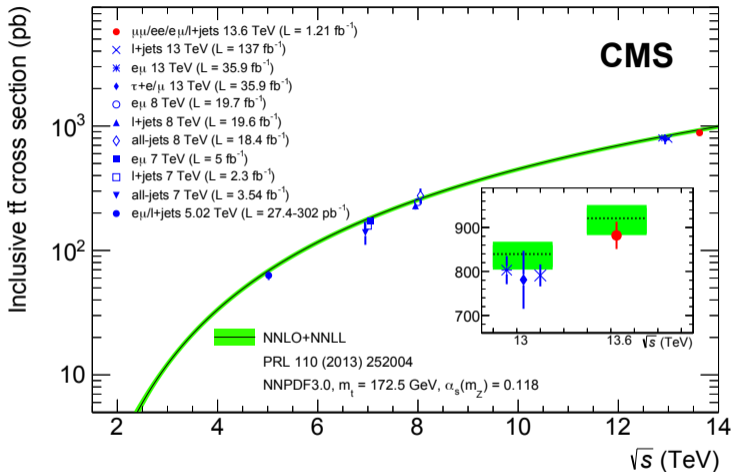
References

📄 CMS Collaboration, "First measurement of the top quark pair production cross section in proton-proton collisions at $\sqrt{s} = 13\,\text{TeV}$", arXiv:2303.10680 (submitted to JHEP). ↗

📄 CMS Collaboration, "Luminosity determination using Z boson production at the CMS experiment", CMS-PAS-LUM-21-001, CERN 2023. ↗

📄 CMS Collaboration, "BRIL luminosity performance plots: Cross-detector stability in early Run 3 data", CMS-DP-2022-038, CERN 2022. ↗

📄 CMS Collaboration, "CMS tracking performance in early Run-3 data using the tag-and-probe technique", CMS-DP-2022-046, CERN 2022. ↗

📄 CMS Collaboration, "Jet energy scale and resolution measurements using prompt Run 3 data collected by CMS in the first months of 2022 at 13.6 TeV", CMS-DP-2022-054, CERN 2022. ↗

📄 CMS Collaboration, "Luminosity monitoring with Z counting in early 2022 data", CMS-DP-2023-003, CERN 2023. ↗

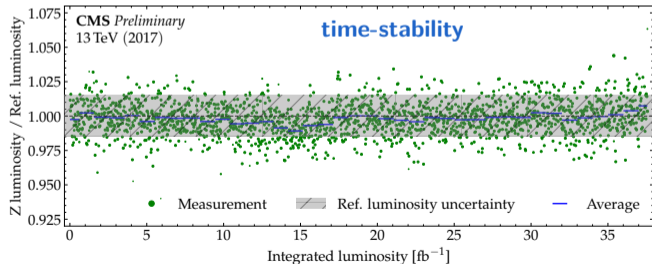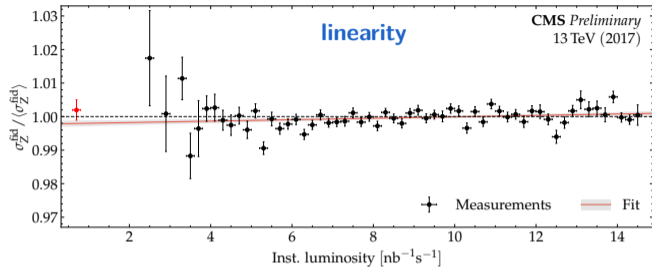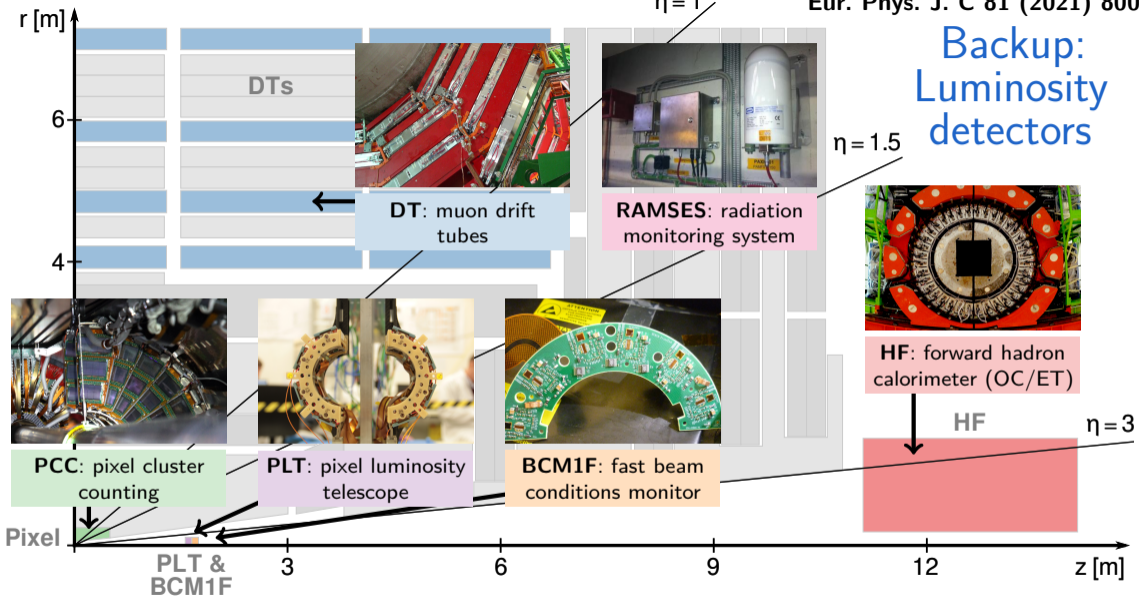# Backup: Luminosity comparison Run 2 vs Run 3
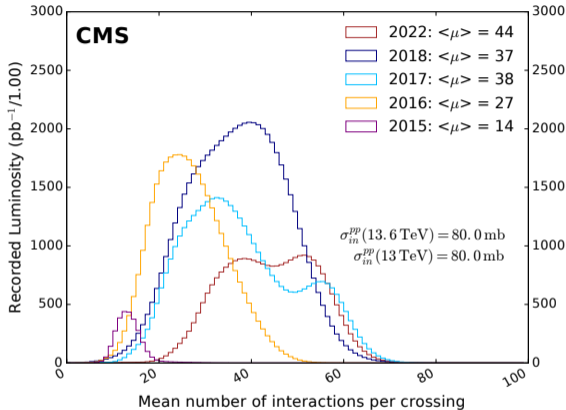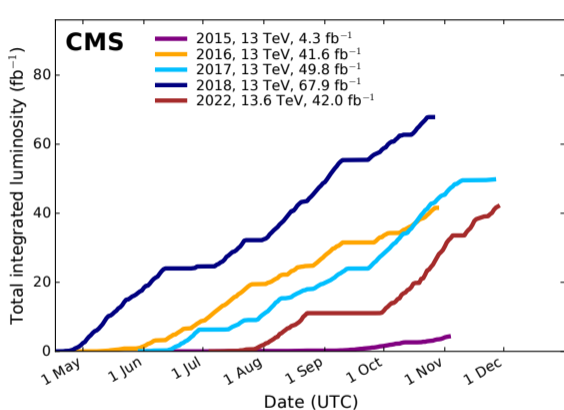
Backup: Z counting: 2017 results

	$\delta\left(N^Z_{\text{highPU}}/N^Z_{\text{lowPU}}\right)$ [%]
HLT correlation C_{HLT}	± 0.02
Dimuon correlation C_{ID}	± 0.01
Inner-outer track correlation $c_{\text{T\&P}}$	± 0.01
Inner track resolution	∓ 0.15
Outer track resolution	∓ 0.01
L1 muon prefiring	0
ECAL prefiring	∓ 0.10
Signal modeling up	$+0.19$
Signal modeling down	-0.21
Background modeling up	$+0.16$
Background modeling down	-0.04
Systematic up	$+0.31$
Systematic down	-0.28
Statistical	± 0.29
Total up	$+0.42$
Total down	-0.40

⇒ total integration uncertainty!

Backup: Luminosity detectors

η = 1

η = 1.5

η = 3

r [m]

DTs

DT: muon drift tubes

RAMSES: radiation monitoring system

HF: forward hadron calorimeter (OC/ET)

HF

PCC: pixel cluster counting

PLT: pixel luminosity telescope

BCM1F: fast beam conditions monitor

Pixel

PLT & BCM1F

z [m]

Backup: Luminosity calibration data

LHC beam positions   Fill 8381 (pp 13.60 TeV)

Legend:
- Beam 1 (x)
- Beam 1 (y)
- Beam 2 (x)
- Beam 2 (y)

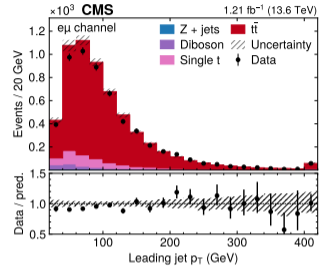y-axis: Nominal beam position [µm]

x-axis: Time [h]
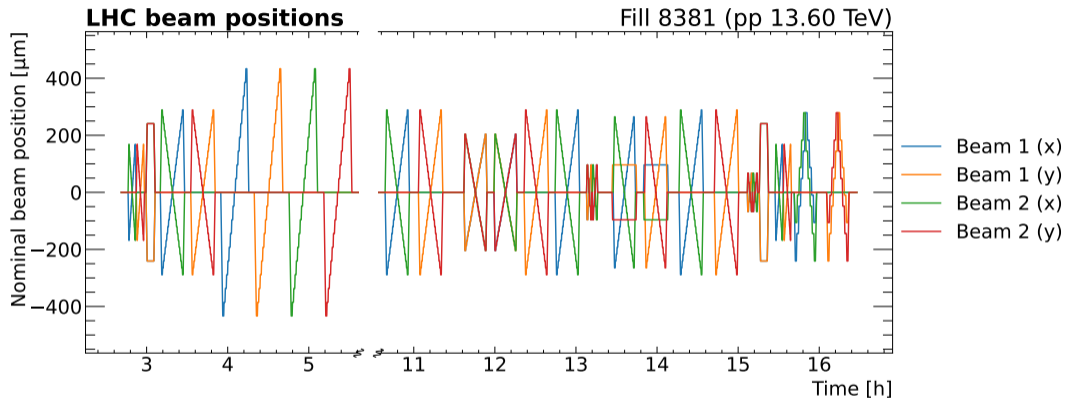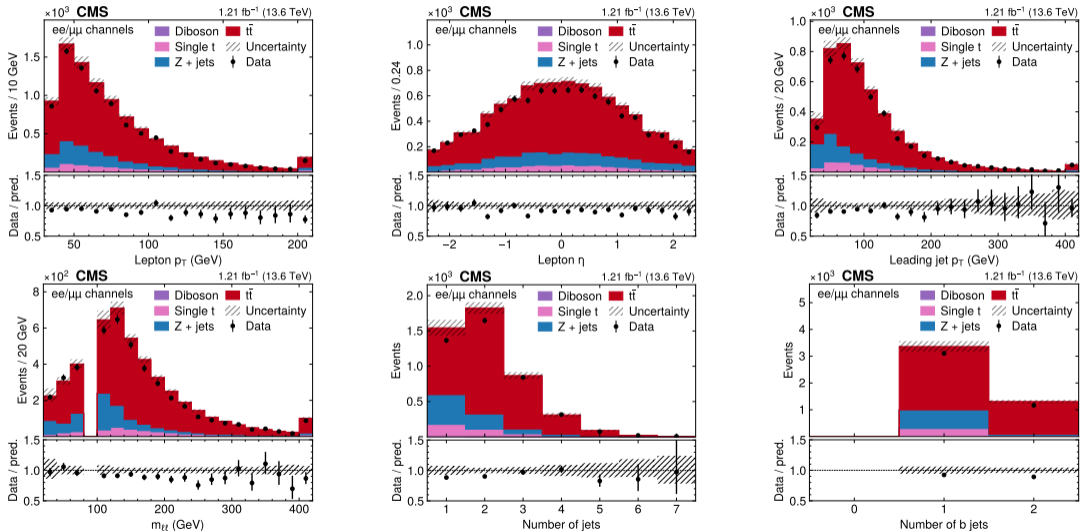
Backup: t$\bar{\text{t}}$ measurement: cross section result

$$\sigma_{\text{t}\bar{\text{t}}} = 882 \pm 23\,(\text{stat+syst}) \pm 20\,(\text{lumi})\,\text{pb}$$

$$\sigma_{\text{t}\bar{\text{t}}}^{\text{C\&C}} = 888 \pm 34\,(\text{stat+syst}) \pm 20\,(\text{lumi})\,\text{pb}$$

$$\sigma_{\text{t}\bar{\text{t}}}^{\text{SM}} = 921\,^{+29}_{-37}\,(\text{scale+PDF})\,\text{pb}$$

Backup: t t̄ measurement: eµ channel

Backup: t̄t measurement: ee & μμ channel

Backup: t t̄ measurement: e+jets & μ+jets channel