

ATLAS highlights and LHC status

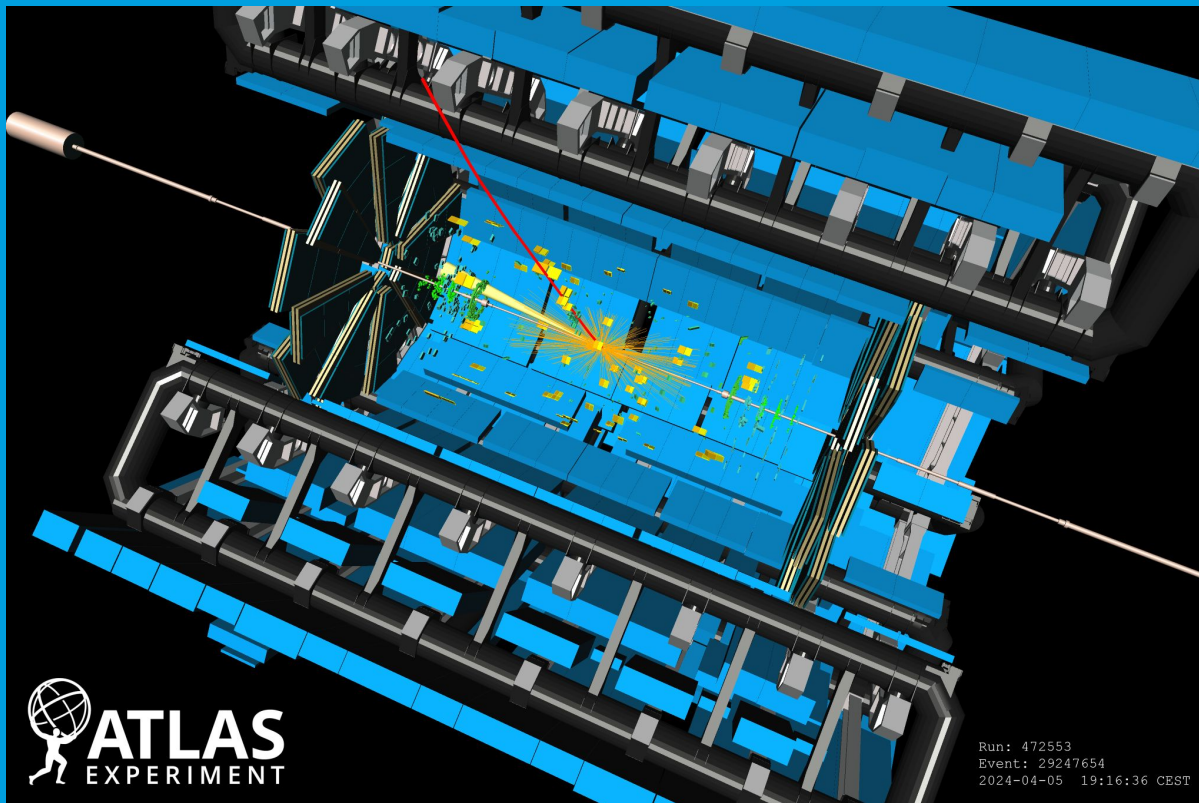
97th PRC meeting



Lydia Beresford on behalf of the DESY-ATLAS group
Hamburg, April 24-25, 2024

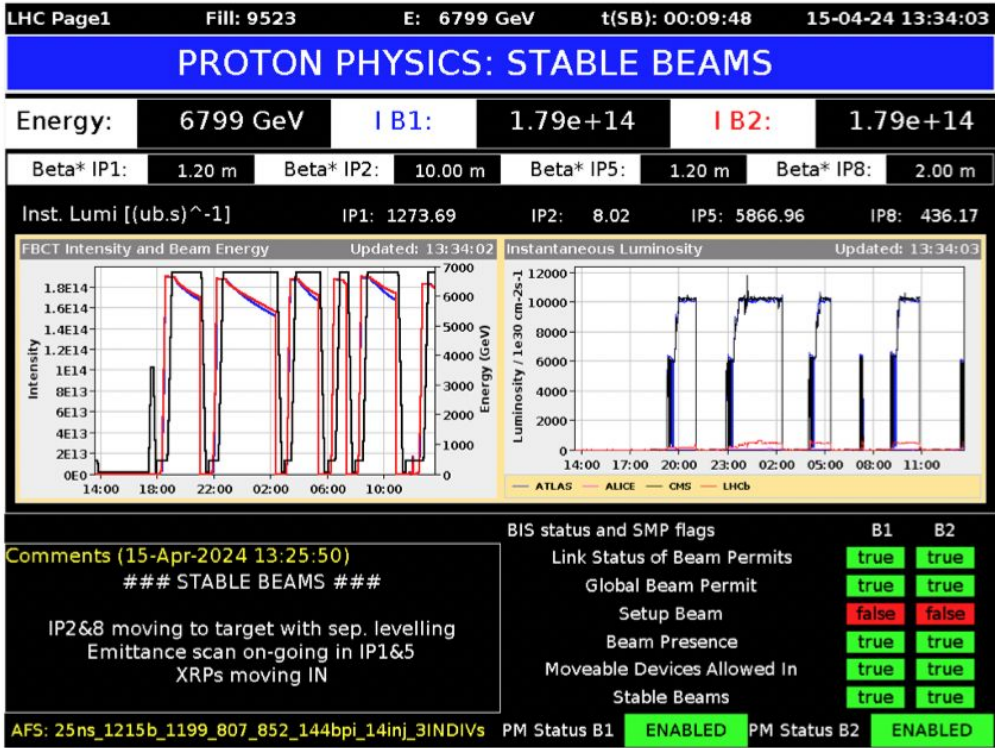
LHC Status

5th April 2024



LHC re-commissioning and intensity ramp

LHC re-commissioning while ramping beam intensity (increasing number of bunches)



LHC schedule

Current 2024 schedule: [v2.0 27 March 2024](#)

- 5 April: **1st 13.6 TeV stable-beams**
- Intensity ramp: **reached 1800 b**, 2400 b planned
- **10 days ahead of ramp schedule** (similar to last year)
- **Decision to shift extended year-end technical stop by 4 weeks** (not extra beam time)
 - Begin: 25 Nov 2024
 - Machine checkout (cavern closed): 2 Apr 2025
 - Beam recommissioning: 7 Apr 2025

		Apr			May			Jun							
		First Stable beams @ 6.8 TeV			Collisions with 1200 bunches										
Wk		14	15	16	17	18	19	20	21	22	23	24	25	26	
Mo	Easter	1	8	15	22	29	6	13	Whitsun	20	27	3	10	17	24
Tu															
We															
Th															
Fr															
Sa															
Su															

	Jul			Aug				Sep				Oct	
Wk	27	28	29	30	31	32	33	34	35	36	37	38	39
Mo	1	8	15	22	29	5	12	19	26	2	9	16	23
Tu													
We								MD 3					
Th										Jeune G.			
Fr													
Sa													MD 4
Su													

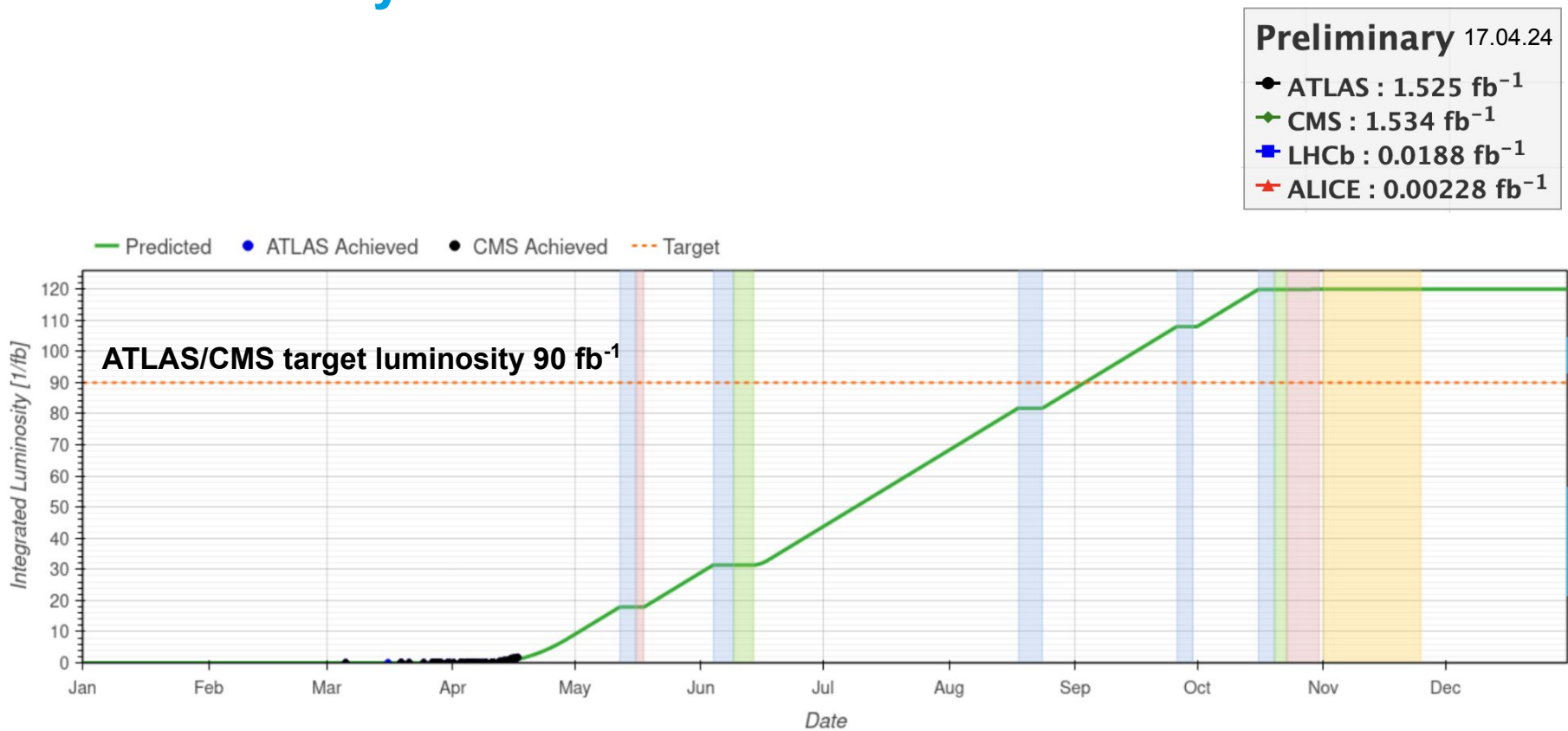
		Nov										Dec			
		VIP visits CERN 70		End 25 ns run [08:00]						End of run [06:00]					
Wk		40	41	42	43	44	45	46	47	48	49	50	51	52	
Mo		30	7	14	21	28	4	MD 6	11	18	25	2	9	16	23
Tu					TS2	p-p ref run									
We															
Th															Xmas
Fr					p-p ref setup	Cryo reconfig.		Pb-Pb Ion run							Annual Closure
Sa				MD 5											
Su						Pb Ion setting up									

★ = Today

New draft schedule for 2025

LHC luminosity status

Delivered 2024 luminosity so far



[Generated at: 2024-04-17 22:18:55]

Comment: update to latest figures & date before PRC

ATLAS DESY group



ATLAS overview

Many leadership roles within ATLAS & beyond

Expertise in wide range of ATLAS analysis & object performance

- Identification and calibration of: **Jets, b-jets, electrons, photons and forward protons**
- **Tracking** for current and upgraded detector
- **SM measurements & searches for new phenomena**

ATLAS detector operation & computing

- Operation, monitoring & calibration of **SCT and luminosity** measurement
- Leading roles in ATLAS **computing and software**
- **Monte Carlo, data reprocessing and modelling of physics processes**

Upgrade of the ATLAS detector

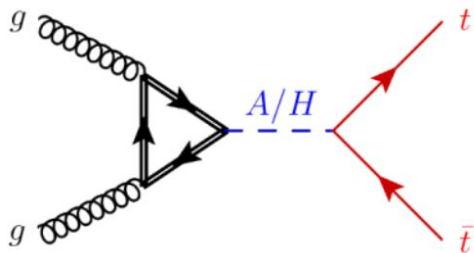
- **Design, test and assembly** of future ATLAS tracking detector for HL-LHC (ITk)
- DESY will provide a full end-cap of the new ITk detector

ATLAS outline

Since last PRC: 17 papers published, 6 submitted, 4 public notes, 4 non-ATLAS papers

Today highlight just a few achievements:

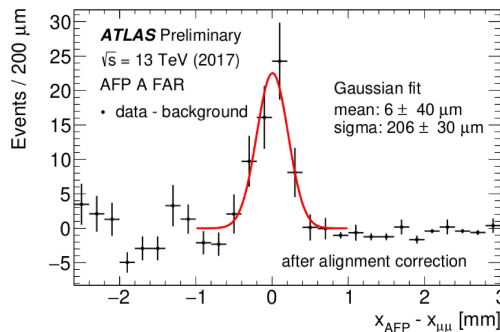
Data analysis



**DESY-led search
for new Higgs Bosons**

ATLAS-CONF-2024-001

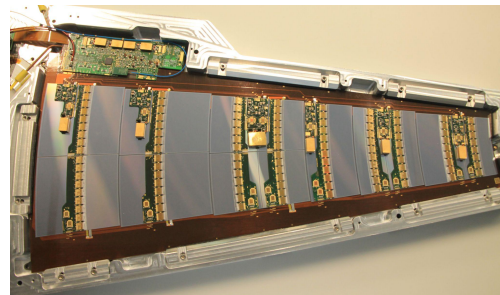
Detector performance



**1st overview of ATLAS Forward
Proton (AFP) performance**

FWD-PUB-2024-001

Detector development



**Inner Tracker (ITk) end-cap
highlights**

**Search for heavy neutral Higgs bosons
decaying to a top quark pair
in 140 fb^{-1} of $\sqrt{s}=13 \text{ TeV}$ pp collision data**

ATLAS-CONF-2024-001

DESY initiated & led analysis: analysis contact, editors, key analysers
Katharina Behr LHC seminar on 19th March

Why Two-Higgs-Doublet Models?

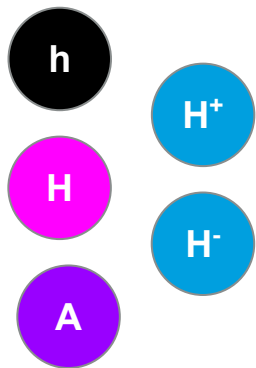
Many BSM models involve extended Higgs sectors:

Hierarchy problem? Dark matter? ...

Simple extension consistent with existing constraints: **2HDMs**

Search for heavy Higgs: **pseudo-scalar (A)** & **scalar (H)** \rightarrow $t\bar{t}$

Considers several models including 2HDM+a for 1st time



Assuming CP-conserving
potential

Today focus on hMSSM

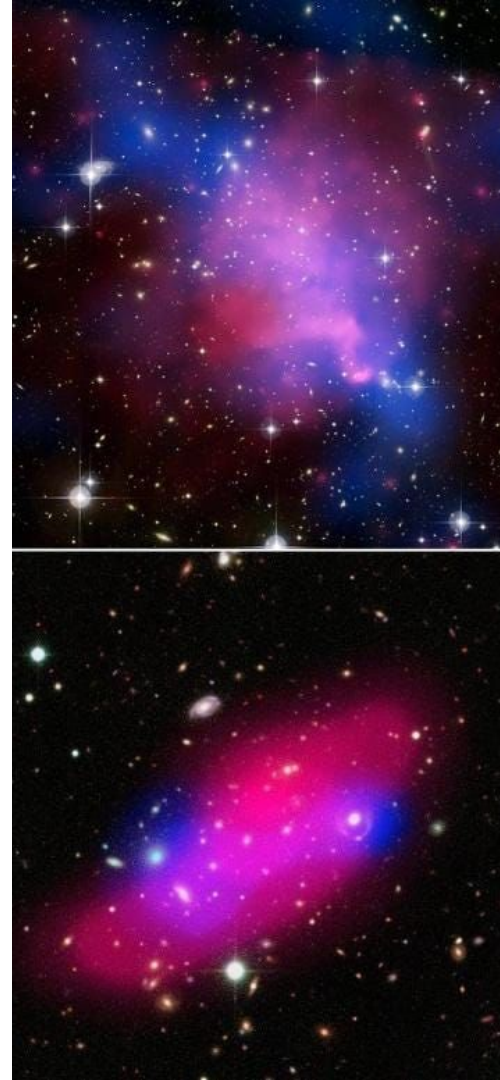
$h = h_{\text{SM}}$

Only 2 free parameters: m_A & $\tan\beta$

SUSY particles assumed to be heavy

Top: X-RAY: NASA/CXC/UVIC./A.MAHDAMI ET AL. OPTICAL/LENSING: CFHT/UVIC./A. MAHDAMI ET AL.

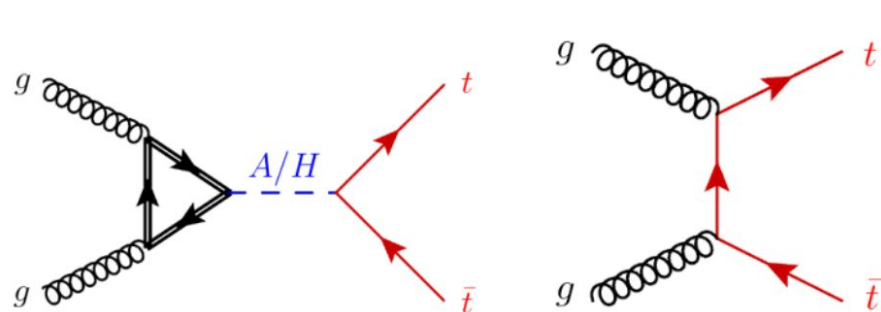
Bottom: ESA/XMM NEWTON/E. CASTALDELO (INAF/IASF MILANO, ITALY)/CEUTIS



Signal process and interference

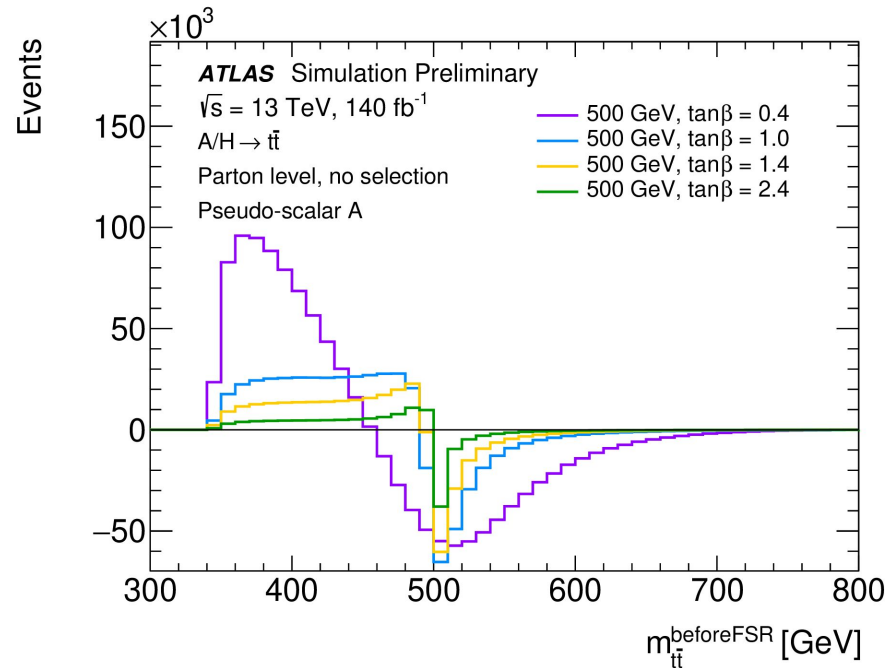
Dominant BR of A/H to $t\bar{t}$ at high mass & low $\tan\beta$

Signal process **interferes** strongly with irreducible background from SM $t\bar{t}$ events



Unique interference pattern:

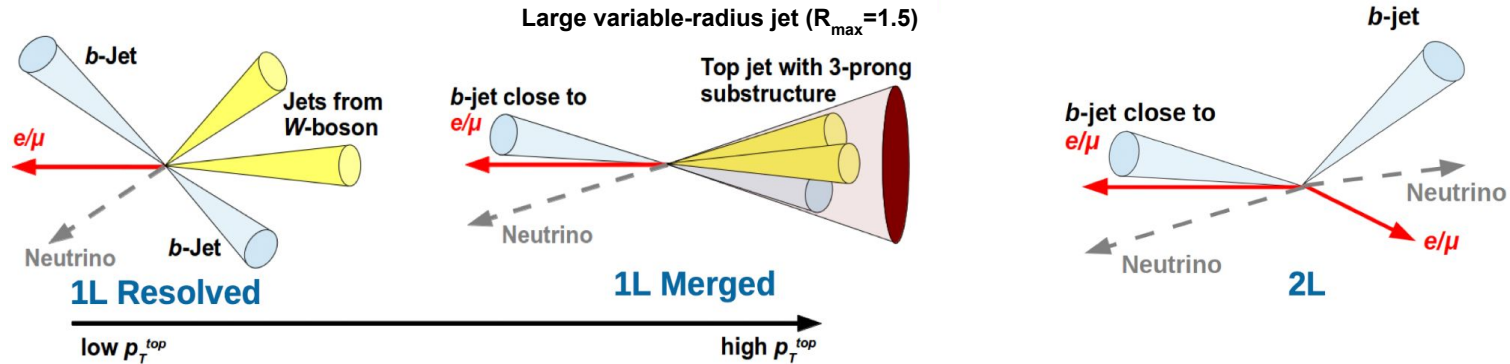
- Peak-dip structure instead of Breit-Wigner peak
- Highly model-dependent



Larger $\tan\beta$ \Rightarrow Smaller total width \Rightarrow Narrower pattern

Analysis strategy

Target 1L (e, μ) and 2L (ee, $\mu\mu$, $e\mu$) $t\bar{t}$ decays & exploit spin information; 16 regions total



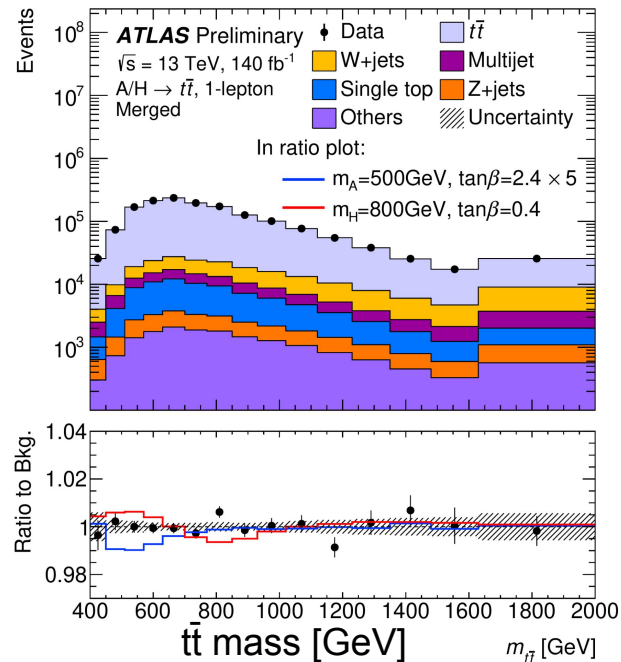
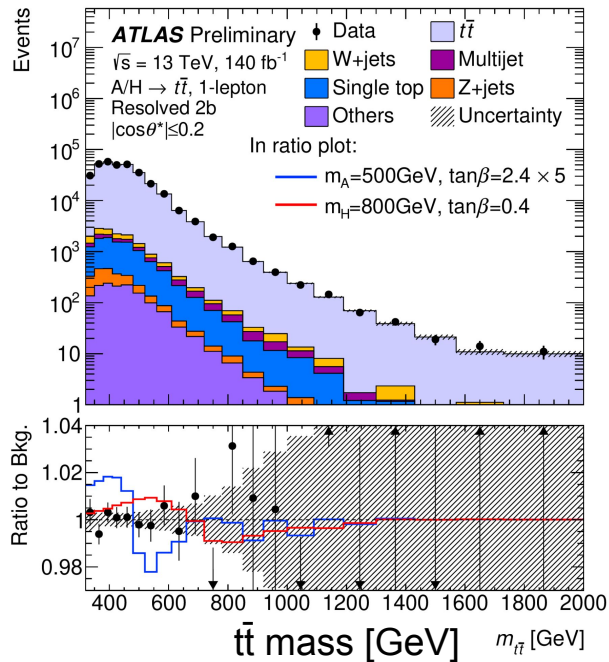
Final discriminant: reconstructed H/A mass (1L: $m_{t\bar{t}}$, 2L m_{LLbb} as proxy)

Improvements wrt Run 1 result:

- Include 2L & 1L Merged
- Reweight SM $t\bar{t}b\bar{g}$ to NNLO-QCD+NLO EW
- Improved statistical treatment
- Wider range of benchmark models (hMSSM, 2HDM+a, model-agnostic interpretation)

Legacy result using 140 fb^{-1} of Run-2 data

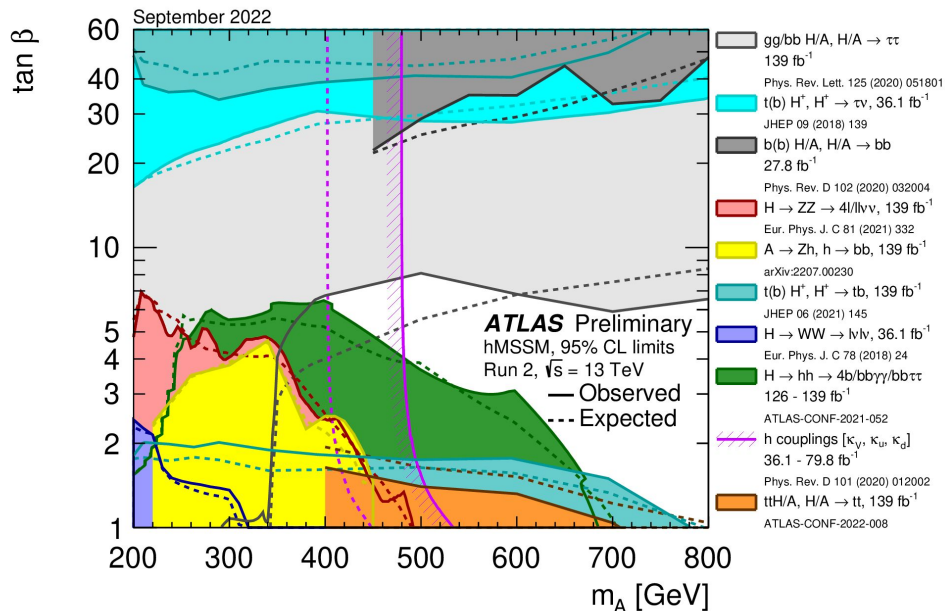
Search stage: test data vs S + I + B hypotheses agreement for masses $[400, 1400] \text{ GeV}$, widths $[1, 40]\%$



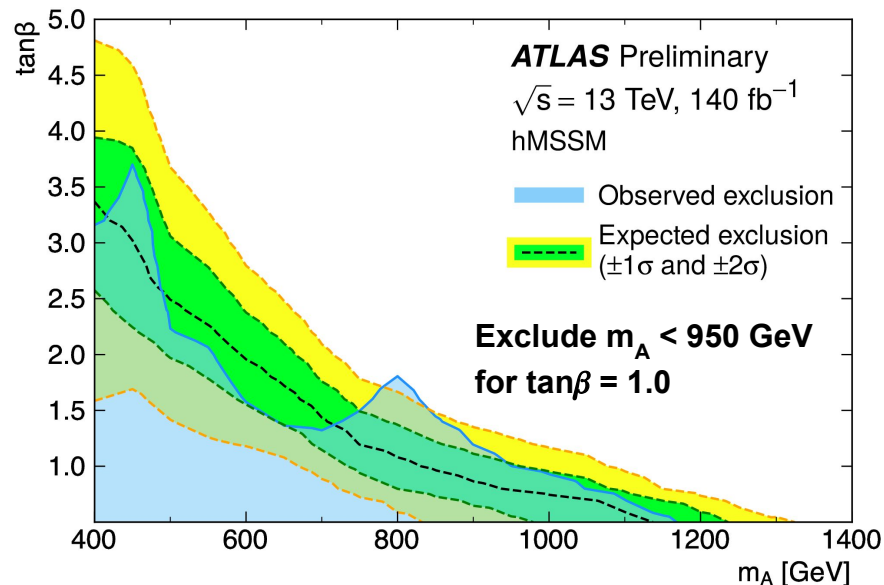
No statistically significant deviation from SM:
 Largest 2.3σ local ($m_A = 800 \text{ GeV}$, $\Gamma_A / m_A = 10\%$ & $\sqrt{\mu} = 4.0$)

Legacy result using 140 fb^{-1} of Run-2 data

Existing constraints



New constraints



**Strongest constraints on 2HDM & hMSSM parameter space
for low $\tan\beta$ + high A/H mass**

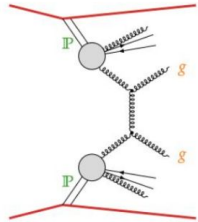
Performance of the ATLAS Forward Proton Spectrometer during High Luminosity 2017 Data Taking

FWD-PUB-2024-001

DESY key analysers & current forward proton coordinator

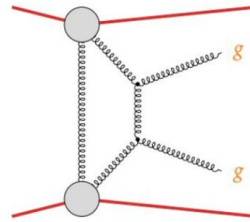
Forward proton motivation

Intact forward scattered protons are a key signature of various diffractive & photon-induced processes



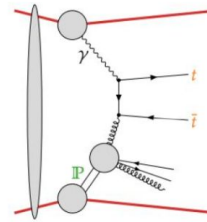
Diffractive jets

ATL-PHYS-PUB-2017-012



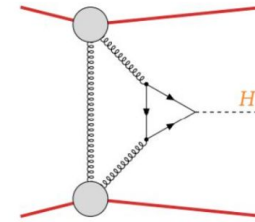
Exclusive jets

Trzebinski et al [1503.00699](#)
Harland-Lang et al [1405.0018](#)



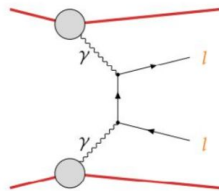
Top quarks

Goncalves et al [2007.04565](#)
Howarth [2008.04249](#)



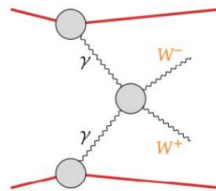
Higgs boson

Cox et al [0709.3035](#)
Heinemeyer et al [0708.3052](#)



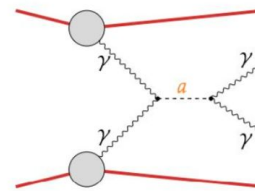
Leptons

CMS [1803.04496](#)
ATLAS [2009.14537](#)



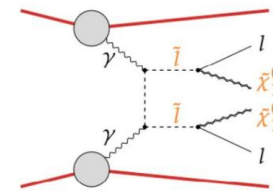
W bosons

Tizchang, Etesami [2004.12203](#)
Baldenegro et al [2009.08331](#)



Axion-like particles

Harland-Lang & Tasevsky [2208.10526](#)
Baldenegro et al [1803.10835](#)

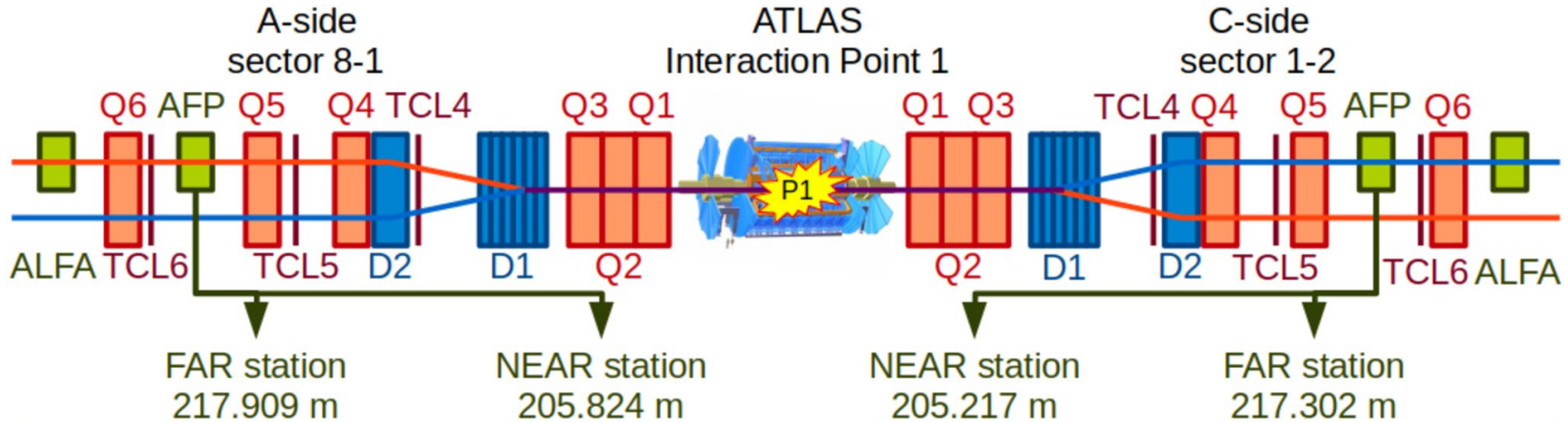


SUSY dark matter

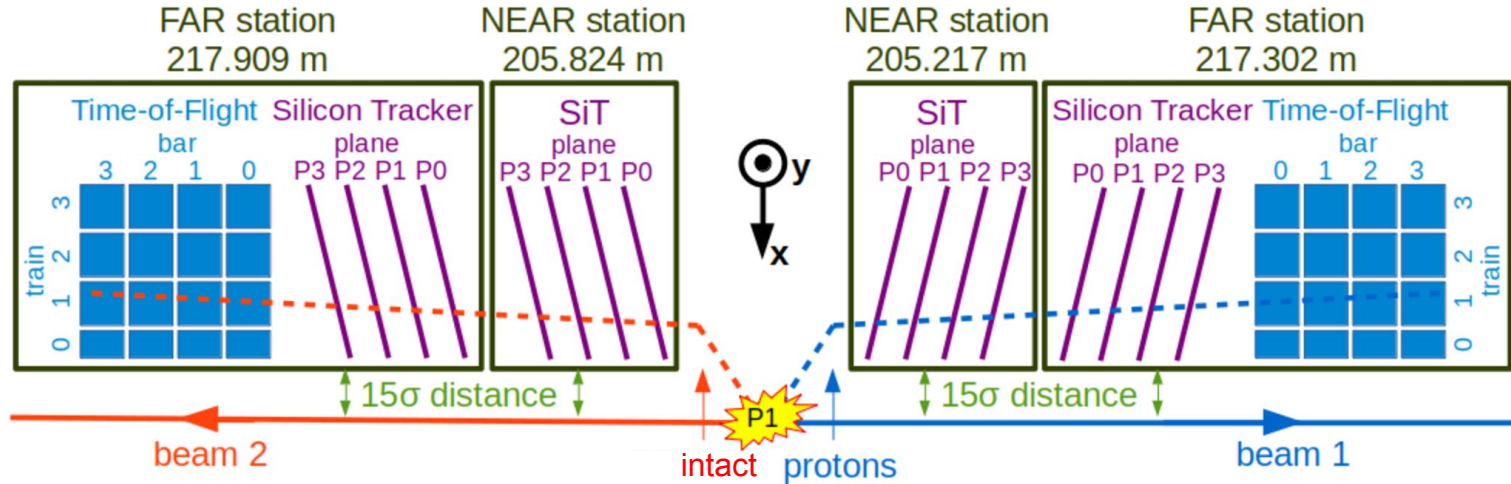
Beresford & Liu [1811.06465](#)
Harland-Lang et al [1812.04886](#)

ATLAS Forward Proton (AFP) detectors

- Measure them using ATLAS Forward Proton (AFP) detectors
- Provides powerful background rejection:
 - New kinematic information e.g. total missing momentum by combining AFP & central ATLAS
- Need to precisely identify and calibrate protons for use in physics analysis

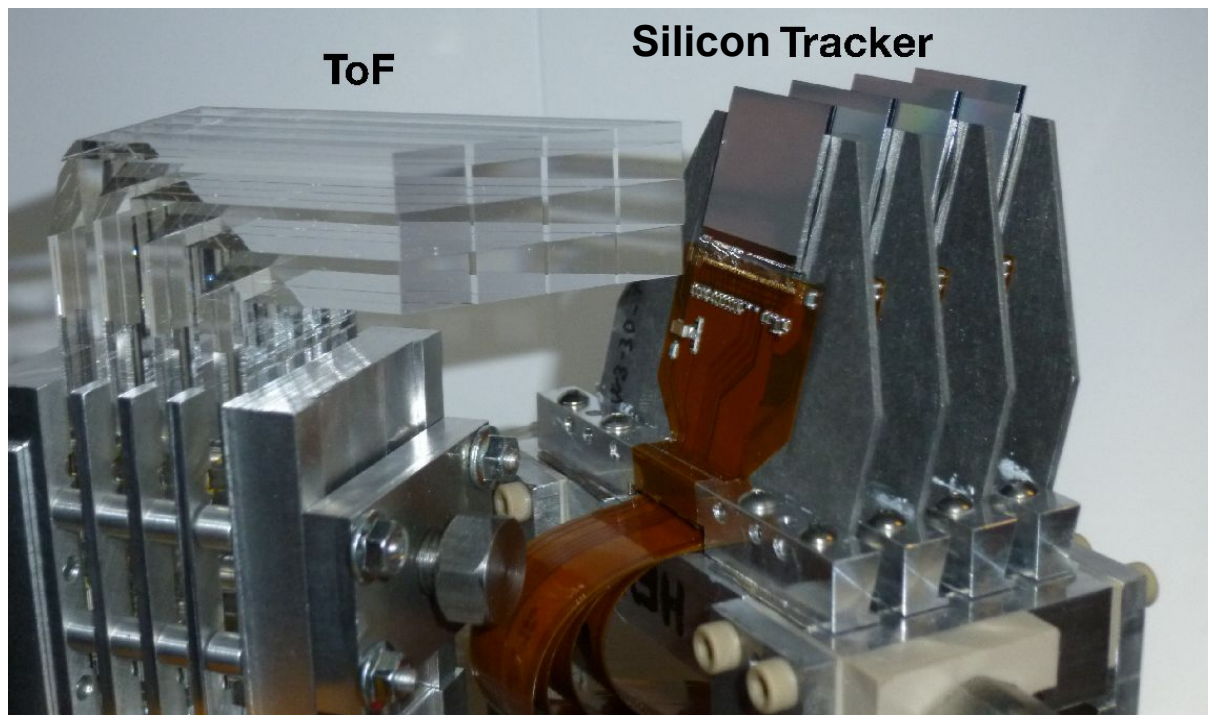


ATLAS Forward Proton (AFP) detectors



- **Silicon Tracker (SiT) with four planes of pixels in each station**
 - Pixel hits → pixel clusters → tracks (per station) → proton
- Time-of-Flight (ToF) detectors in FAR stations
- Housed in Roman Pots, **inserted to within ~2 mm of the beam**

ATLAS Forward Proton (AFP) detectors



Cherenkov detector
L-shaped quartz bars
Microchannel Plate PMT

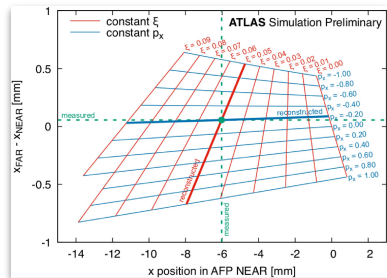
~30 ps timing resolution

3D silicon pixels like ATLAS
insertable B-layer (IBL)
'slim-edge' ~100 μm

Active area 1.68 x 2 cm²

AFP performance overview

During high luminosity 2017 data taking



Parameterisation

Varying magnetic field

Optics

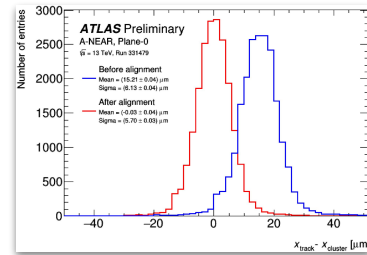
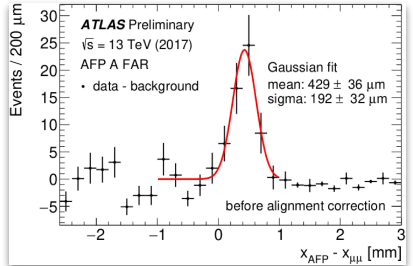
BBA

BPM

Alignment

Excl. $\mu\mu$

Inter-plane



Components of AFP performance

(x,y)

p_T

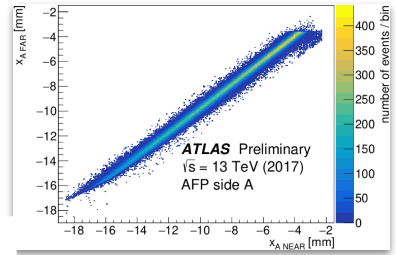
ξ

Proton resolution

Background

Combinatorics

Beam halo



Time-of-flight

Efficiency

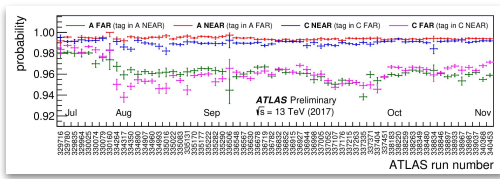
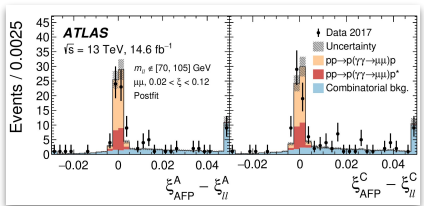
Trigger

Track

Proton



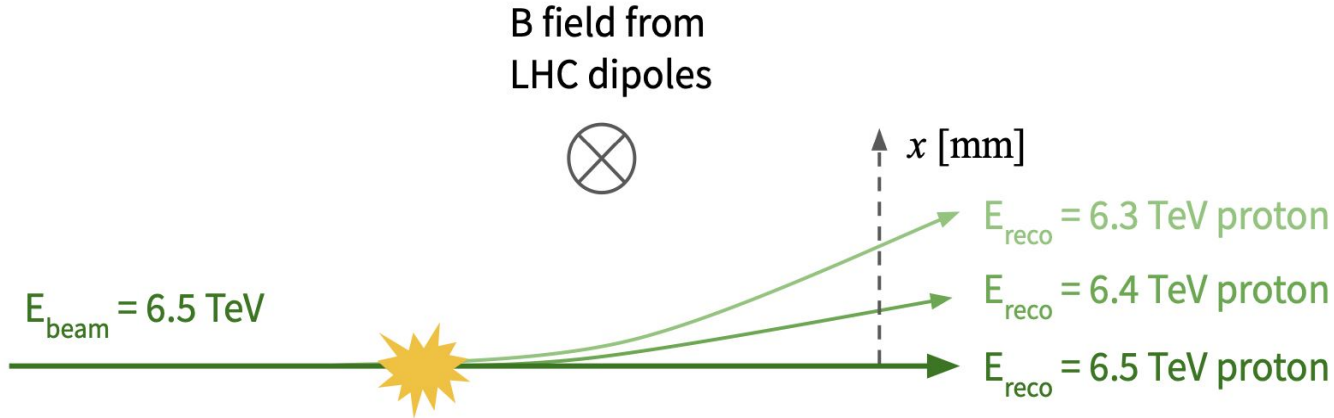
2402.06438



AFP in-situ global alignment

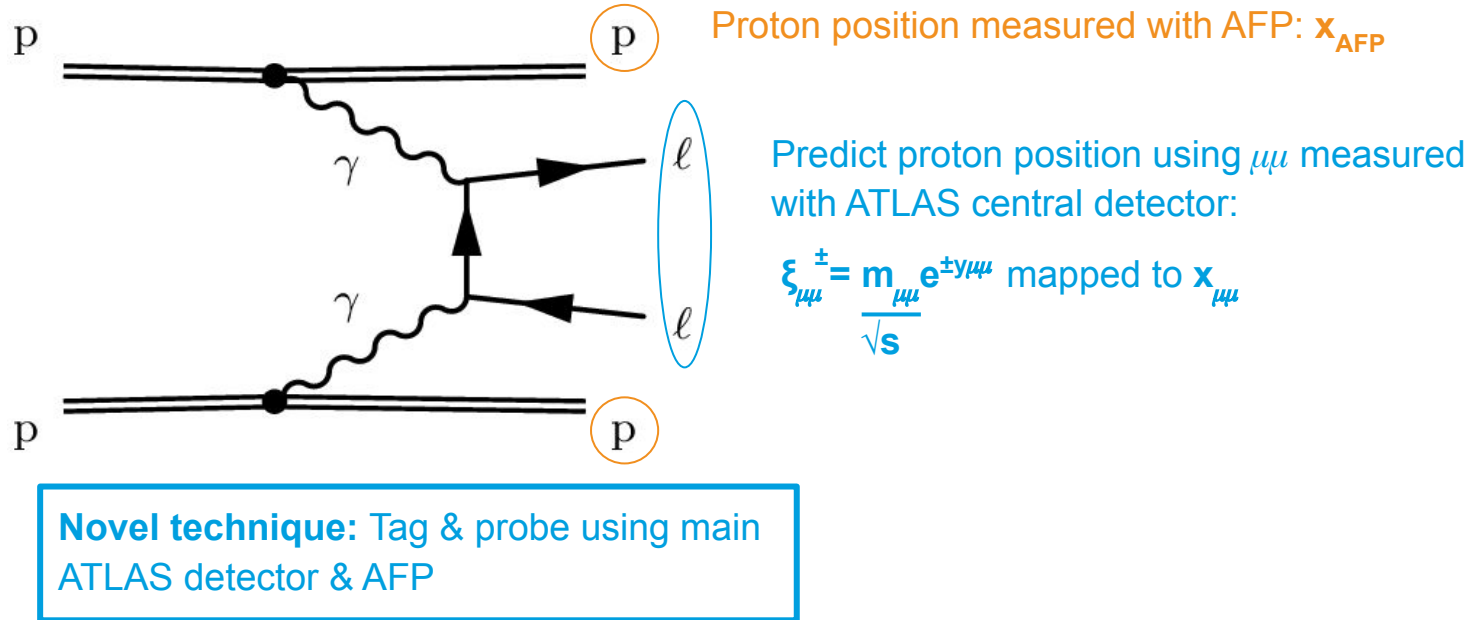
Position protons hit AFP SiT x_{AFP} depends on relative proton energy loss $\xi_{\text{AFP}}^{\text{A,C}} = 1 - \frac{E_{\text{reco}}}{E_{\text{beam}}}$

→ Need to align detectors!



AFP in-situ global alignment

After inter-plane alignment & beam based alignment perform final in-situ step of global alignment

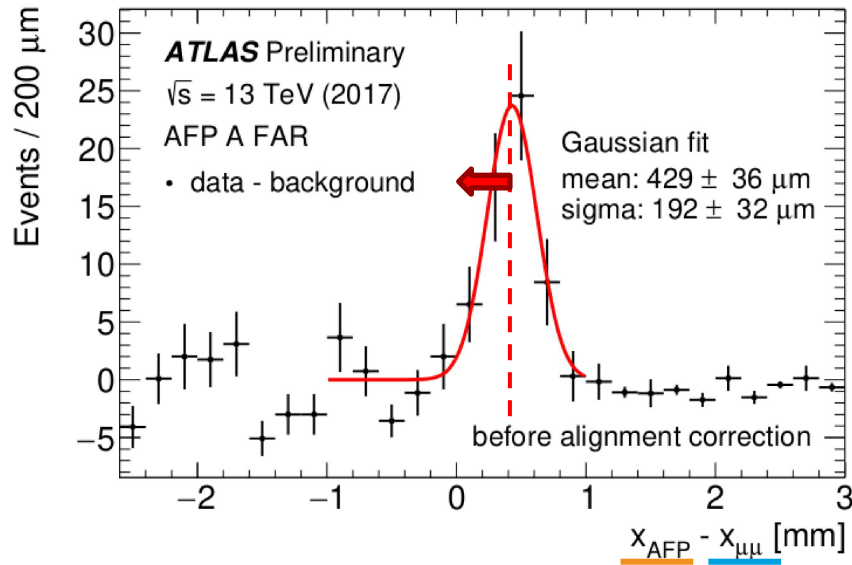


Comment: replace equation & symbols with LaTeX versions

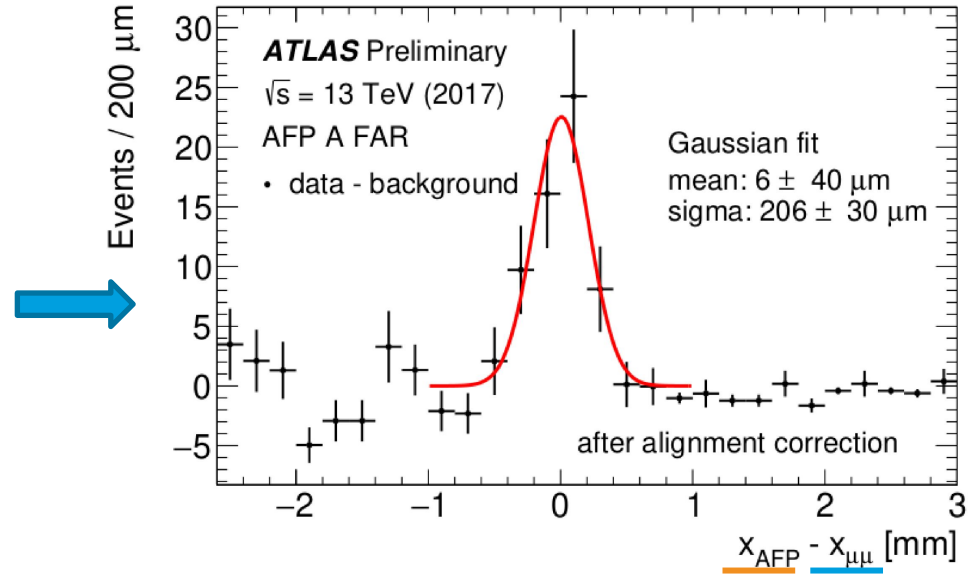
AFP in-situ global alignment

Fit and shift $x_{\text{AFP}} - x_{\mu\mu}$ for each station \rightarrow Alignment constants

Before in-situ alignment



After in-situ alignment



Systematic uncertainty of $\pm 300 \mu\text{m}$ in Run 2

DESY performing in-situ
global alignment for Run 3

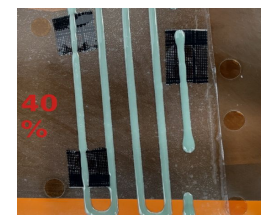
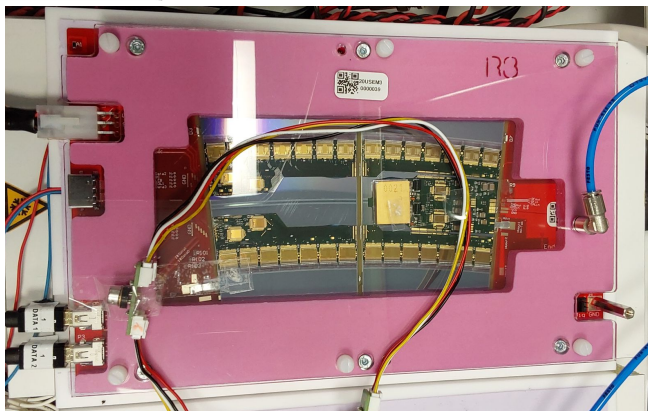
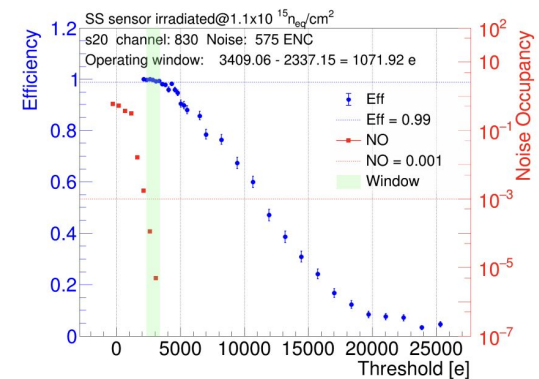
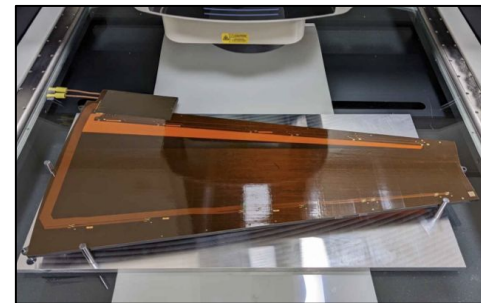
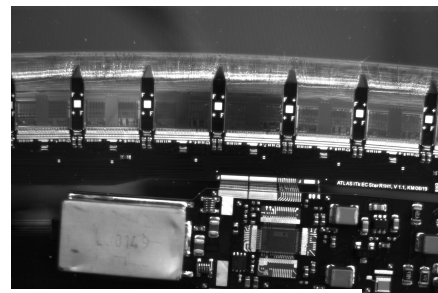
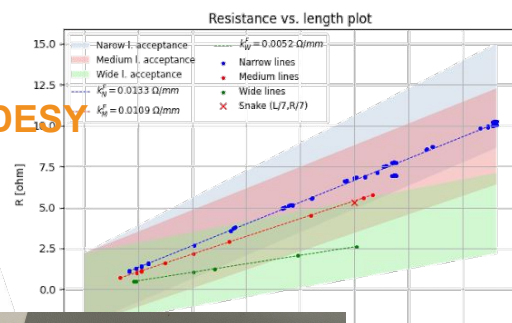
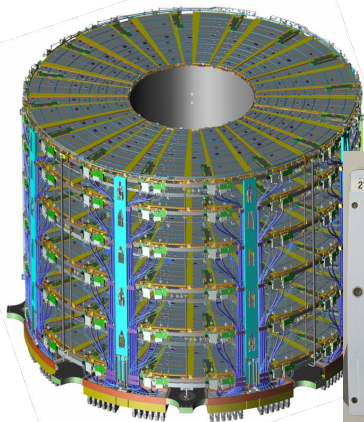
ATLAS detector upgrade

Inner Tracker (ITk) end-cap

Huge DESY endeavor: responsible for building one ITk end-cap & more

The ITk

Lots of progress at DESY



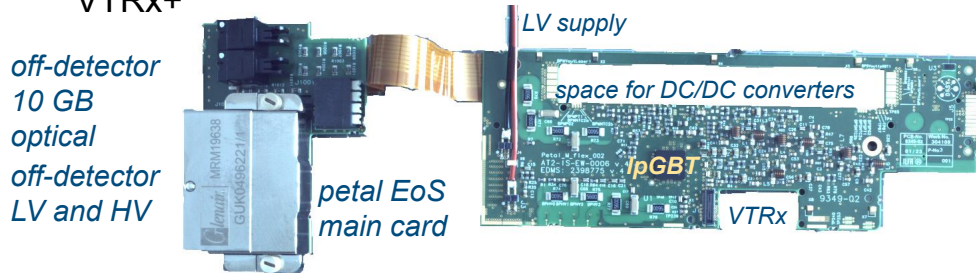
... and much more! Here only some highlights

In Production: End of Substructure (EoS) Card

Gateway between on- and off-detector systems – data, communication, power

QC = quality control
QA = quality assurance

- DESY is building EoS cards for endcap and barrel ITk strips
- Designed at DESY around the CERN ASICs: IpGBT and VTRx+



Main EoS card for petal. Space for DC/DC converters and VTRx.

Pre-production with prototype and final ASICs finished. Production started

- **Deliverable:** a total of **1552 cards** plus spares
 - 2 types of cards for end-caps
 - 12 types of cards for barrel (due to geometry)
- Cards from industry, loading and testing at DESY
- Elaborated QC chain, including e.g. bond pad pull test, X-ray, optical and IR imaging, etc.
- **Pre-production:** 130 cards for card QA and petal & stave population
DONE
- **Production:**
 - 75% of all electrical test structure delivered
 - EoS cards: >40 cards done (~3%)
- EoS card production is not going to limit petal or stave production

Building fully loaded Petals

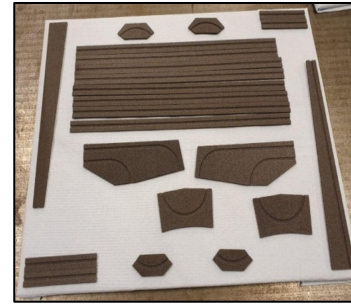
Pre-production ongoing - input to ongoing studies

- Production of parts for petal cores in-house well under way
- First six petal cores produced in industry and about to get QC'ed
- First pre-production-B petal (final parts) fully loaded at DESY
- DESY strongly contributing to ongoing studies to get ready for production

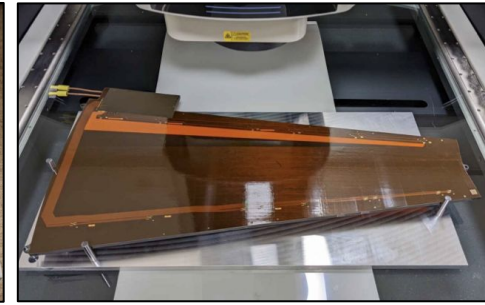
DESY is ready to produce and complete fully loaded petals.



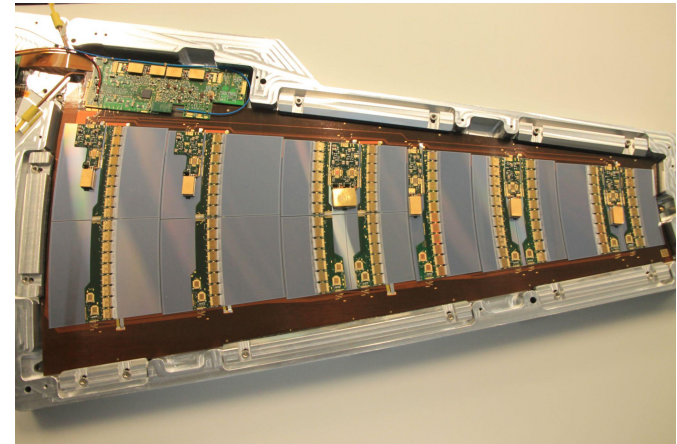
First tests with Hysol, loaded with different fractions of alumina filler



*Thermal foam set
(60% blocks received)*



*Pre-production core undergoing
geometrical metrology*



First PPB fully loaded petal@DESY

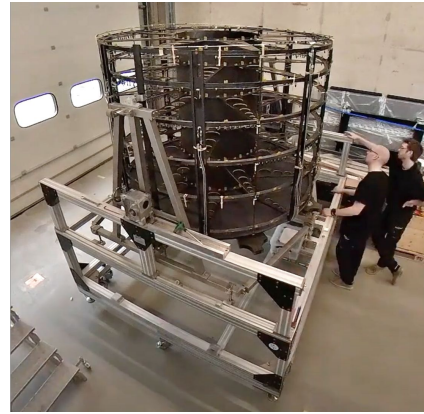
Moving towards Full End-cap

Getting ready for petal installation

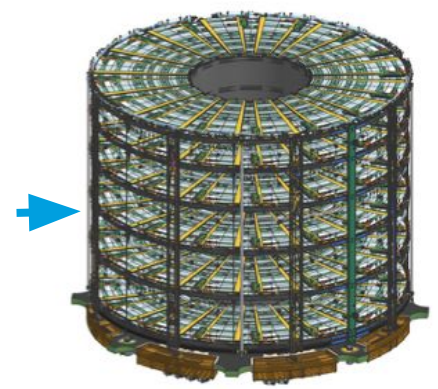
- The skeleton for the DESY end-cap (EC1) is **ready** at Nikhef
 - Getting ready for transport to DESY in early July
- Cooling infrastructure in commissioning
- Petal insertion procedure proven in system test at DESY and in the EC structure at Nikhef
 - All needed hardware in hands
- Assembly platforms delivered last week

DAF in Building 26 is filling up
and getting ready
for the full end-cap

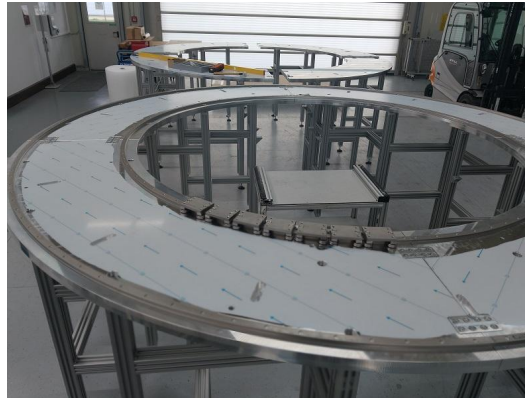
*Comment: pics to be replaced
by new ones before PRC*



*EC1 mounted on the
superframe@Nikhef*



CAD of fully loaded EC



Tower platform (left) and access platform (right) built at company

Summary

Beams are back: 2024 proton running in progress

DESY ATLAS:

- Making significant contributions to detector operations, performance, tools & software
- Leading role in many impactful data analyses yielding exciting new results & publications
- Team fully committed to the ATLAS upgrade and delivering a whole end-cap for the ITk Detector



Backup

LHC luminosity status

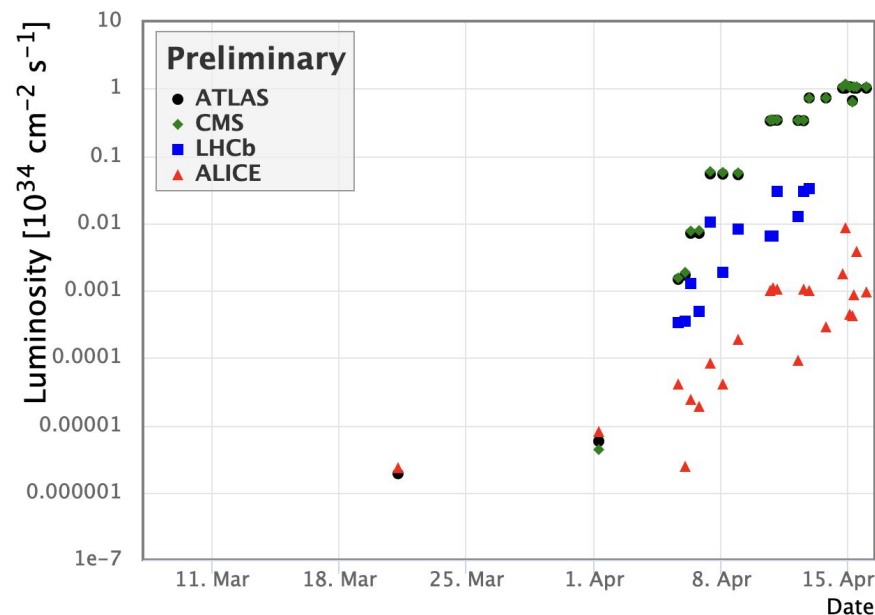
- Peak luminosity slightly higher for CMS than ATLAS (1-2%)
- Update of CMS calibration may increase difference
- Update by ATLAS on 1 May may reduce it again

Delivered 2024 luminosity

Preliminary

● ATLAS : 1.525 fb^{-1}
◆ CMS : 1.534 fb^{-1}
■ LHCb : 0.0188 fb^{-1}
▲ ALICE : 0.00228 fb^{-1}

Peak luminosity in 'Stable Beams'



Comment: update with latest figures before PRC