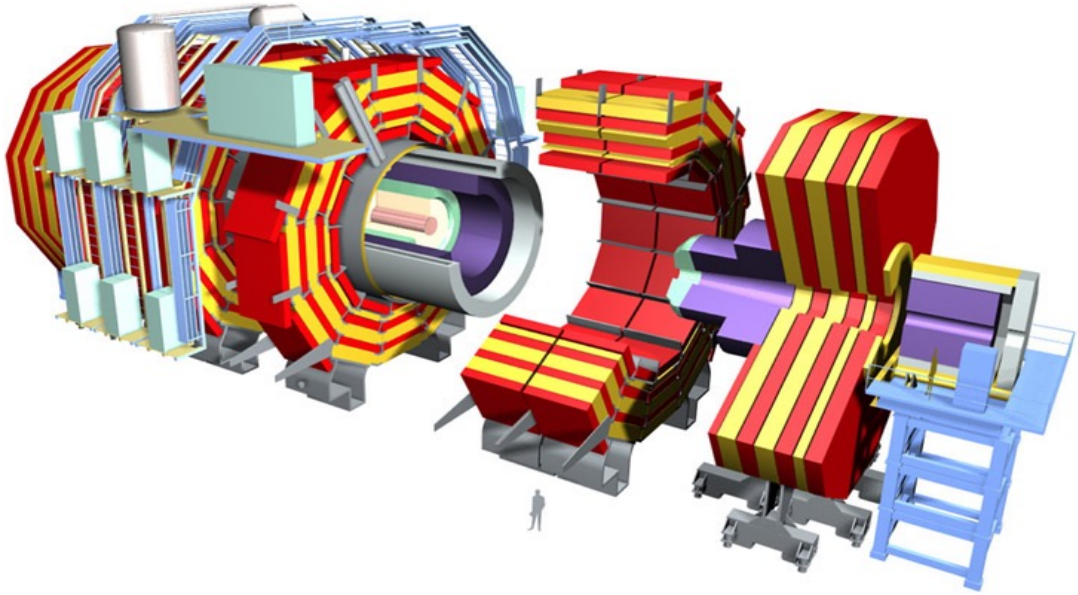
LHC and CMS @ DESY Status

- Report to the 82th Physics Research Committee



Alexis Kalogeropoulos
On behalf of the DESY-CMS group

82th PRC – Public Talk
Zeuthen,
20 October 2016

Talk outline

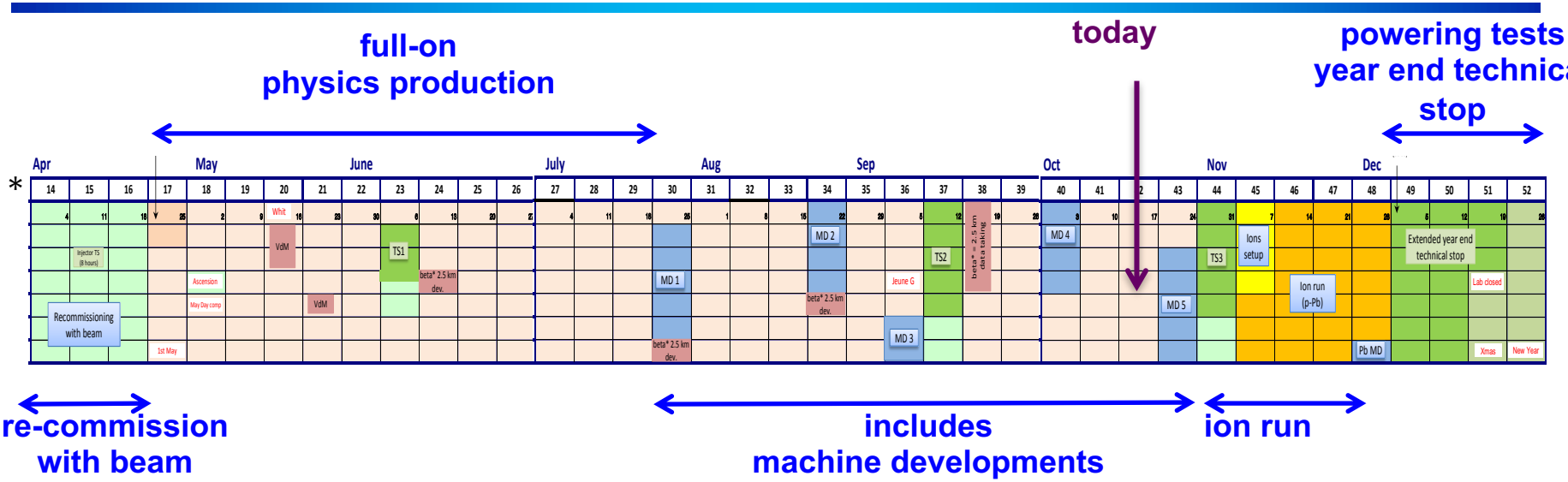
- LHC current status and plans
- News from CMS
- News from DESY – CMS

Upgrades
- Pixel
- Tracker

Operations/Components
- Computing

Physics Analysis
- SM - QCD
- TOP
- Higgs
- SUSY
- Open Data

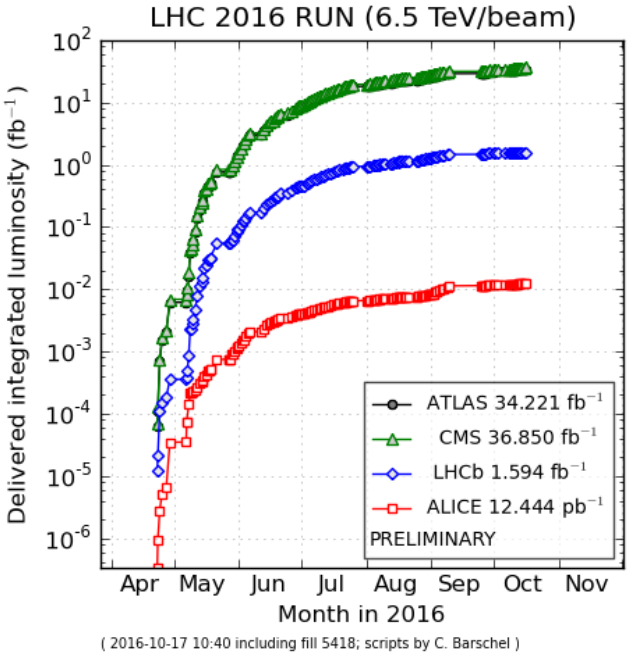
LHC – Status & Plans since last PRC



- ✓ Heading towards end of p-p physics run
  - Will be followed by ~4 weeks of Ion run (p-Pb)
  - Then Extended Year End Technical Stop (20 weeks)
- ✓ Planning for 40-45 fb^{-1}/year in 2017-18

LHC achieved its goal of design luminosity

Many thanks and congratulations to all involved!!



* legend

Technical Stop

Machine development

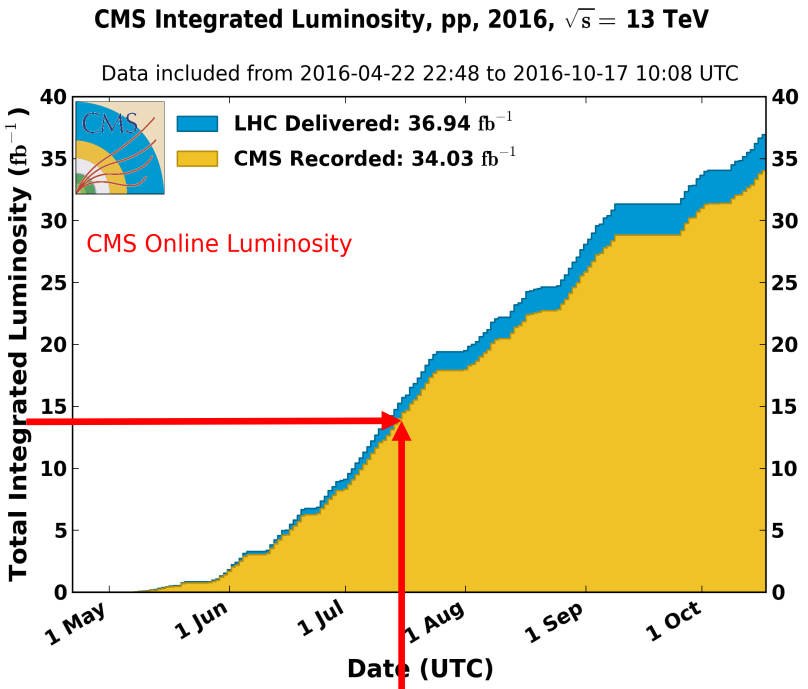
Recommissoning with beam

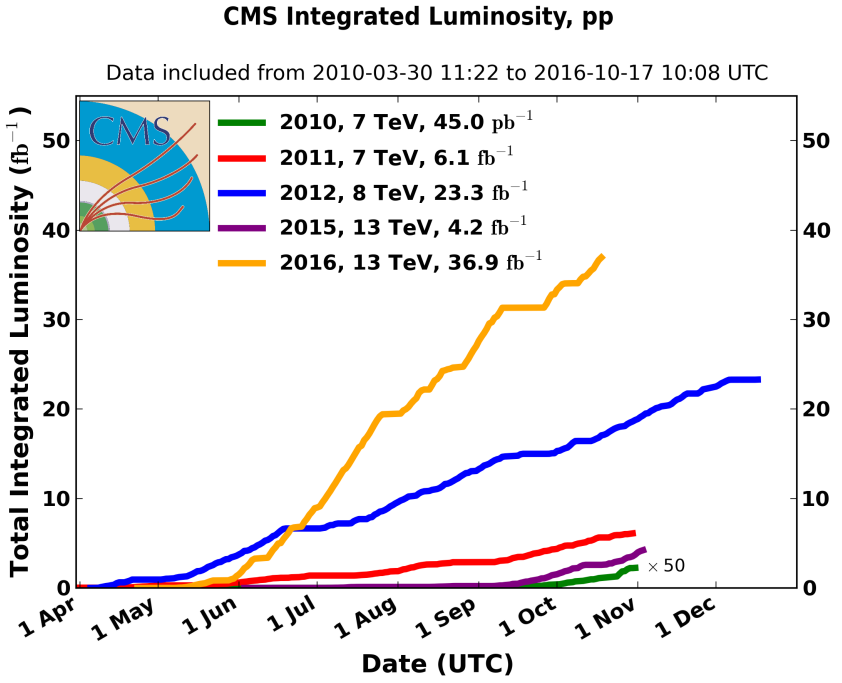
Special physics runs

Scrubbing

CMS status

https://twiki.cern.ch/twiki/bin/view/CMSPublic/LumiPublicResults





Summer Conferences dataset ~13/fb

- Already more than 34/fb of data : more than 28M $t\bar{t}$, 1.8M Higgs
  - ✓Efficiency of >92%
  - ✓Expect to reach ~40/fb until end of p-p physics run

Last year's cryogenic problems fully resolved!

Upgrades

- Pixel
- Tracker

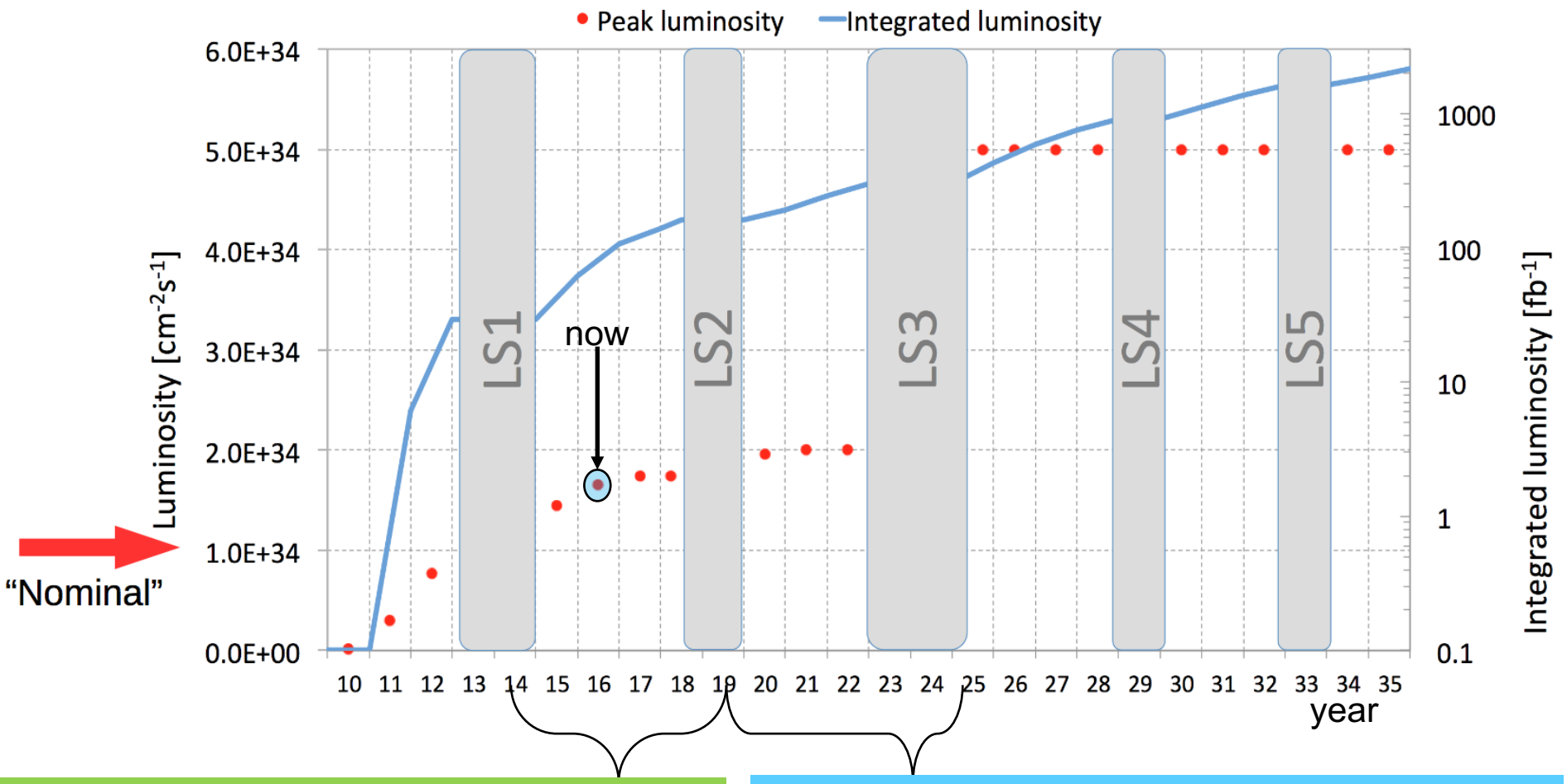
Operations/Components

- Computing

Physics Analysis

- SM - QCD
- TOP
- Higgs
- SUSY
- Open Data

Facing the Future : Upgrades



Phase I Upgrades

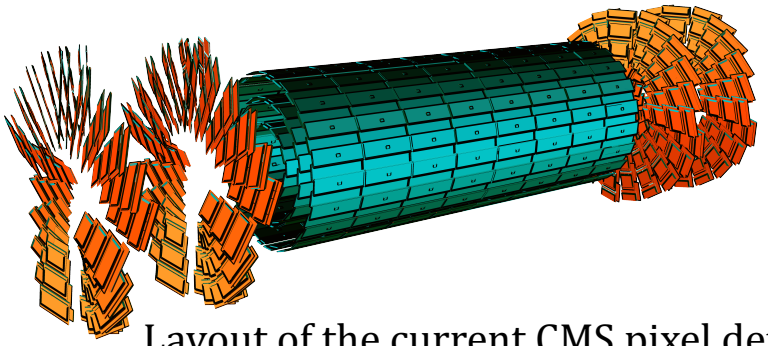
Targeted at 2X nominal PU and up to ~500/fb of Integrated luminosity

Phase II Upgrades

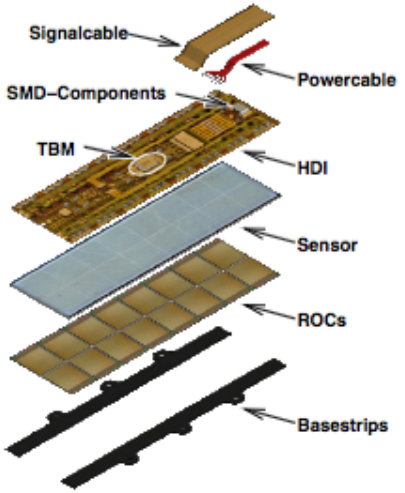
Targeted at 5-8X nominal PU and up to ~3000/fb of Integrated luminosity

Phase I Pixel Upgrades

- Present Pixel detector has performed very well during LHC RunI:
  - Resolution r-φ: 10 μm, z: 20-40 μm
  - Efficiency O (99%)
- After LHC restarts next year, Pixel needs to cope with :
  - ✓ Higher instantaneous luminosity ~$2x10^{34}$/ cm^2s
  - ✓ Higher occupancies
  - ✓ Higher fake rates at higher pileup
  - ✓ Radiation damage



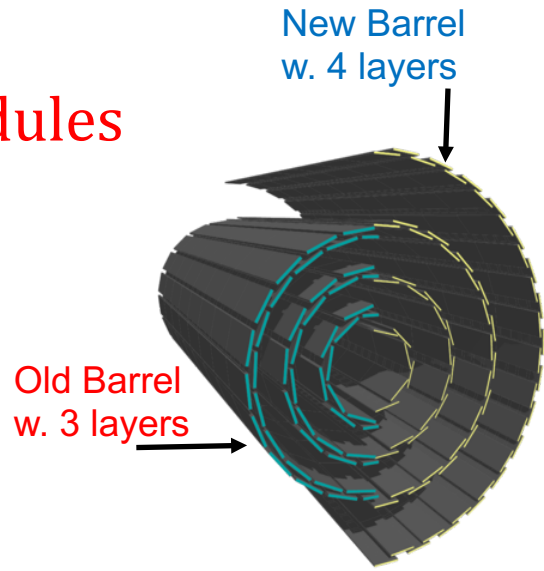
Layout of the current CMS pixel detector

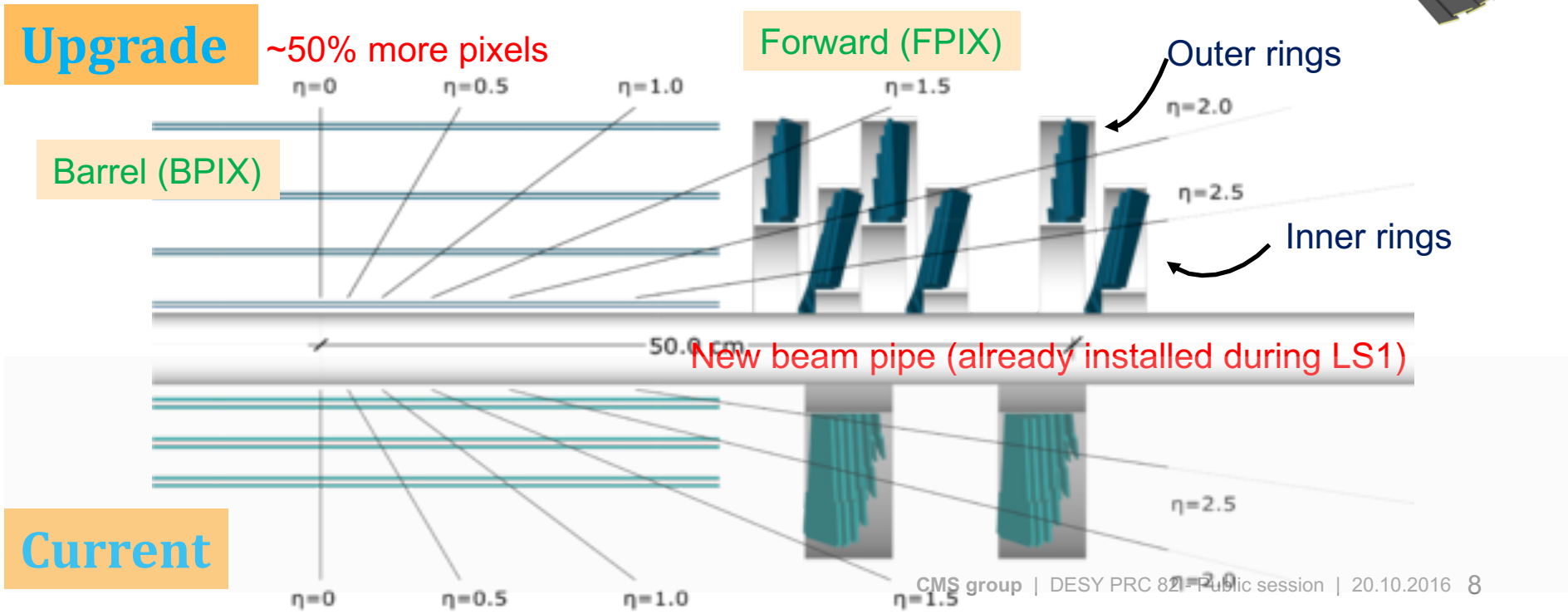


View of a barrel module

Phase I Pixel Upgrades

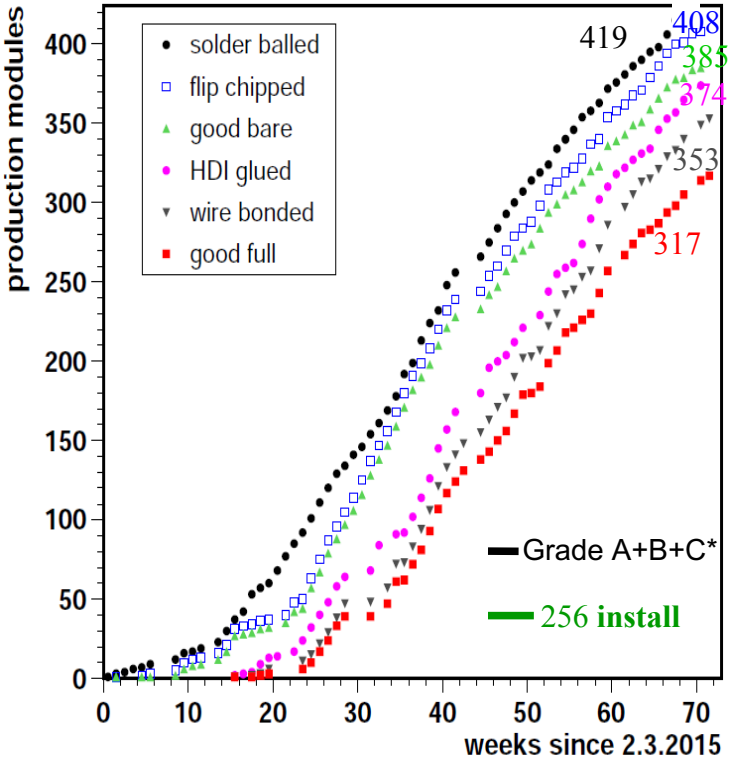
- Four barrel layers instead of current three
  - ✓ D-CMS is responsible for producing the modules of the 4th layer (half from DESY & UniHH)
- 3-disk forward system instead of current 2-disk
- Inner rings tilted for optimal resolution and efficiency
- 4-hit coverage up to $|\eta|<2.5$
- Reduced material budget, higher tracking efficiency





Pixel Module Production finished

- Pixel module production finished mid 2016
  - All Si sensors used up: 419
  - Placed 29.3 M solder balls
  - Flip chip bonded 6528 r.o. chips 94% yield
  - Made 224 k wire bonds, all good
  - Full calibration and high rate X-ray test

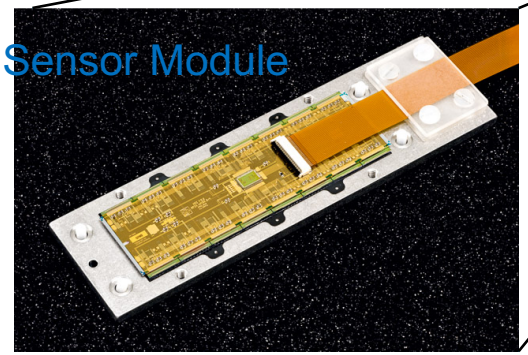


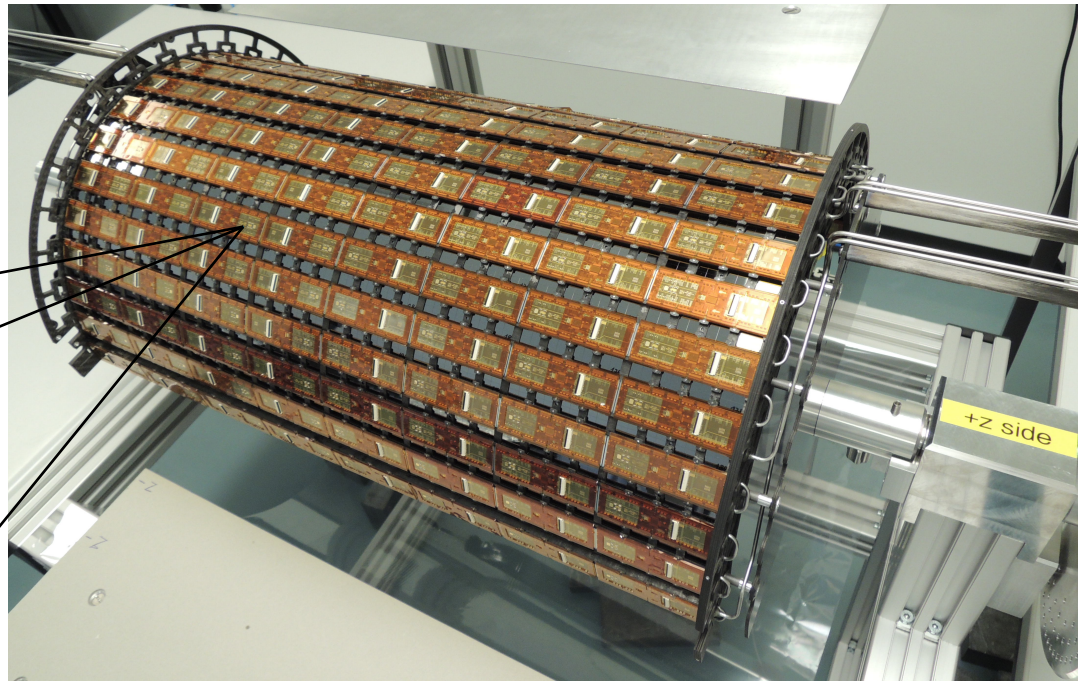
- Delivered 287 modules to PSI
  - Includes 12% spares
  - Module mounting at PSI

Phase 1 Upgrades : Pixel tracker

Barrel Pixel Layer 4 outer (+x) half shell already mounted with 256 DESY +UniHH modules at PSI.

- Facing modules are also done (last Monday).
- Cabling & testing this week.

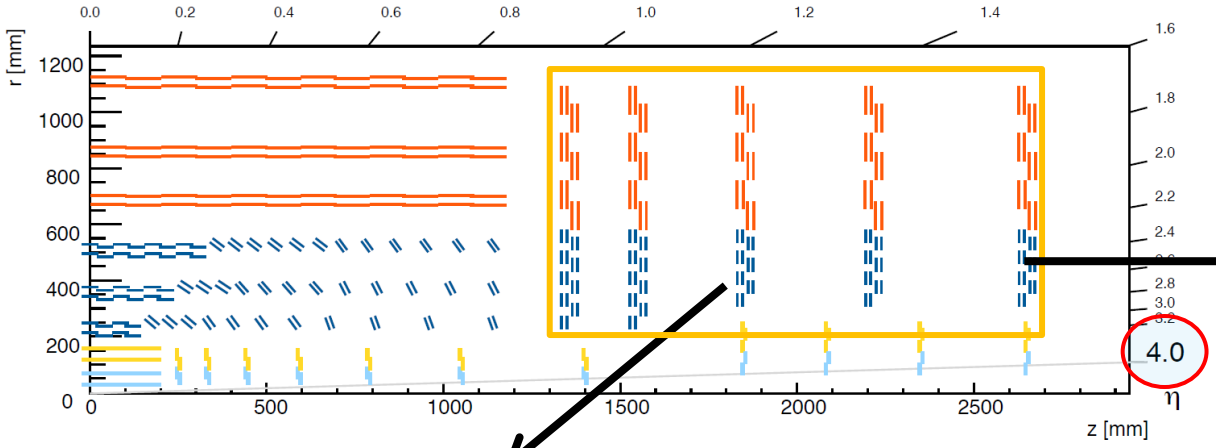




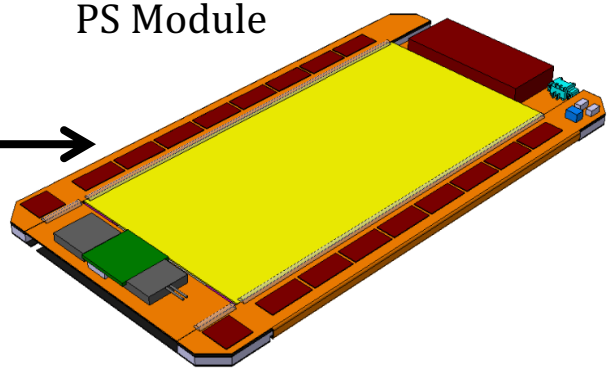
Phase II Tracker Upgrades

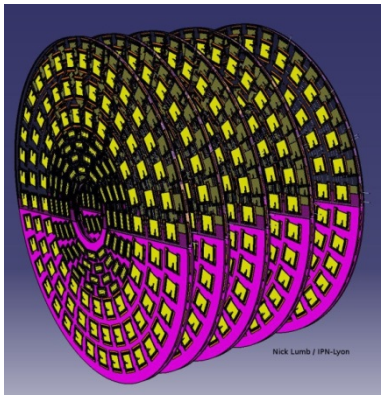
2025-35 : CMS gets a completely new Inner and Outer Tracker (HL-LHC era)

- Coverage up to |η|<4, 4-6X finer granularity, radiation tolerant, fast information to L1 trigger

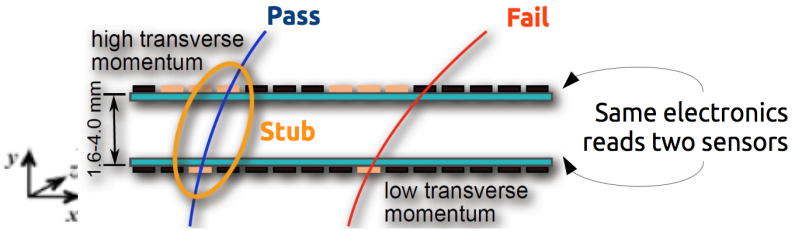


PS Module





6 barrel layers
2x5 Double Disks
2 Module types :
r < 60 cm: Pixel-Strip (PS)
r > 60 cm: 2Strip (2S)



Pt discrimination at detector level providing track information for L1 trigger

Endcap
Radius ~ 110 cm
Length ~ 140 cm

One Tracker Endcap Double Disk (TEDD) will be built by Aachen, KIT, DESY

Infrastructure for Tracker Upgrades

Common Infrastructure for module production and detector integration for ATLAS and CMS :
→ Detector Assembly Facility (DAF)

Project to build and operate DAF including necessary resources has been approved.

DAF will be realized in two existing buildings.

Module production in Bld. 25c

- Clean room ISO 6 ~ 250 m²
- Labs & Storage ~ 200 m²

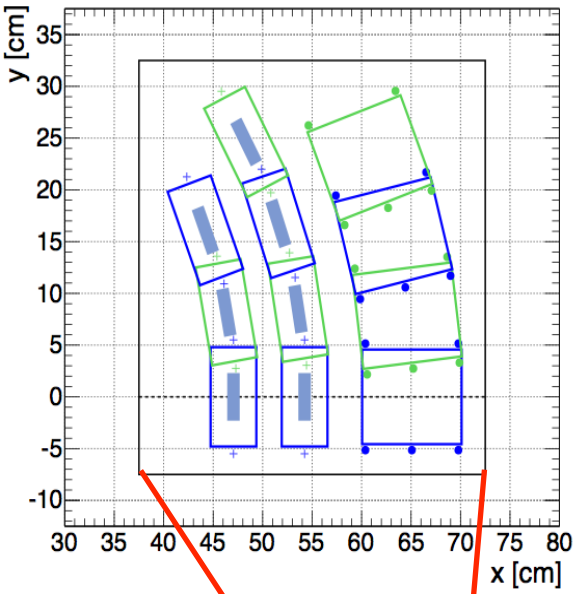
Construction has started in Bld. 25c

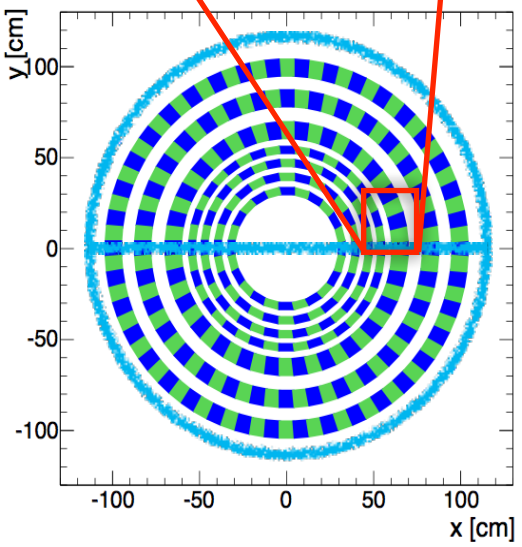
Module mounting and assembly in Bld. 26

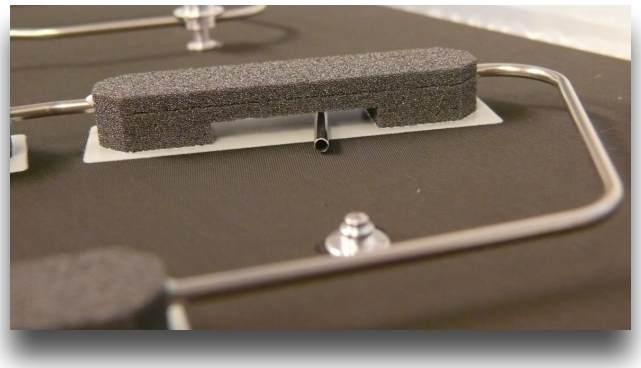
- Module mounting ~ 320 m² (ISO 7)
- End cap assembly ~ 420 m² (ISO 7)
- Technical rooms ~ 140 m²

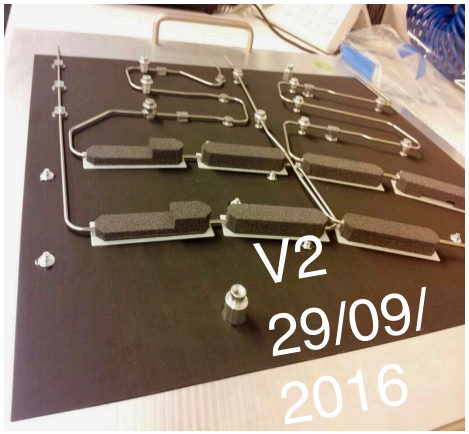
Tracker Endcap Double-Disk (TEDD) Dee Prototyping

- small (35 cm x 40 cm) part of a dee with all features
  - transition between PS and 2S regions
  - edge of dee
  - two small cooling sectors
- second version of dee :
  - with a few changes in the design compared to v1
  - geometrical precision expected to be within specs



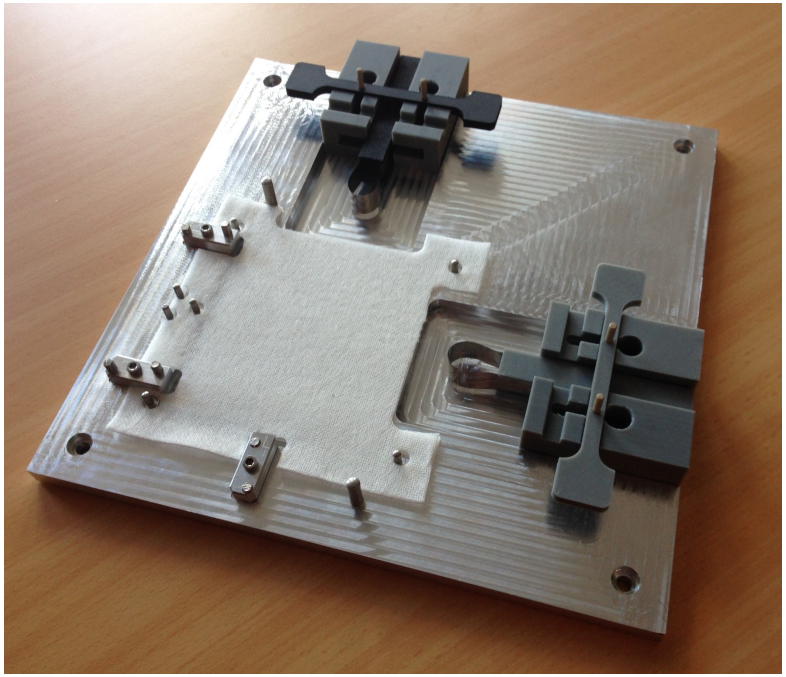






Jig-based Module Assembly

- assembly jigs are ready for first test assemblies
- dummy bridges made of standard Al are being machined at DESY
- glass dummy sensors are available
- first mechanical dummy expected in the next couple of months
  - sensor to sensor alignment will be measured at RWTH Aachen
- once precision assembly is established switch to real components (sensor and hybrids) and produce working 2S module



Upgrades

- Pixel
- Tracker

Operations/Components

- Computing

Physics Analysis

- SM - QCD
- TOP
- Higgs
- SUSY
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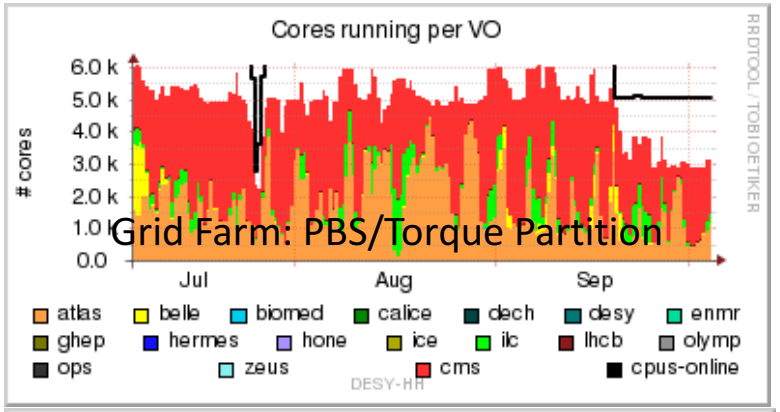
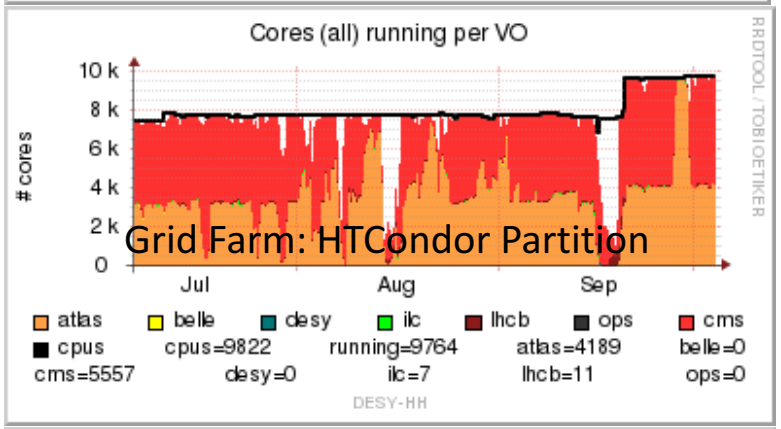
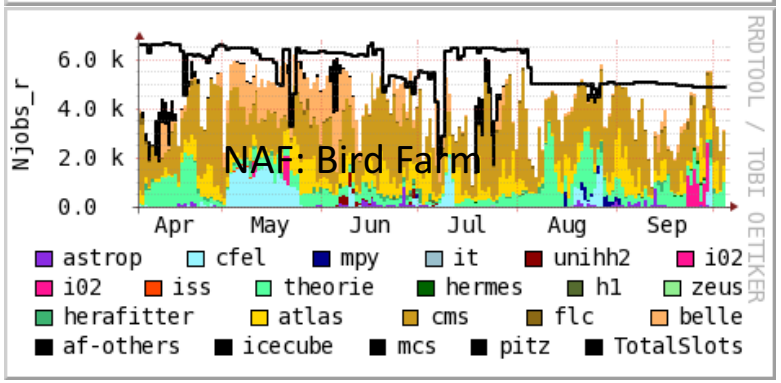
DESY Grid Center and National Analysis Facility (NAF)

- Resources well utilized by CMS users (NAF) and central teams
- HTCondor batch system
  - Grid resources migrating transparently from old to new HTCondor system
  - Pilot system for local submission in preparation
- NAF Storage system
  - New instance commissioned and successfully used during DAS school
  - CMS group will move to new system by end of October
  - Storage capacity doubles



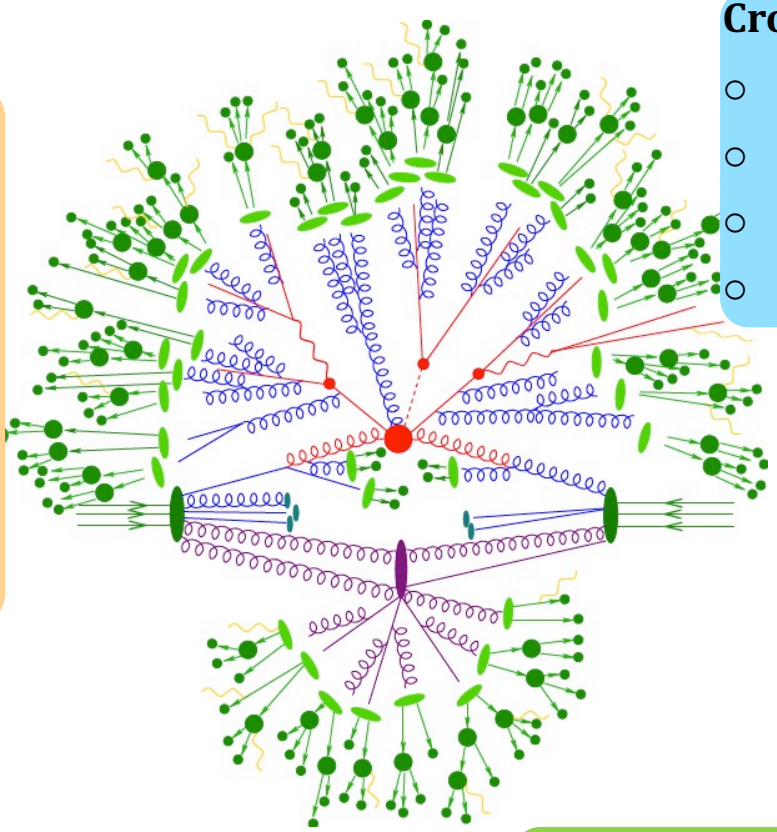




QCD Physics @ DESY

Physics topics:

- Parton Distributions
- Strong coupling
- Quark masses
- Multi-Parton Interactions
- Underlying Event
- Monte-Carlo Tuning



Cross section measurements

- Inclusive particle production
- Inclusive jet production
- Multi-jet production
- W+charm production

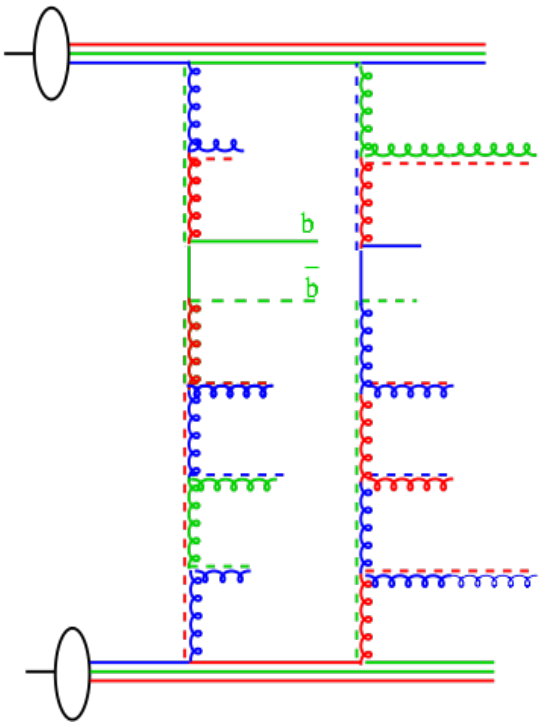
CMS coordination roles/convenorships:

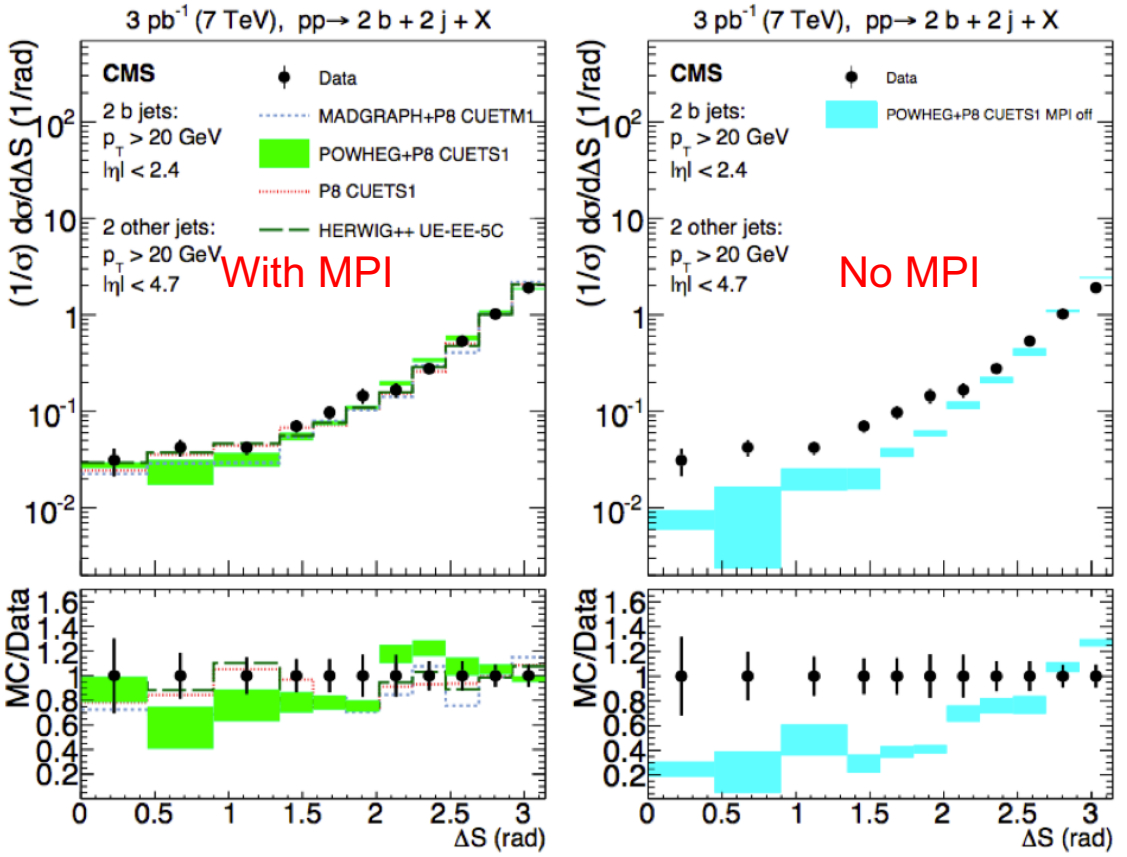
- Jet group convener
- Gen group (comparisons and tunes)
- LPCC (min. bias and underlying event)
- PDF forum

QCD Analysis : 2b + 2 jets

- study correlations of b-jets and other jets
- sensitive to Double Parton Scattering
  - ΔS : azimuthal angle between dijet pairs

FSQ-13-010, arXiv 1609.03489

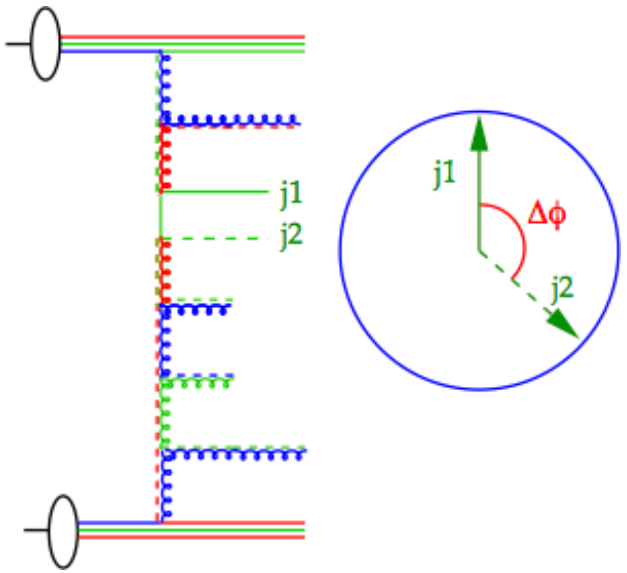


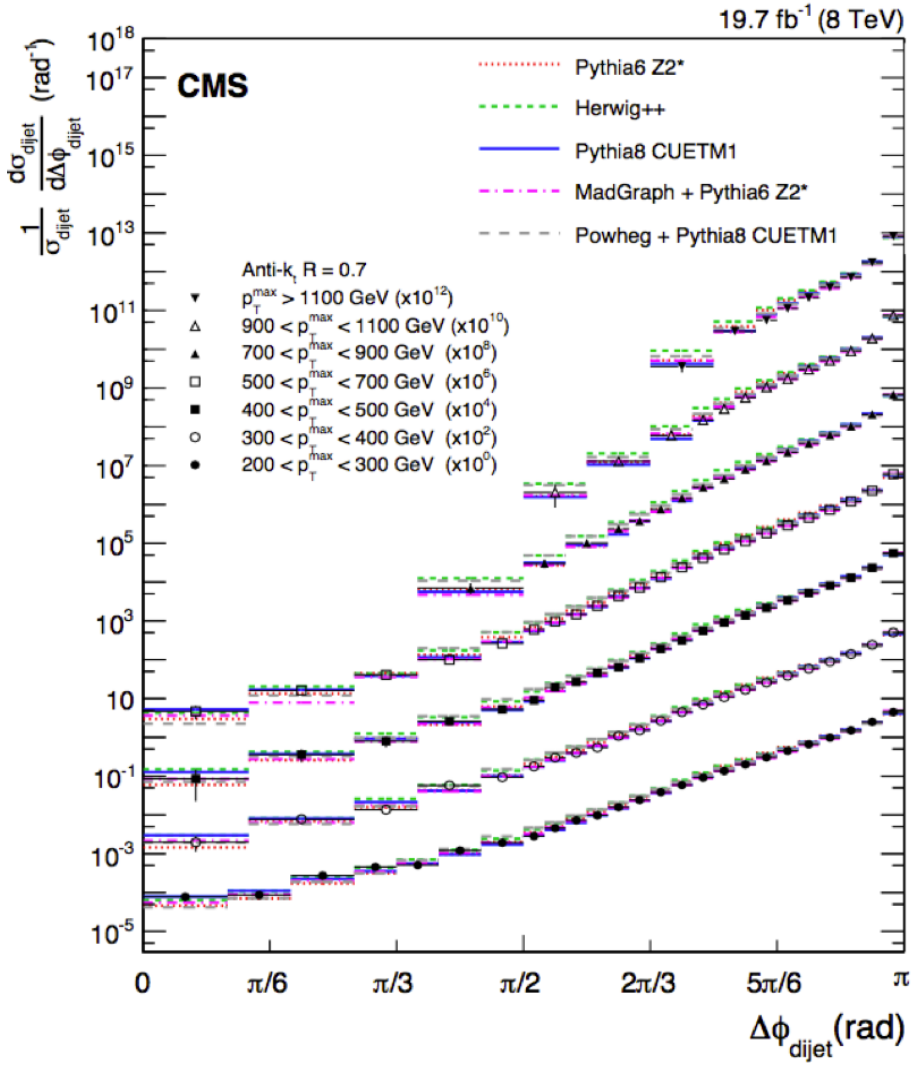


QCD Analysis : Azimuthal correlations

- Study azimuthal correlations in dijet events
- Sensitive to higher order contributions
- 8 TeV measurement released to EPJC
- DESY performs analysis at 13 TeV with full 2016 statistics

SMP-14-015, arXiv 1602.04384



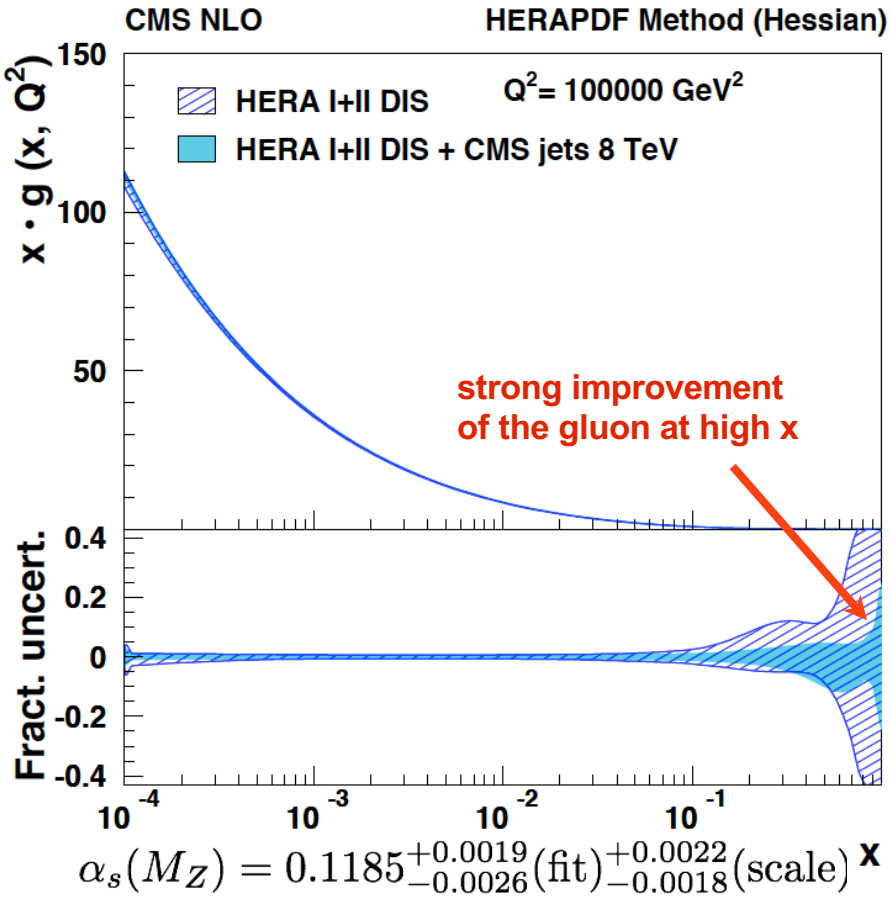


QCD Analysis : Inclusive jets

Measurement of inclusive jet cross sections, sensitive to PDFs and α_s (M_Z)

RunI

arXiv:1609.05331, submitted to EPJC

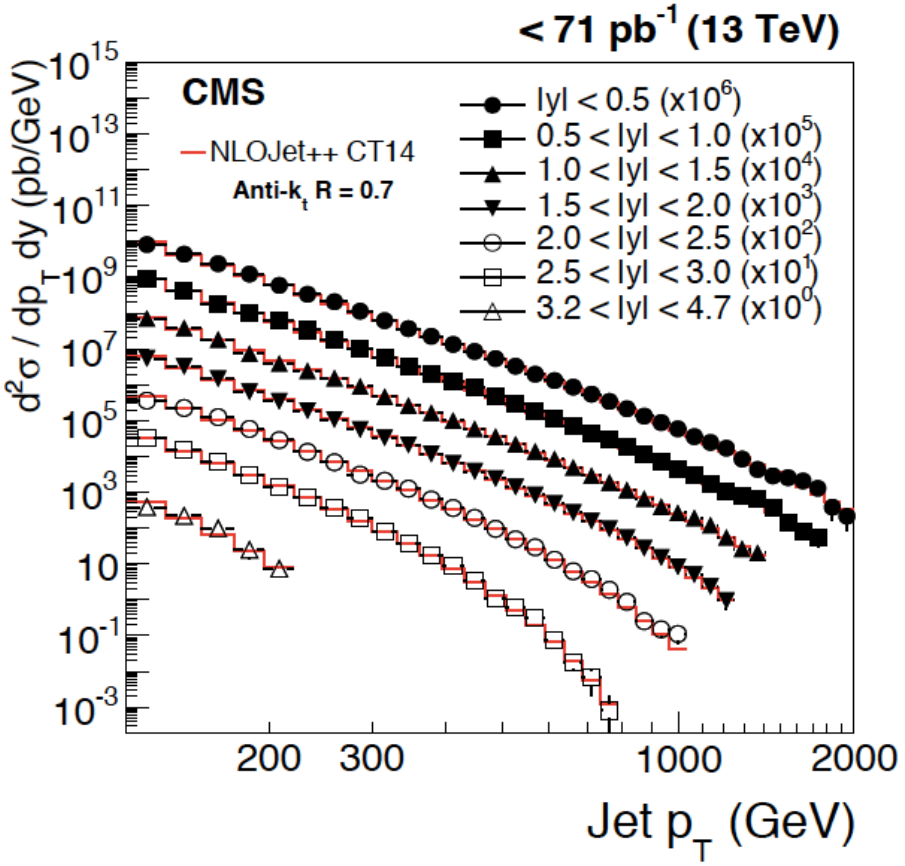


very good agreement with world average

RunII

First measurement published @13TeV

Eur. Phys.J. C76 (2016) no.76, 451



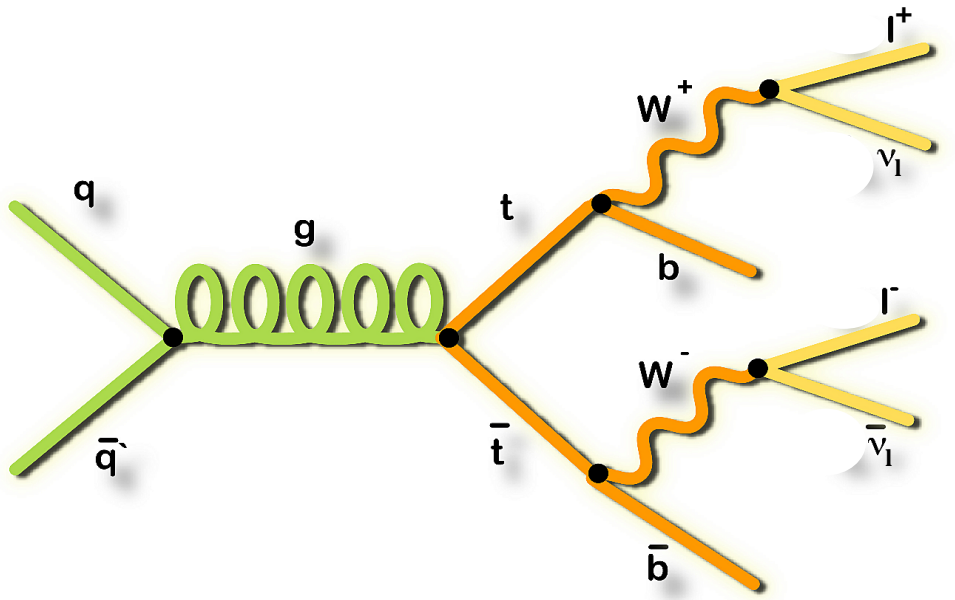
TOP Physics at DESY in 2016

Focus on dilepton channel

Cross sections:
- Inclusive xsec
- LHC combinations
- 1D & 2D differential
- tt+jets
- tt+H(bb)

BSM in tt

Top mass from tt cross sections



Technical contributions:
- MC validation for TOP
- Trigger & lepton efficiencies for several TOP & HIG analyses
- Jet charge tool
- Jet-parton assignment tool (GenHFHadronMatcher)

CMS coordination roles/convenorships:
- TOP cross sections group convener
- TOP mass group convener
- MC validation & integration convener
- Contacts in: GEN, MUO, EG, TRIG, LHCtopWG ttxsec combinations, TOP-HIG discussion forum

2D differential tt cross section at 8 TeV

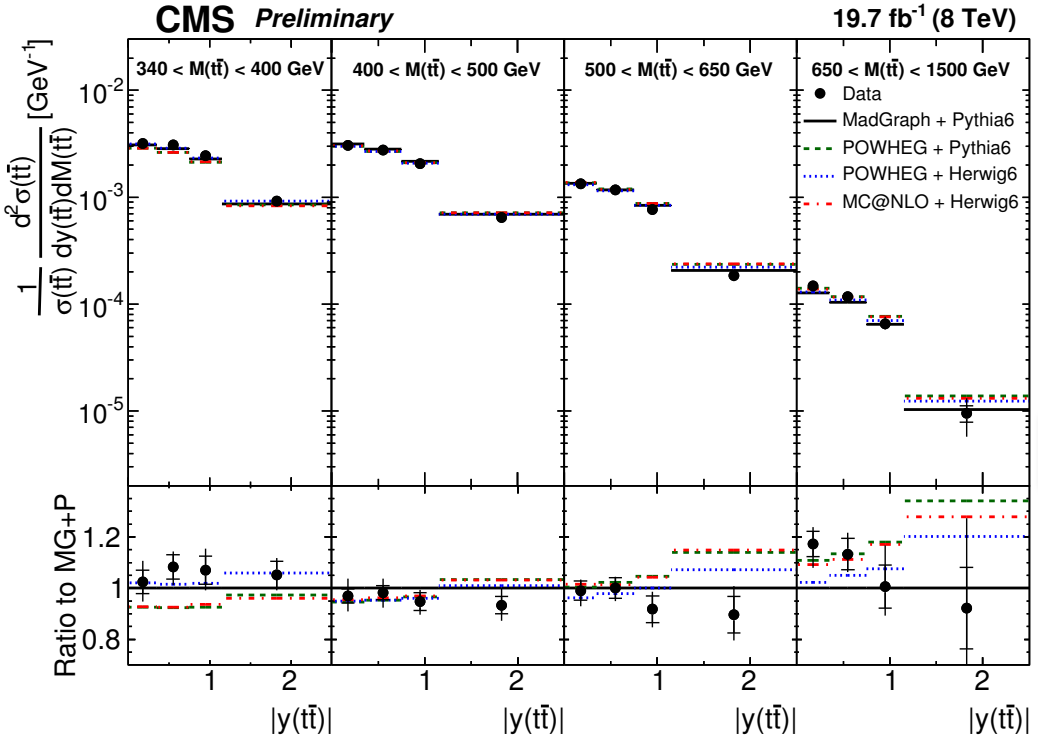
Aug'16

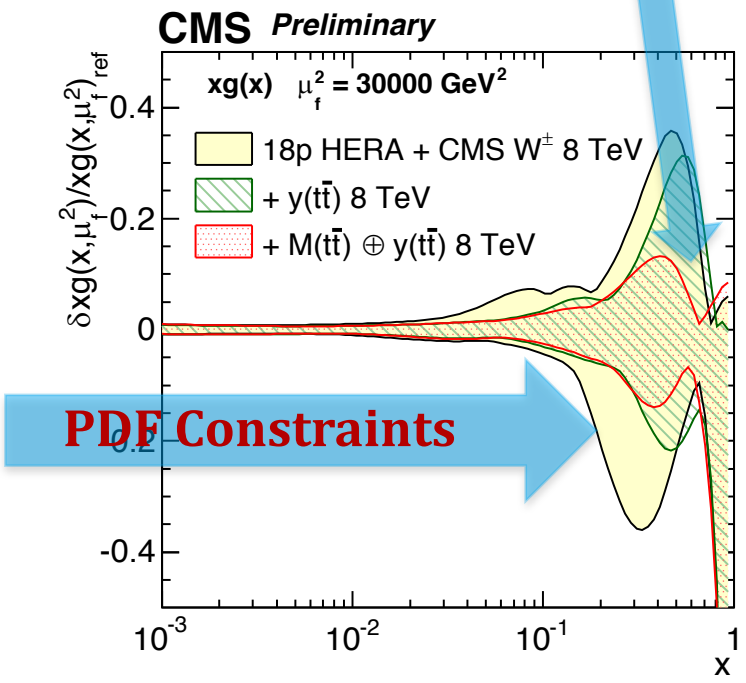
Deeper insight into top and tt kinematics using the e-μ channel

CMS-PAS TOP-14-013, paper in preparation

- Stringent tests of pQCD, enhance sensitivity to BSM physics
- **First measurement of its kind**
- Bin tt events in two variables, e.g, p_T(top) – y(top), m(tt) – y(tt)
- 2D distributions provide stronger PDF constraints than 1D

Significant reduction of uncertainty at high-x





PDF Constraints

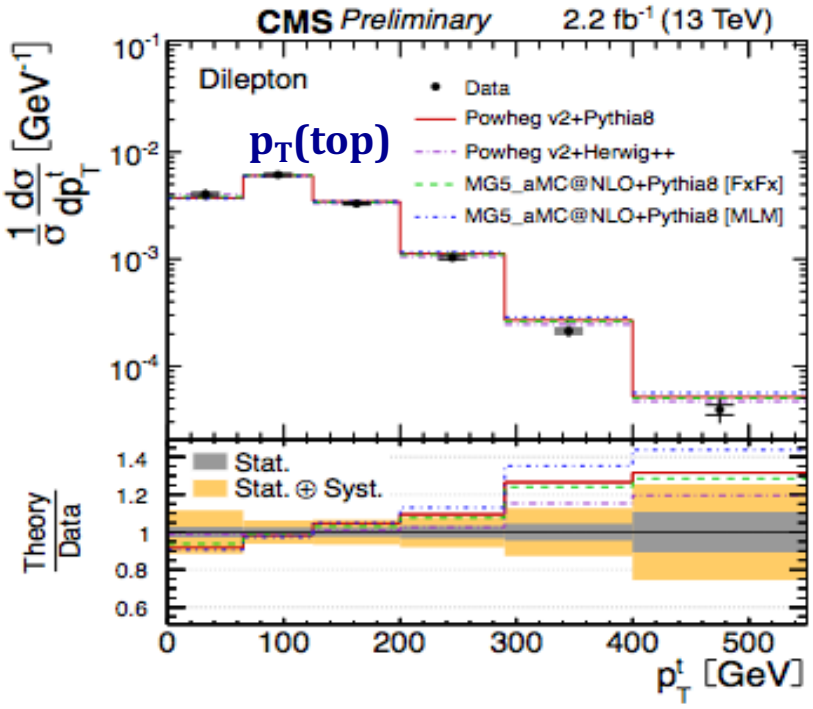
tt differential cross sections at 13 TeV

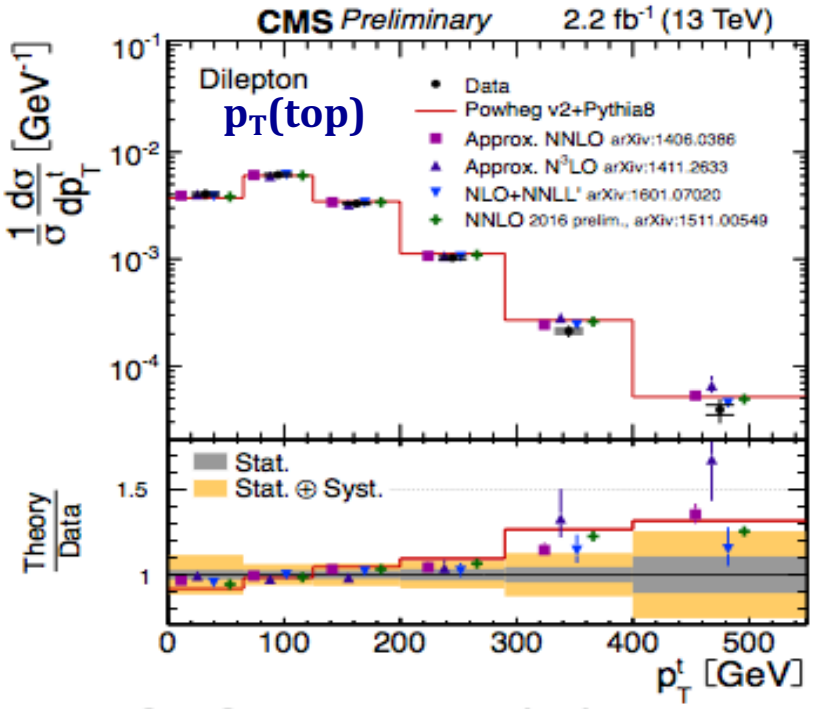
Probing top and tt kinematics at the new energy regime using 2015 data

Comparison to new NLO+Parton Shower (PS) generators and tunes for Run-II

Comparison to beyond NLO QCD calculations

CMS-PAS TOP-16-011





- p_T(top) better described by predictions beyond NLO (softer in data with respect to NLO+PS predictions), as observed in Run-I

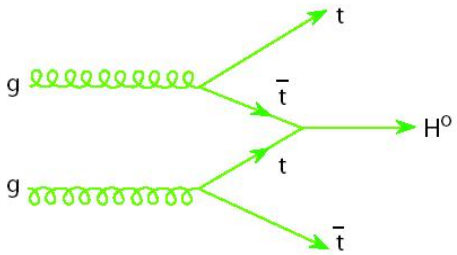
Ongoing analyses with RunII data

Inclusive & differential tt cross section in dilepton channel Using full 2016 dataset

- As a function of top and tt kinematics, in full and fiducial phase space

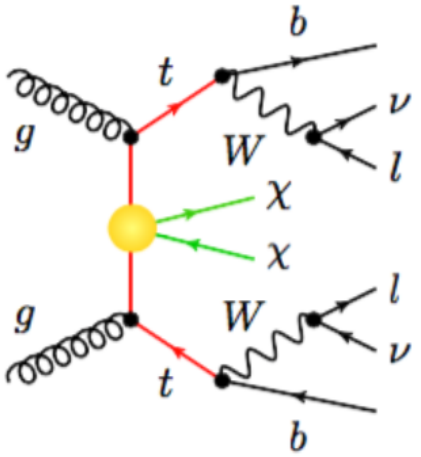
Search for ttH(→bb) production

- Result with 2015 data was made public for Moriond , presented at last PRC
- Updates include 2016 data
- Employ MVA techniques : Input variables such as object kinematics, b-tagging discriminant, angular separation…



Search for dark matter (DM) in tt events:

- Heavy (pseudo)scalar decays to tt
- DM associated production : using MET as signature
- Focus on observables sensitive to the nature of the coupling to the new particle (spin correlation, polarization)



Planned (full 2016 dataset)**:**

➢ 2D differential cross sections ➢ Top quark mass extraction from cross sections

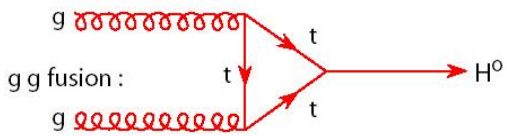
Higgs Physics at DESY in 2016

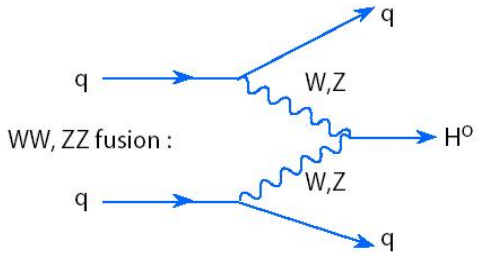
Cross sections:

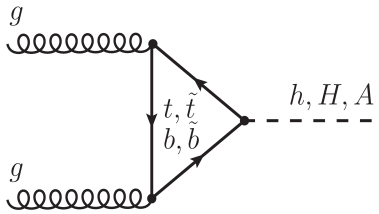
- H(τ-τ)

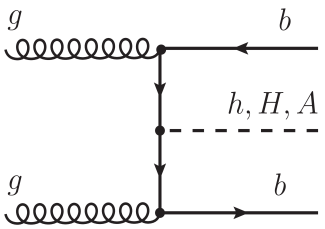
Searches :

- MSSM H(bb)
- MSSM H(ττ)
- NMSSM H(ττ)









Technical contributions:

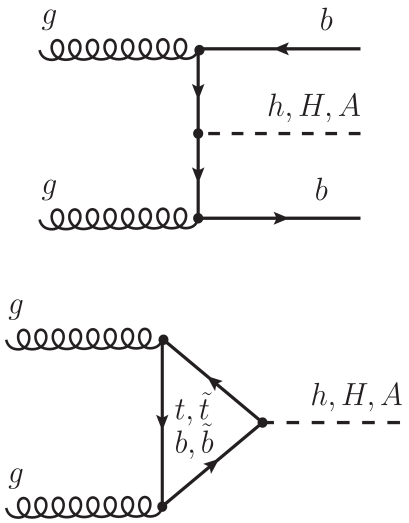
- Trigger studies
- Trigger & lepton efficiencies
- Tau-iD measurements (CMS Tau-16-002)
- Tau Fake Rate measurements
- MC corrections

CMS coordination roles/convenorships:

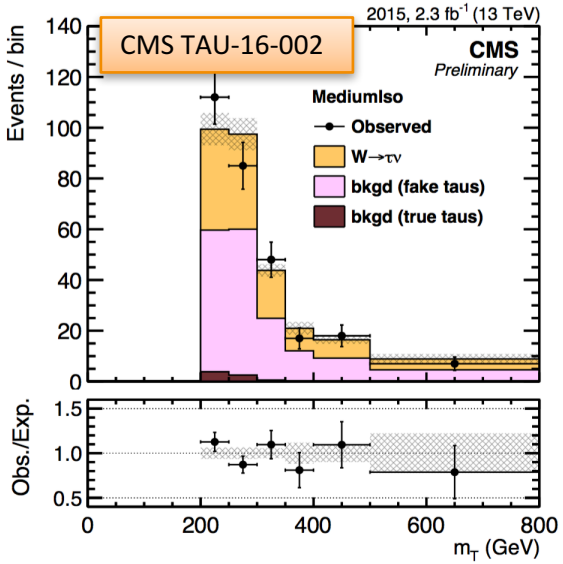
- Higgs-to-b quarks group convener
- Higgs MC contact
- Higgs trigger contact
- CMS Data Analysis School committee
- Higgs pubcom member

Higgs Physics: (MSSM) Higgs in b-b and in τ-τ

- DESY Group commitments in the MSSM H → b-b channel:
  - Development of a trigger with two b-jets in the final state and determination of its efficiency
  - Contribution also to inclusive X(750)->bb resonance search (CMS PAS HIG-16-025)

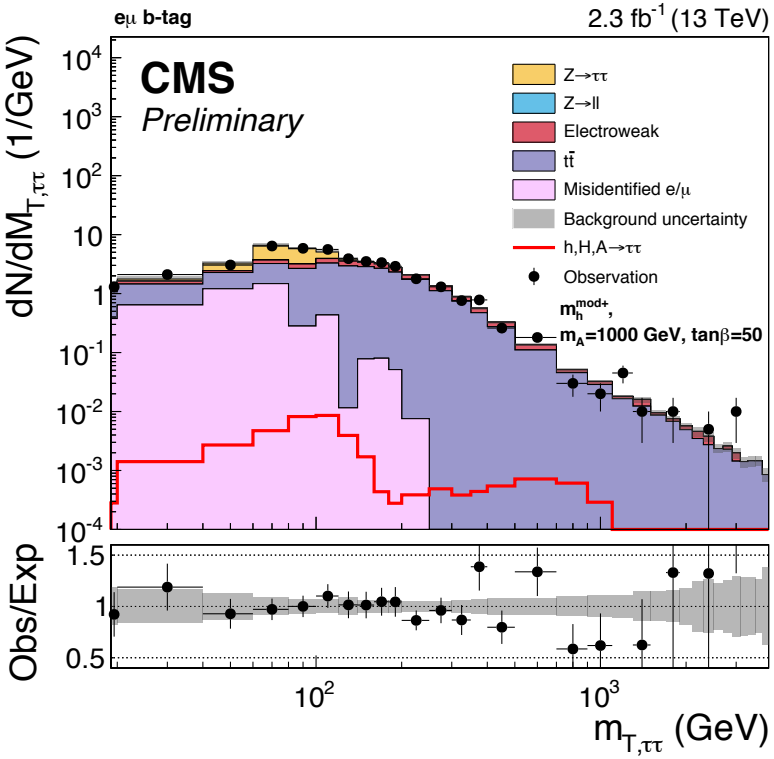


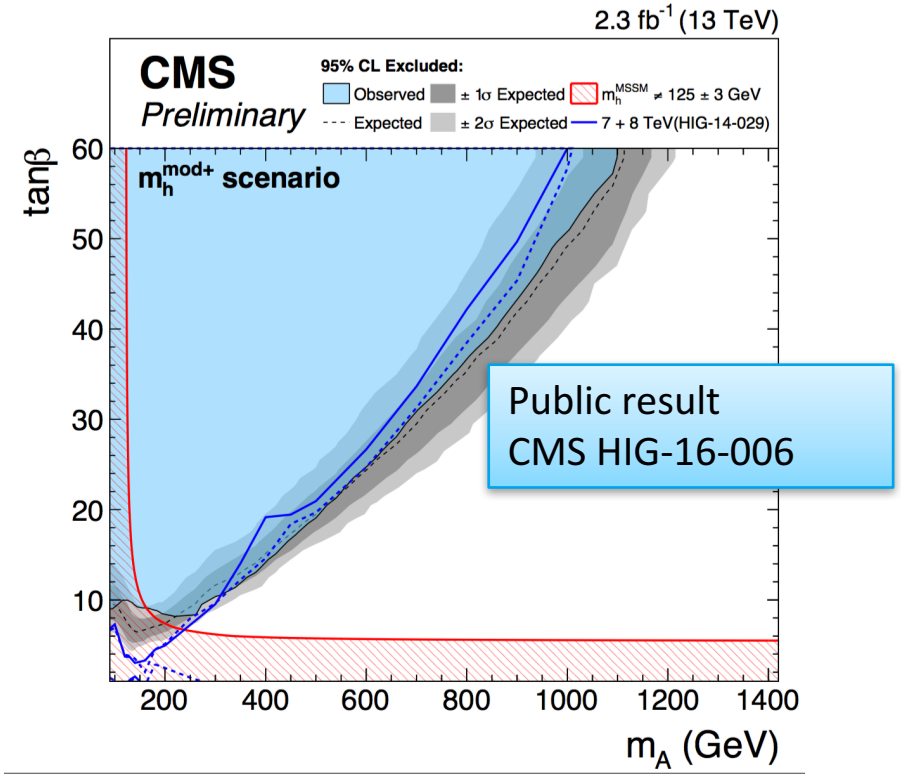
- DESY Group commitments in the τ-τ channel:
  - Determination of electron and muon efficiencies
  - Efficiency of hadronic taus at high p_T using W^* decays (CMS PAS TAU-16-002)
  - Determination of jet & μ→τ, e → τ fake rates
  - Recoil corrections to the missing transverse energy



MSSM Higgs in τ-τ

- Preliminary result with 2015 data presented at LHCP
- Limits already more stringent than Run I
- Working towards preliminary results with 2016 data





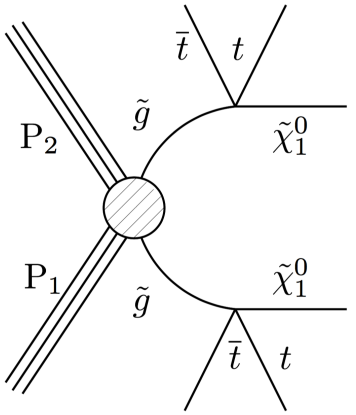
Supersymmetry searches at DESY in 2016

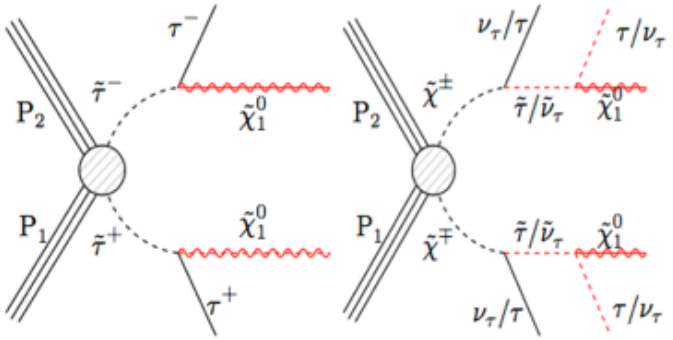
Search for SUSY in 1-ℓ final states with the $\Delta\Phi$ variable.

- Analysis presented at ICHEP and submitted to journal
- Top-up with more data

Search for SUSY w. (in)direct staus

- Both 1-ℓ & 2-ℓ final states
- Aiming Moriond2017





Technical contributions:

- Missing transverse tails studies
- Trigger & lepton efficiencies

CMS coordination roles/convenorships:

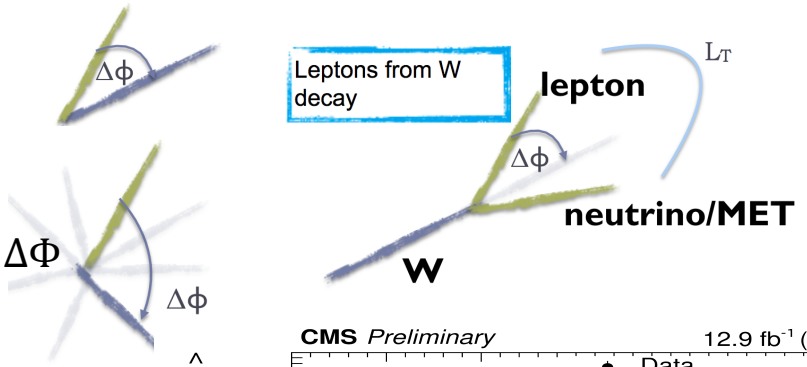
- Inclusive searches group convener
- SUSY pubcom member
- CMS Publication Review Committee

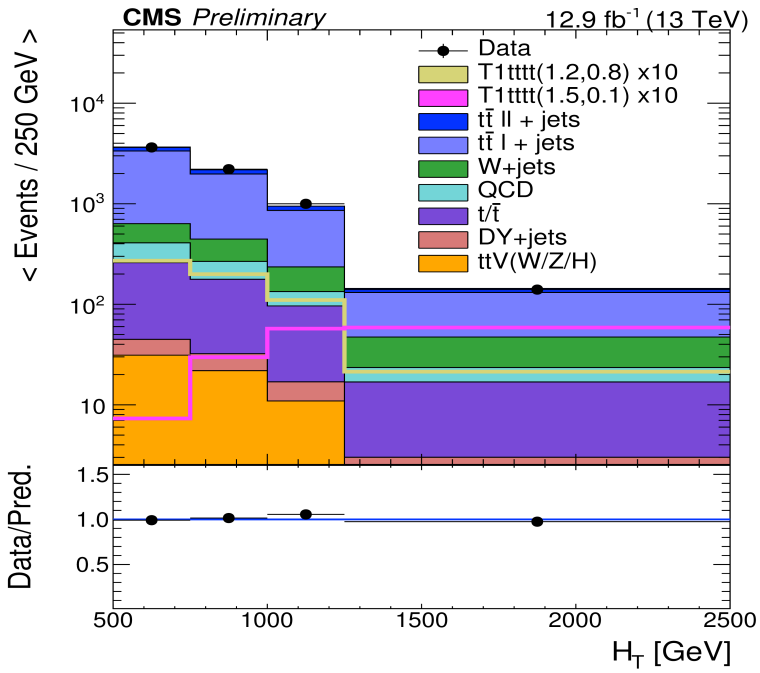
Search for SUSY in 1- ℓ with the ΔΦ variable (SUS-16-019)

- Search includes two categories : 0 & ≥ 1 b-tag
- Discriminant variable : ΔΦ : Angle between ℓ and W direction (reconstr from ℓ+MET)

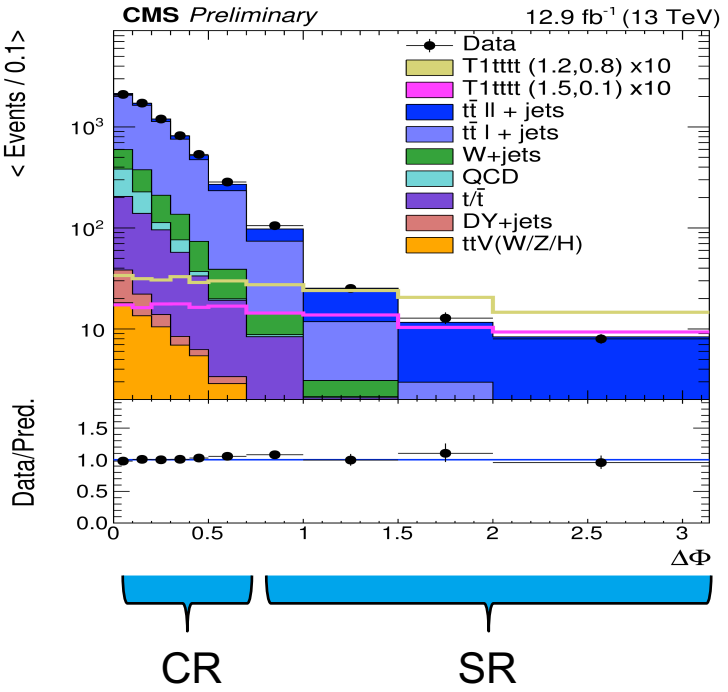
SM: ΔΦ small since MET mainly due to ν

SUSY: MET (mainly) due to LSP → randomized ΔΦ



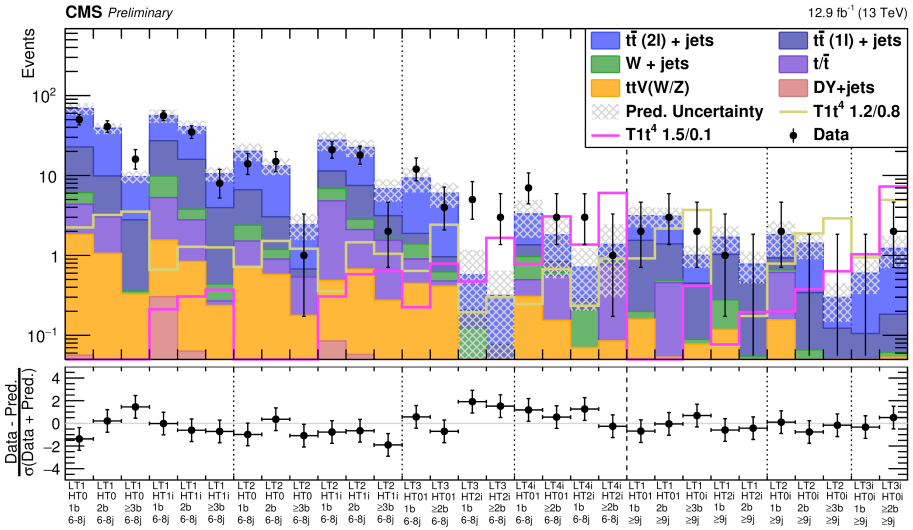


Scalar sum of jet pT (HT)

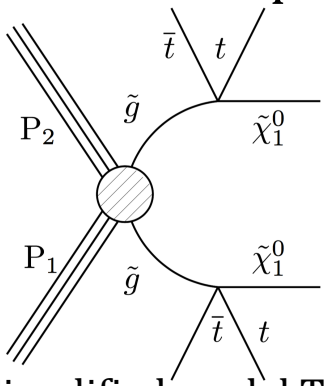


Search for SUSY in 1- ℓ with the ΔΦ variable (SUS-16-019)

- Breakdown of search regions

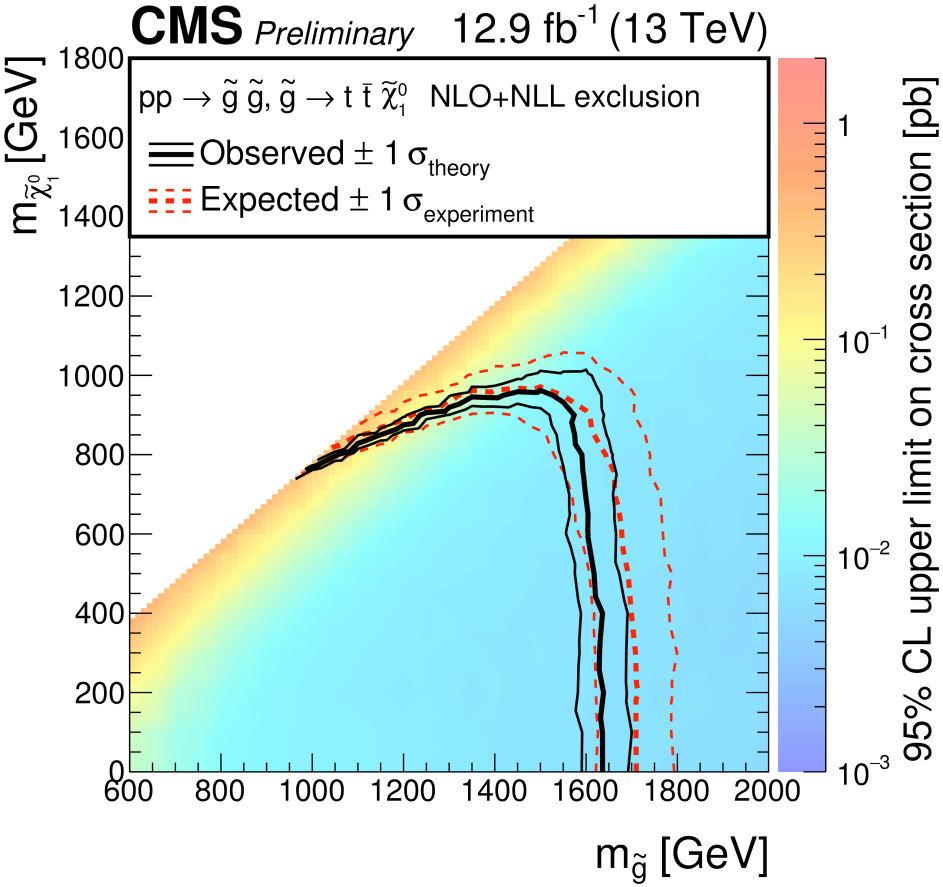


- Interpretation in Simplified Models



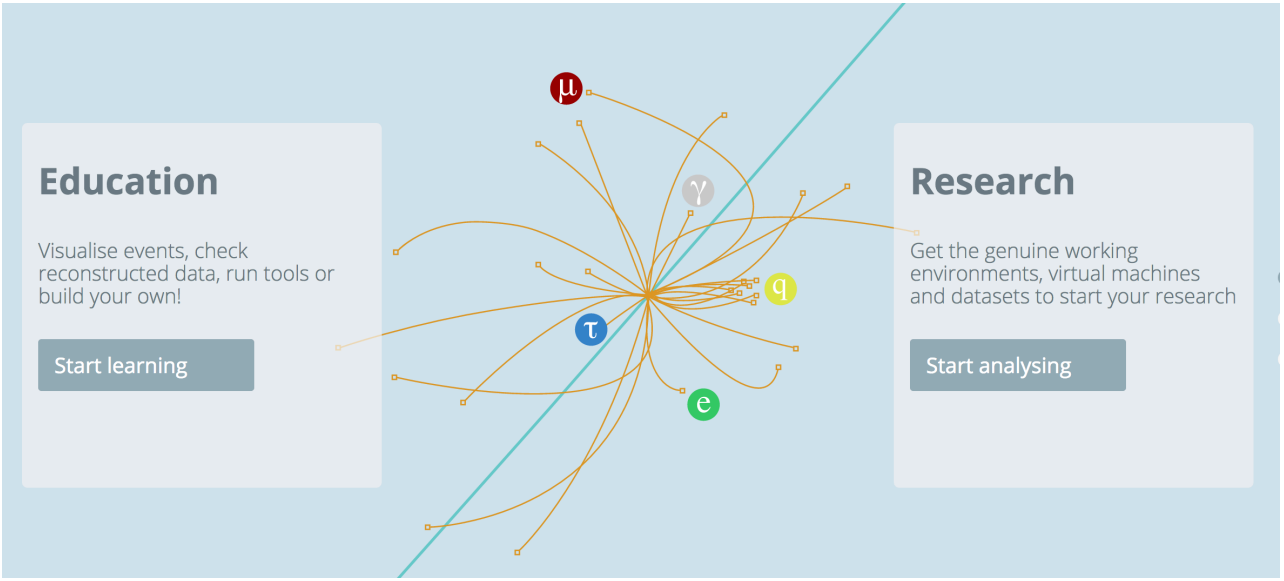
Simplified model T1tttt
gluino-pair production

Exclusion limit extended by ~150 GeV
compared to 2015 Data



Open Data Project

http://opendata.cern.ch/



Open Data

- Targets educational applications
- Some knowledge of HEP concepts needed

CMS :

- Open release of 2010 Data (part of it) in fall 2014
- 2011 Data (part of it) and MC in spring 2016

CMS coordination roles/convenorships:

- Deputy Data Preservation and Open Access coordinator

Open Data : Validation of open data and analysis platform

- CMS Portal http://opendata.cern.ch/about/CMS

AOD format, real analysis can be done by Bachelor-level students (ie summer students)

Examples:

2010 pp data „ridge“;

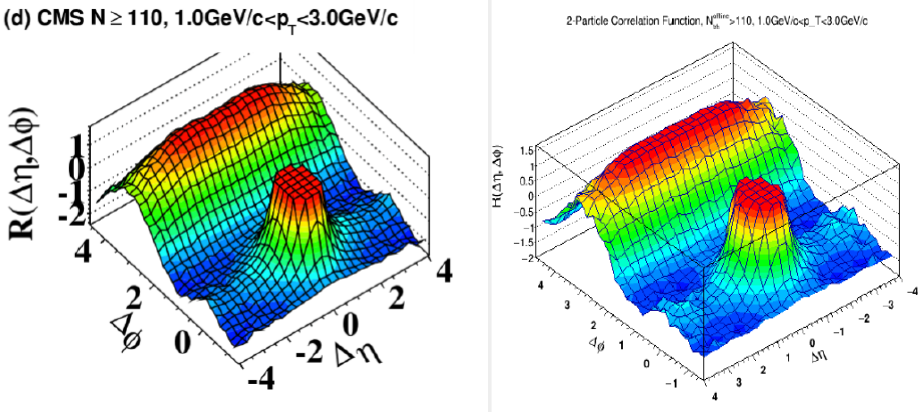
CMS Paper

JHEP 1009 (2010) 091

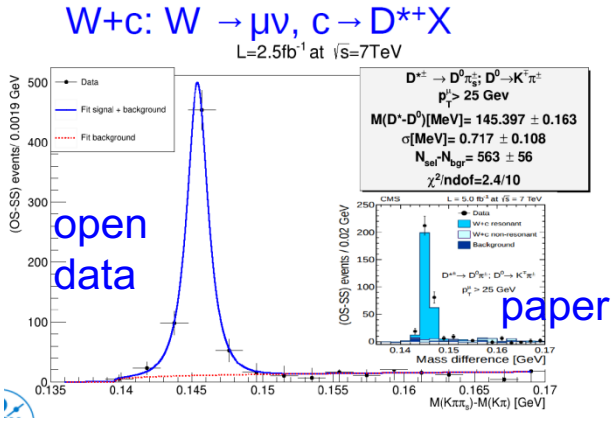
CMS open data

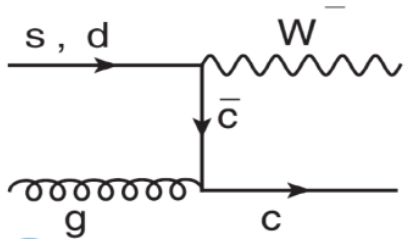
(Minimum Bias data set)

(on office desktop)



2011 W+c cross section





Summary and Outlook

- Pixel module production for Phase 1 upgrade successfully finished
  - 287 modules delivered to PSI in time,
  - 256 already mounted in 4rth half layer this week
- Tracking detector Phase 2 upgrade gaining strength
  - Work for the detector assembly facility started
- Physics analyses going strong
  - CMS-DESY group is a key player in many flagship analysis
- Open Data project : CMS only LHC experiment released original Data
- Very successful data taking in 2016 will bring many interesting results

exiting times at LHC ahead

Backup

Coordinating roles in CMS

Management

- K. Borras: Deputy Spokesperson (Jan. 2014 – Aug 2016); Head of Engagement office, FB, MB member
- M. Kasemann: Chair of the Authorship Board; FB member, CB advisory

Physics

- M. Aldaya Martin: convener of top quark cross section group (L3)
- Y. Chen : Higgs trigger contact
- C Diez Pardos : Convener of the top mass group (L3)
- E. Gallo: Member of HIG pub. committee
- A. Grohsjean : Generator integration and validation (L3 , GEN Group)
- H. Jung: FSQ-PRF pub. committee, Chair of "Theorists in CMS committee", convener SMP-Jets (L3, SMP)
- P. Gunnellini: Convener of "Physics Comparison and Generator Tunes" (L3, GEN Group)
- A. Kalogeropoulos: SUSY Trigger, MC & Interpretation (L3), CMS Publication Review Committee
- J. Keaveney : Convener of the Top cross-section
- A. Meyer: member of TOP/BPH pub. committee
- I. Melzer-Pellmann: SUSY pub. committee
- B. Roland: Convener of LPCC: Minimum-bias and underlying event WG"
- C. Seitz : Convener of SUSY Inclusive searches (L3)
- R.Mankel: Convener of Higgs to b quarks group (L3)

Coordinating roles in CMS

Statistics Committee

- O.Behnke – Chair

Computing, PPD

- C. Wissing: Operation (L2)
- M. Kasemann: Chair of Computing Resource Board
- Online: U.Behrens: Web-Based-Monitoring (L2)
- A. Geiser : Open data and preservation – Deputy
- G. Mittag : AlCaDB Softwae Coordinator (L3)

Tracker

- G. Eckerlin: MB phase 1/2 upgrade MBs, Tracker Finance Board
- D. Eckstein : Member of Tracker Pub.Comm.
- A. Mussgiller: Convener of Strip-Tracker Module-Design group

Beam Radiation Instrumentation & Luminosity (BRIL)

- W. Lohmann: Chair of Institutional Board
- J. Leonard –DPG (L2) , BCM1F (L3)
- R. Walsh BCMF1 WG (L3)

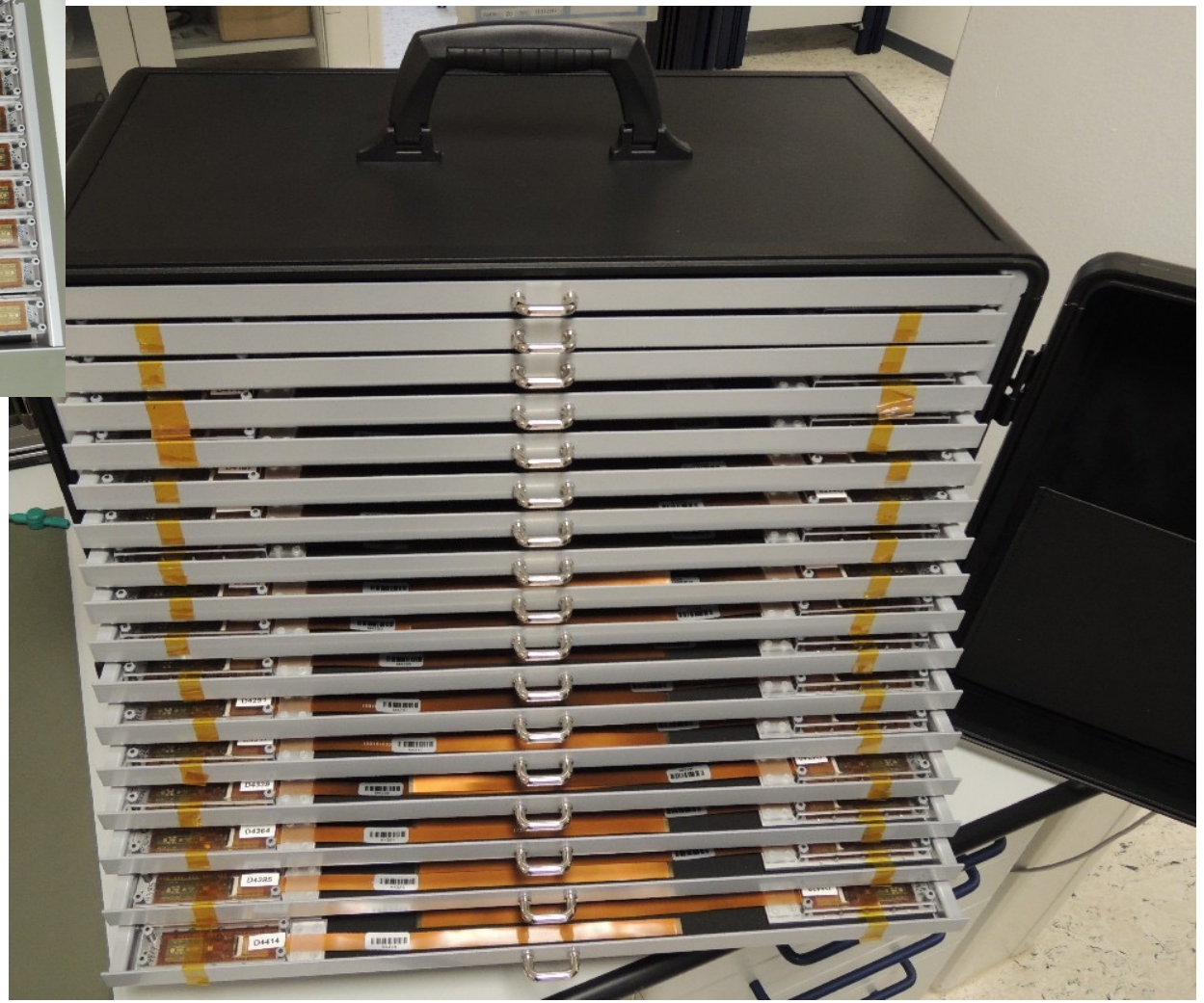
Publications with substantial contributions from DESY

- Measurement of the double-differential inclusive jet cross section in proton–proton collisions at sqrts=13 TeV Eur. Phys. J. C (2016) 76: 451. arXiv 1605.04436
- Measurement of the differential cross section and charge asymmetry for inclusive pp to W + X production at sqrt(s) = 8 TeV, Eur.Phys.J. C76 (2016) no.8, 469
- Measurement and QCD analysis of double-differential inclusive jet cross-sections in pp collisions at sqrt(s) = 8 TeV and ratios to 2.76 and 7 TeV Submitted to Eur.Phys. J.C. [arXiv:1609.05331]
- Search for supersymmetry in events with one lepton and multiple jets in proton-proton collisions at sqrt(s) = 13 TeV Submitted to PRD [arxiV: 1609.09386]
- Measurement of the t-tbar production cross section in the e-mu channel in proton-proton collisions at sqrt(s) = 7 and 8 TeV, JHEP 1608 (2016) 029 [arXiv:1603.02303]
- Measurement of t-tbar production with additional jet activity, including b quark jets, in the dilepton channel using pp collisions at sqrt(s) = 8TeV, Eur.Phys.J. C76 (2016) no.7, 379 [arXiv:1510.03072]
- M.Ö. Sahin, D. Krücker, I.-A. Melzer-Pellmann , "Performance and optimization of support vector machines in high-energy physics classification problems", arXiv:1601.02809, accepted by NIM A

Publications with substantial contributions from DESY

- Measurement of t-tbar production with additional jet activity, including b quark jets, in the dilepton channel using pp collisions at sqrt(s) = 8TeV, Eur.Phys.J. C76 (2016) no.7, 379 [arXiv:1510.03072]
- CMS-PAS TOP-13-006: "Determination of the normalised invariant mass distribution of tt+jet and extraction of the top quark mass"
- - CMS-PAS TOP-14-013: "Measurement of double differential cross sections for top quark pair production in pp collisions at sqrt(s)= 8 TeV"
- - CMS-PAS TOP-16-016: "Search for standard model production of four top quarks in proton-proton collisions at 13 TeV”
- CMS PAS HIG-16-006: Search for a neutral MSSM Higgs boson decaying into tautau at 13 TeV
- CMS PAS HIG-16-025: Search for a narrow heavy resonance decaying to bottom quark-antiquark pairs at sqrt(s) = 13 TeV
- CMS PAS TAU-16-002 : Performance of reconstruction and identification of tau leptons in their decays to hadrons and nutau in LHC Run-2

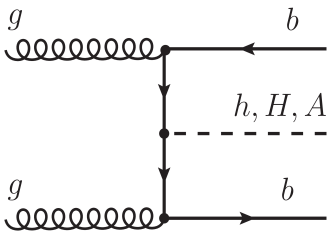
Pixel module transport box



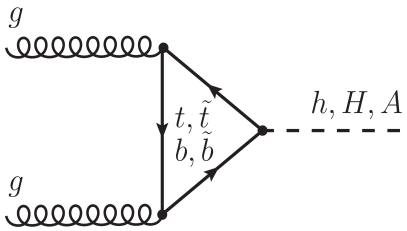
- 16 trays with 18 modules
- ESD safe
- 230 k EUR material value
- 1 M EUR replacement value insured by DESY

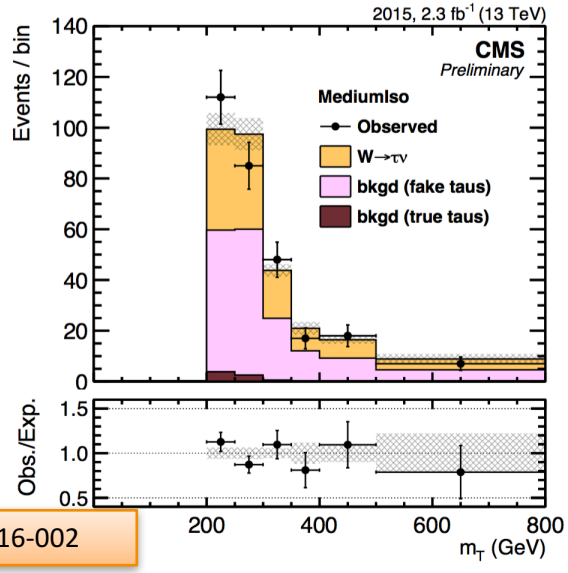
Higgs Physics: (MSSM) Higgs in b-b and in τ-τ

- DESY Group commitments in the MSSM H → b-b channel:
  - Development of a trigger with two b-jets in the final state and determination of its efficiency, used also by other exotics searches (i.e. X(750)->bb resonance search, CMS PAS HIG-16-025 presented at ICHEP2016)



- DESY Group commitments in the τ-τ channel:
  - Determination of electron and muon efficiencies
  - Efficiency of hadronic taus at high p_T using W^* decays (CMS PAS TAU-16-002)
  - Determination of jet & μ→τ, e → τ fake rates
  - Recoil corrections to the missing transverse energy
  - Responsible of the analysis in the eμ channel





CMS TAU-16-002