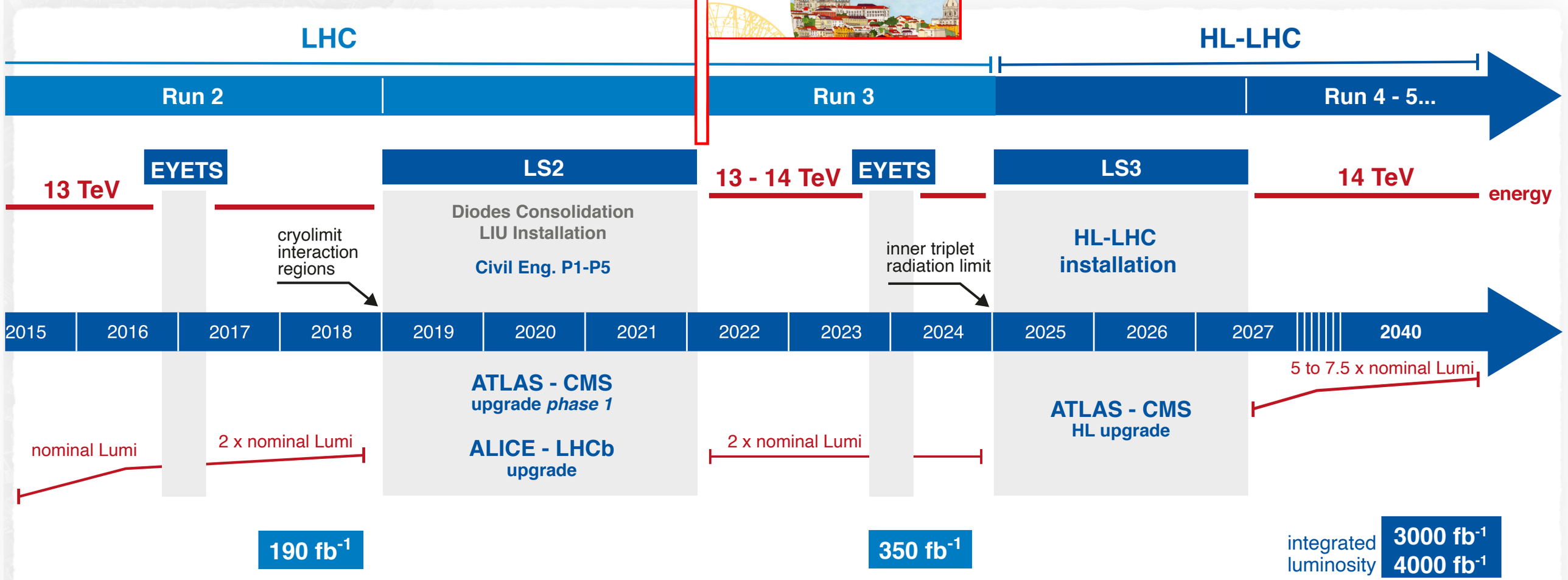
INFN ROMA
Istituto Nazionale di Fisica Nucleare
Sezione di Roma

Prospects for BSM at LHC (experimental vision)

Livia Soffi on behalf of ATLAS and CMS Collaboration

Setting the stage



- **Long Shutdown 2** (Phase-1 upgrade) preparing **Run 3**
  - Luminosity at 2 x 10^{34}/cm^2/s, possible increase to $\sqrt{s}$=13.6 or 14 TeV

- **Long Shutdown 3** (Phase-2 upgrade) preparing **HL-LHC**
  - Luminosity at 7.5 x 10^{34}/cm^2/s at $\sqrt{s}$=14 TeV
  - Large data samples and major experimental challenges

Run 2 close out

LHC

Run 2

EYETS

13 TeV

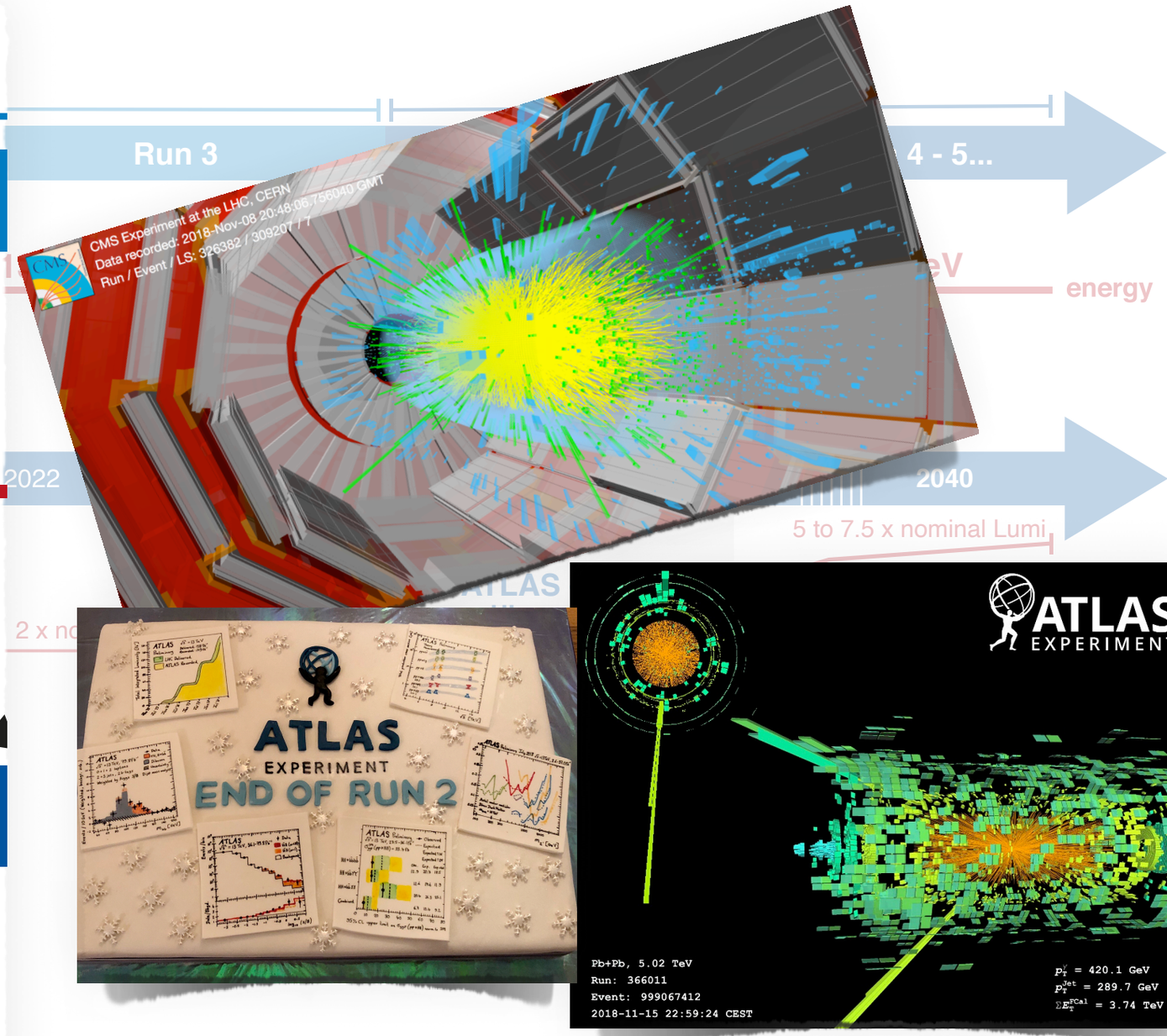
cryolimit
interaction
regions

2015 | 2016 | 2017 | 2018

nominal Lumi

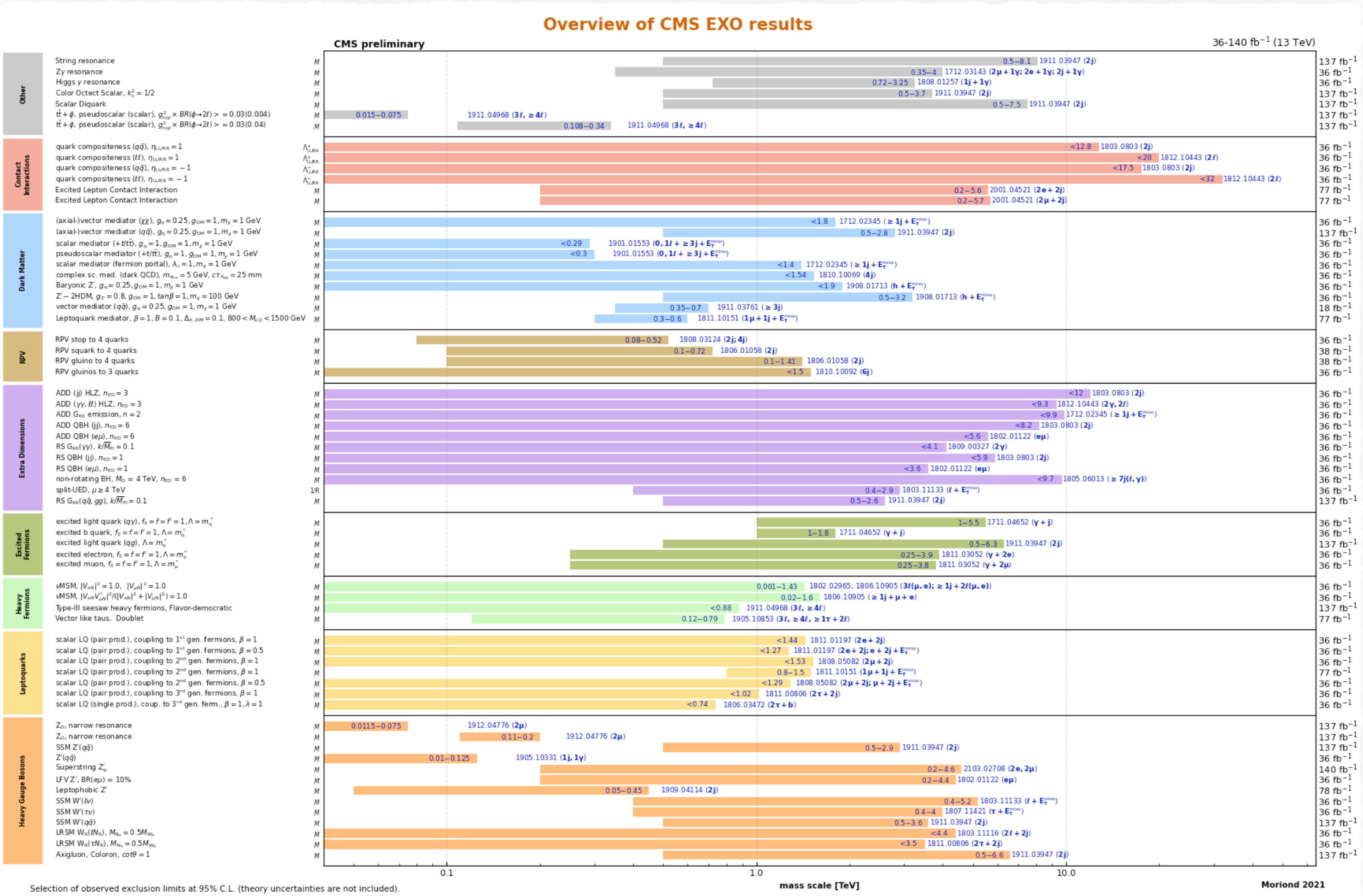
2 x nominal Lumi

190 fb^{-1}



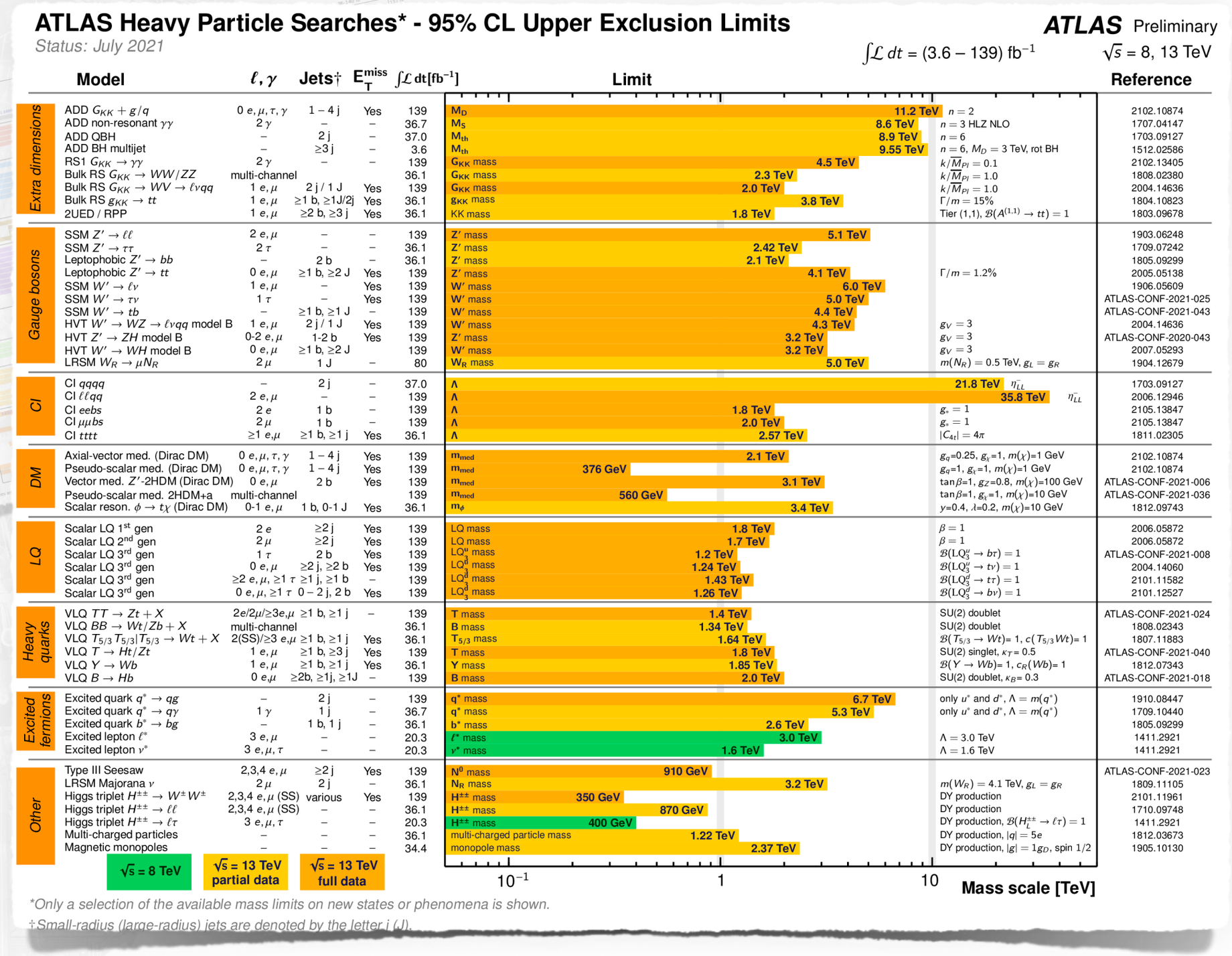
Run 2 extraordinary exploration of the high-energy frontier!

A New Understanding of Particle Physics



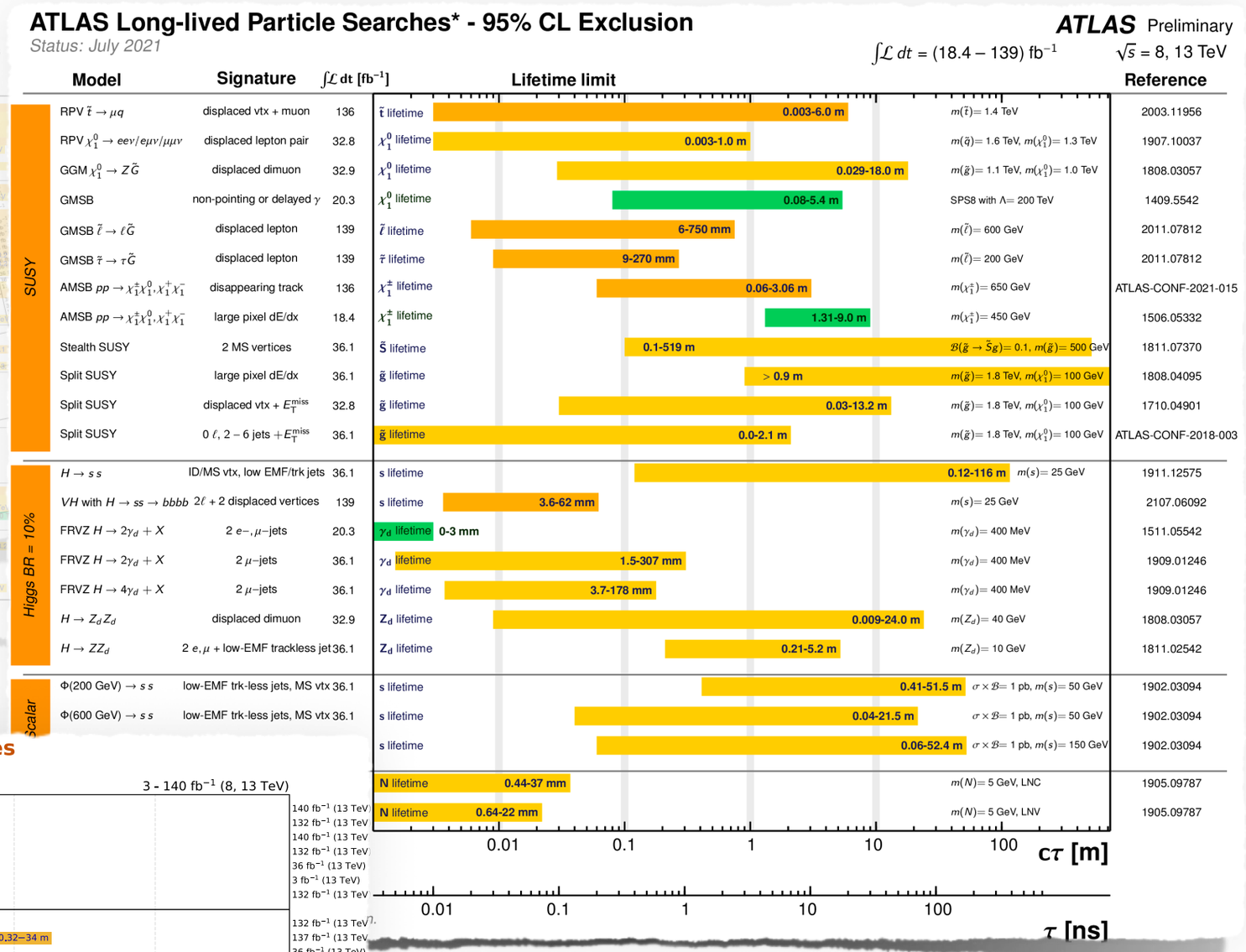
CMS EXOTICA Summary 2021

A New Understanding of Particle Physics

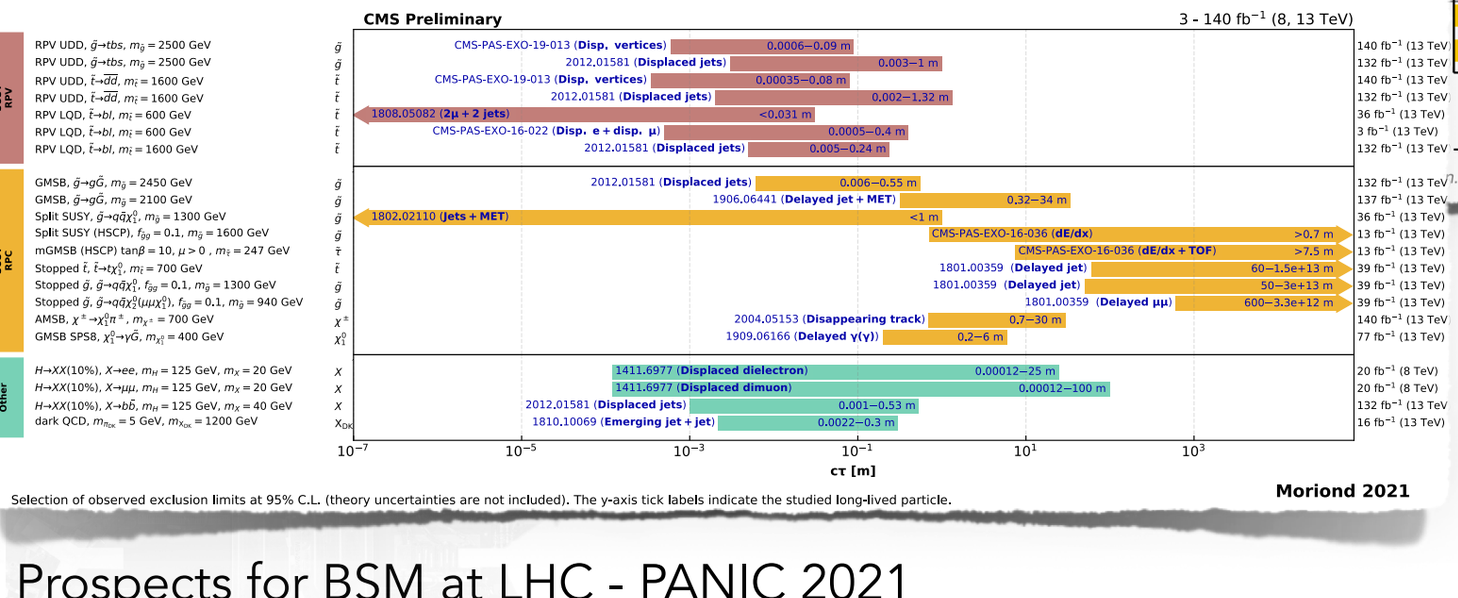


ATLAS EXOTICA Summary 2021

Focus on Long Lived Particle Physics

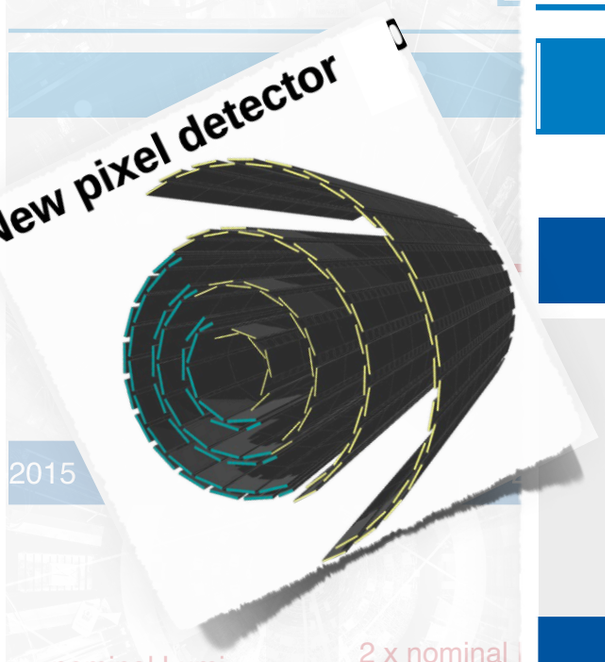


Overview of CMS long-lived particle searches



Selection of observed exclusion limits at 95% C.L. (theory uncertainties are not included). The y-axis tick labels indicate the studied long-lived particle.

Long Shutdown 2: preparing for Run 3



Run 3					
LS2			13 - 14 TeV	EYETS	
2019	2020	2021	2022	2023	2024

Diodes Consolidation
LIU Installation

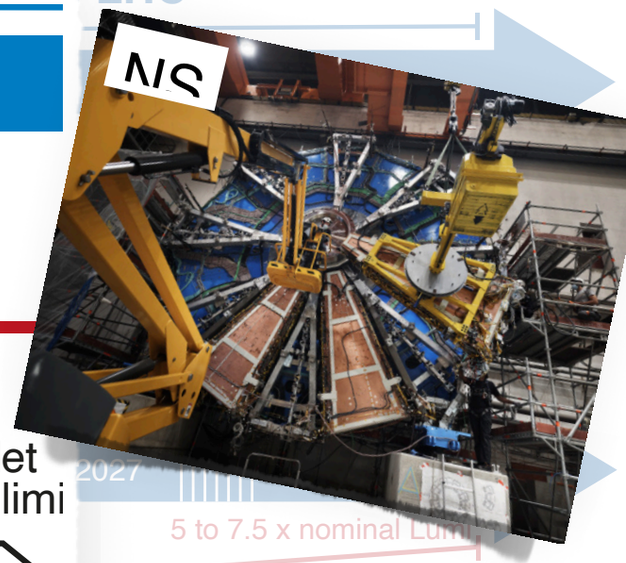
Civil Eng. P1-P5

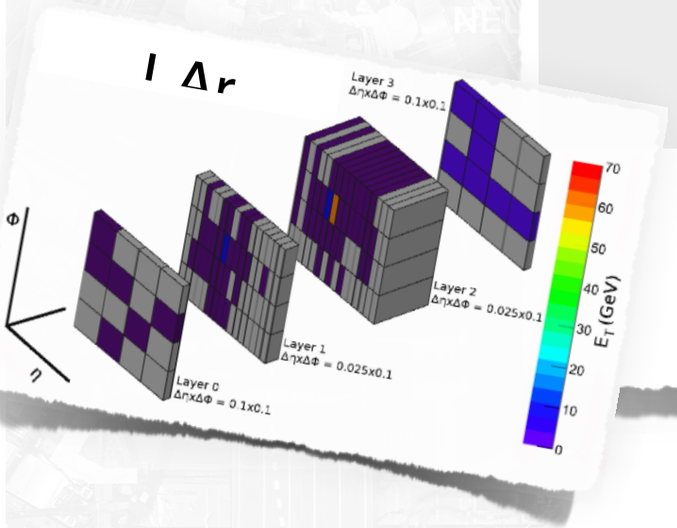
ATLAS - CMS
upgrade *phase 1*

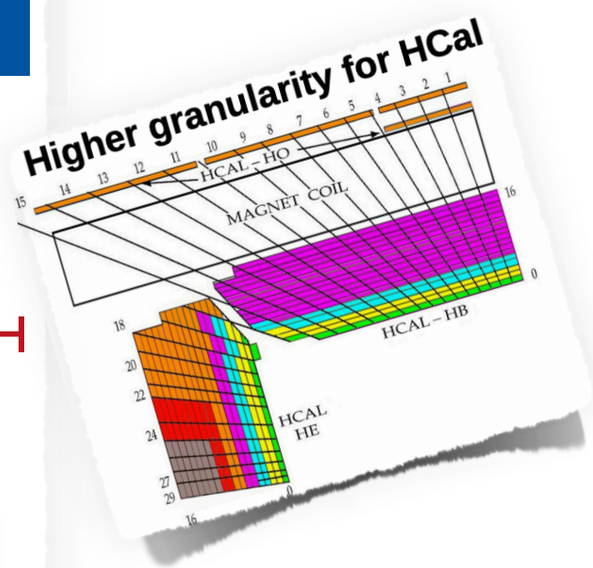
ALICE - LHCb
upgrade

2 x nominal Lumi

350 fb^{-1}



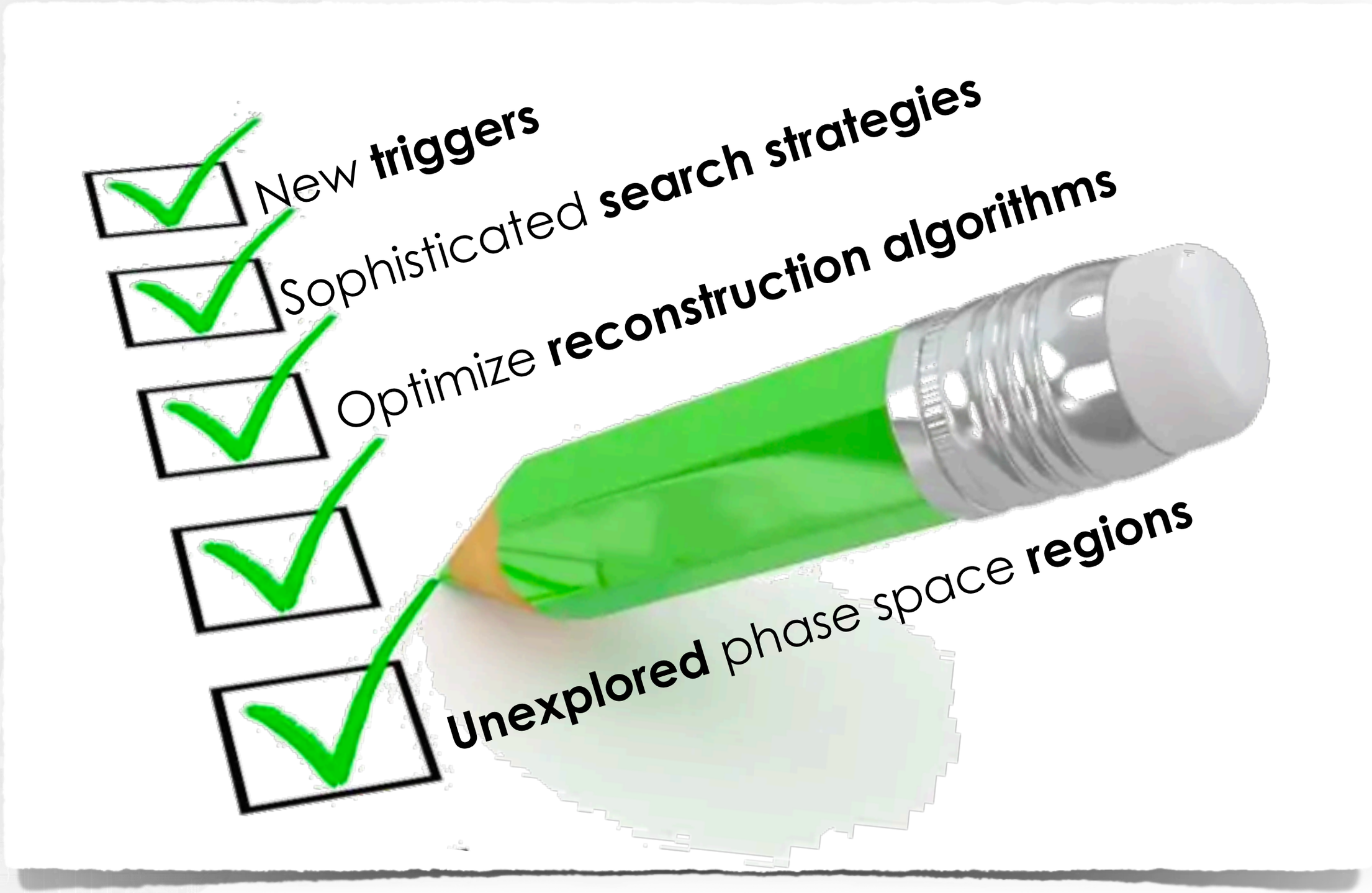




Run 3 approaching fast.. getting ready!

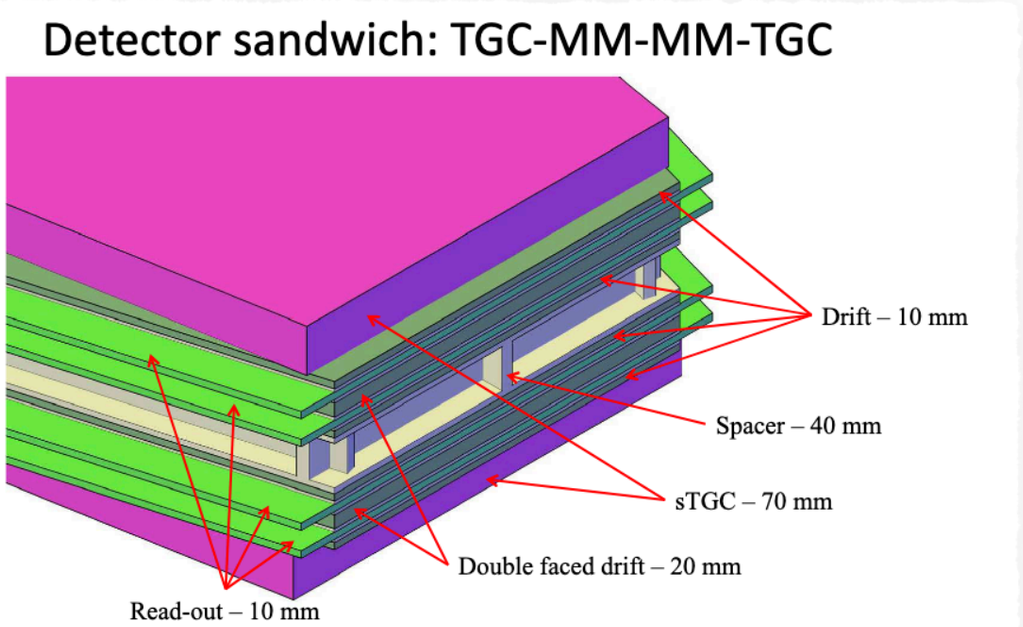
Planning up to Run 3

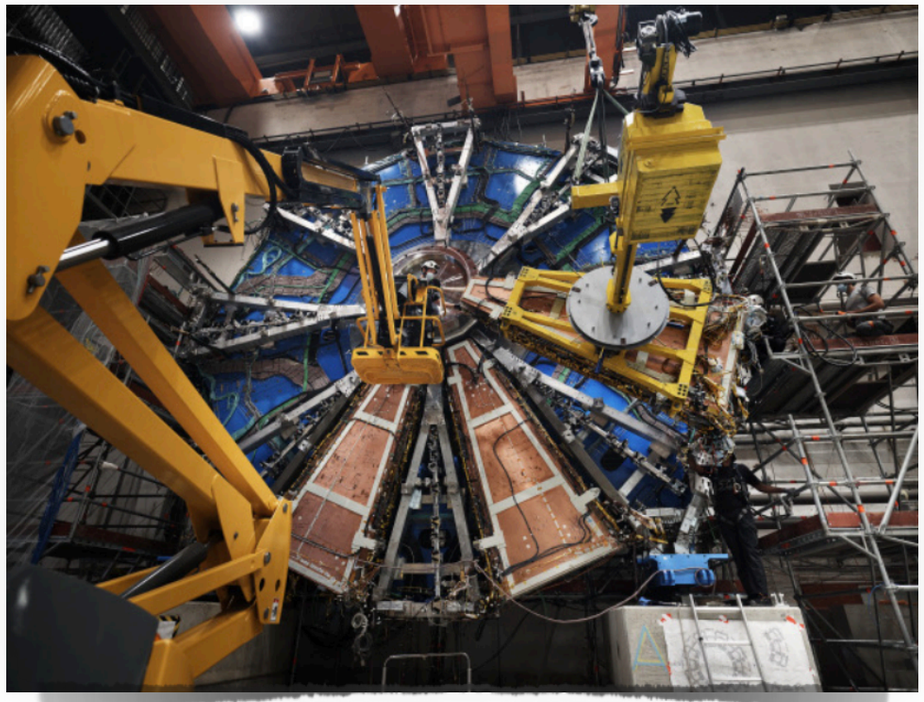
- **Reach search program** in preparation for run 3



Trigger Developments for Run 3:ATLAS

- **ATLAS New Small Wheel**: Fast readout and precision tracking resolution





- **ATLAS LAr L1**:Coarse trigger towers replaced by super cells: Improved fake rejection and maintain low EM trigger thresholds

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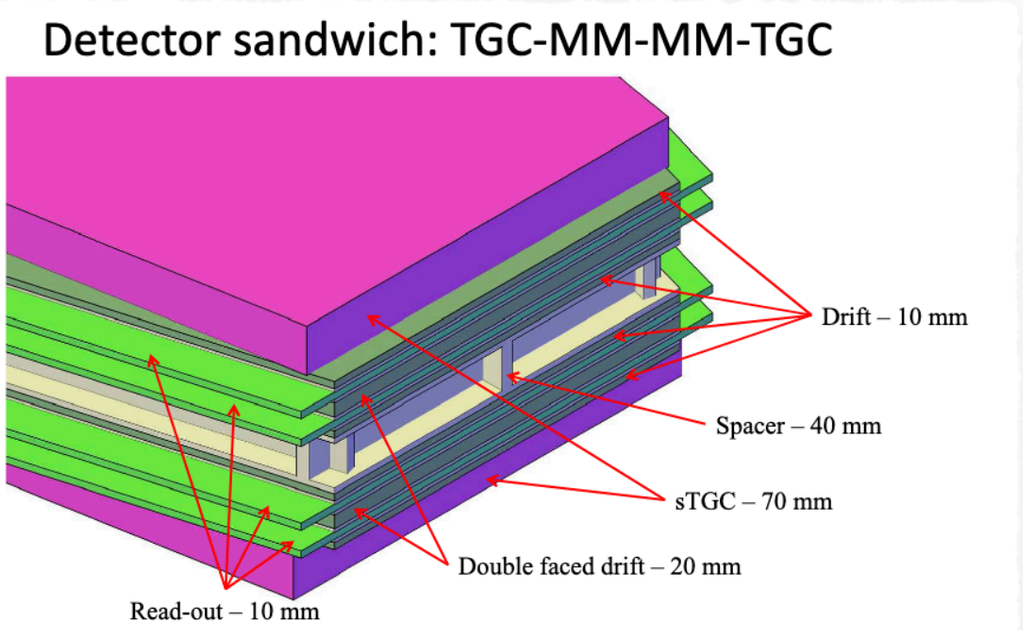

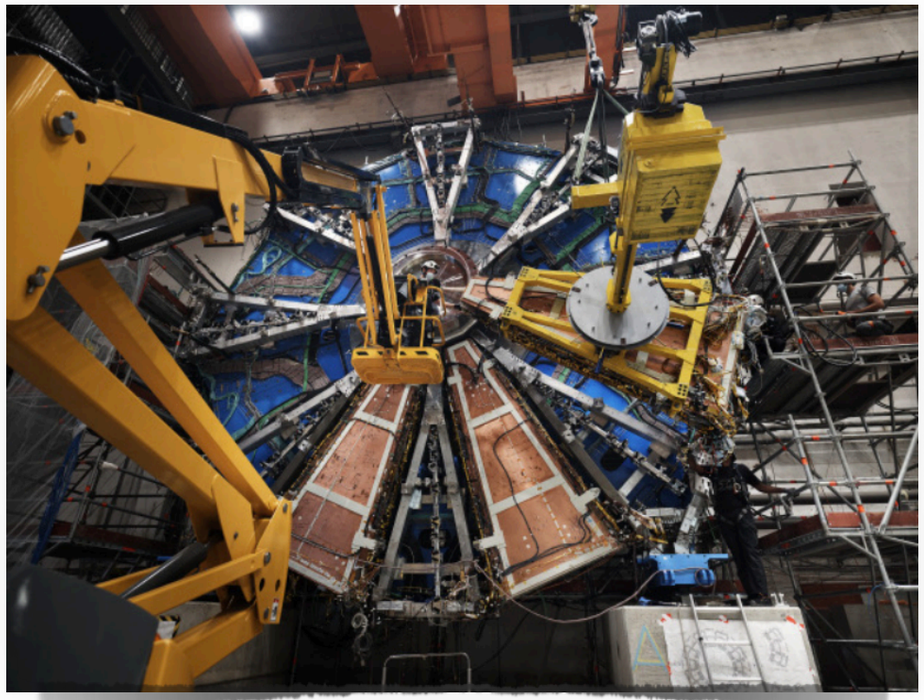

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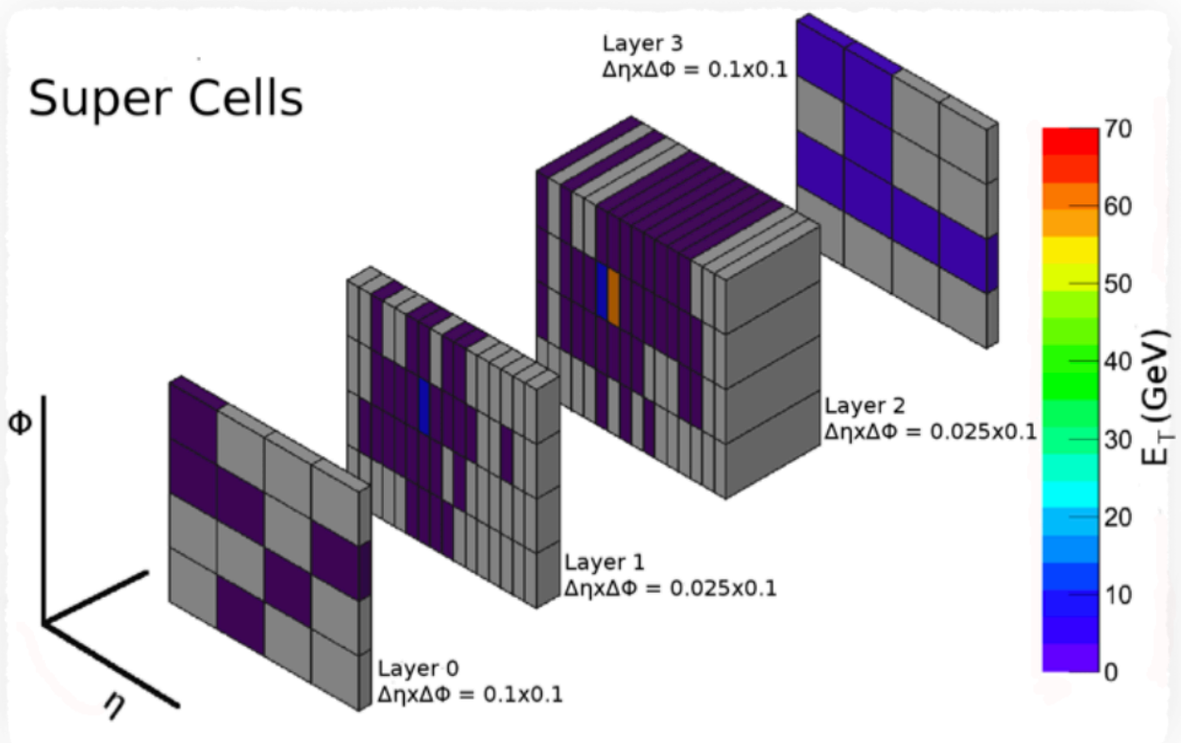
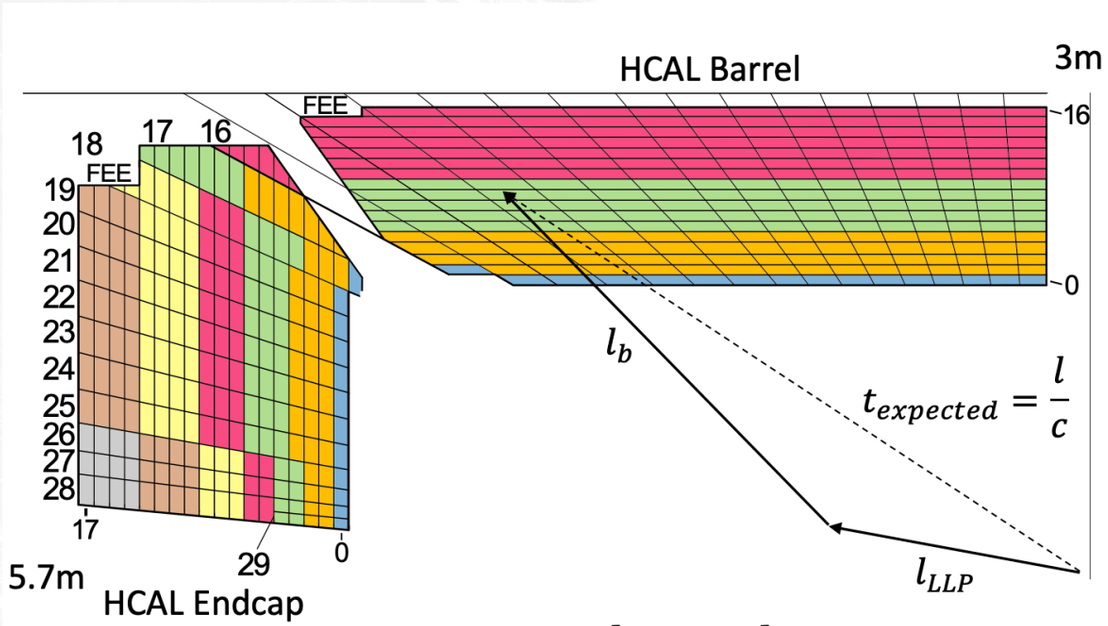
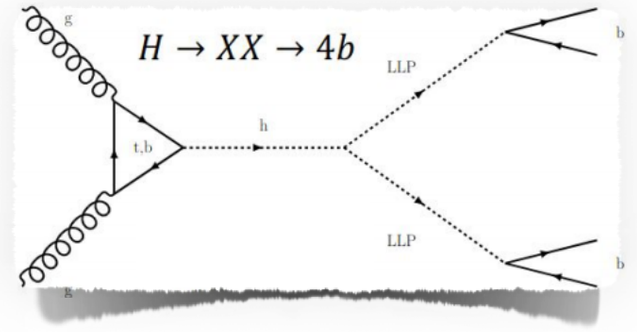


Trigger Developments for Run 3:CMS

- New **handles at CMS** L1 trigger on objects that do not come from the primary vertex
  → Target long-lived particle **(LLP) signatures**

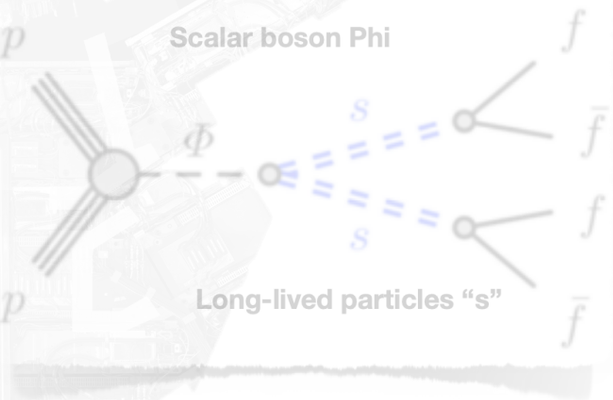


$$\Delta t = \frac{l_{LLP}}{v_{LLP}} + \frac{l_b}{c} - t_{expected}$$



- LLPs using **HCAL timing**, **depth+H/E**
  → Target displaced jets that would be otherwise missed due to high trigger thresholds (e.g. HT360)

- New **CMS L1 Muon system algorithm** including also **GEM chambers**



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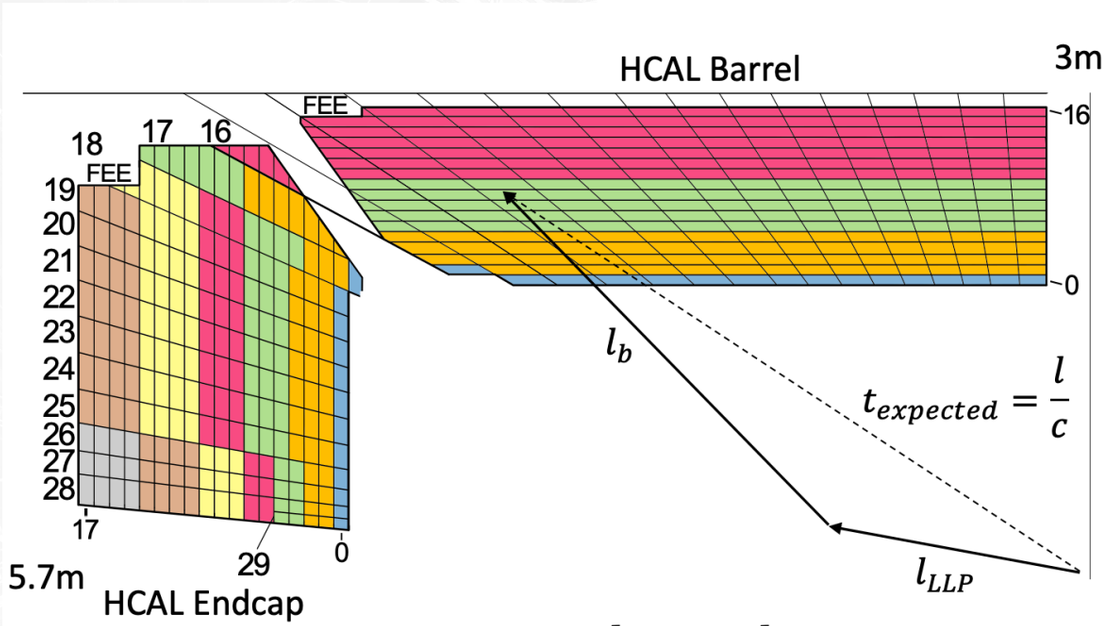

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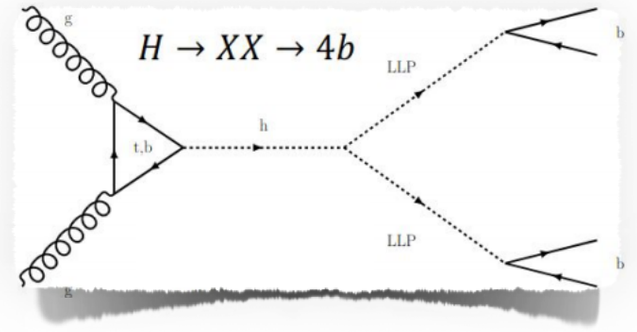

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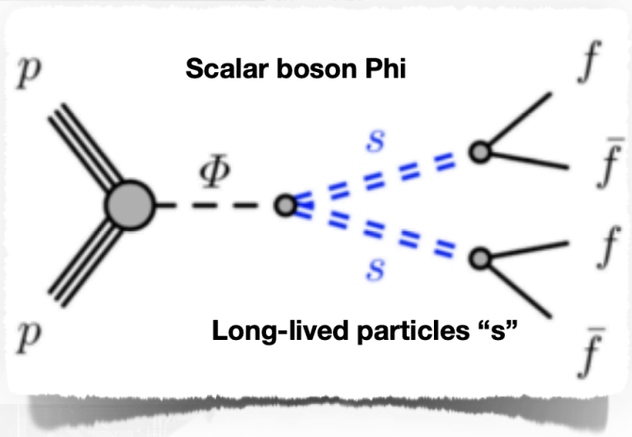
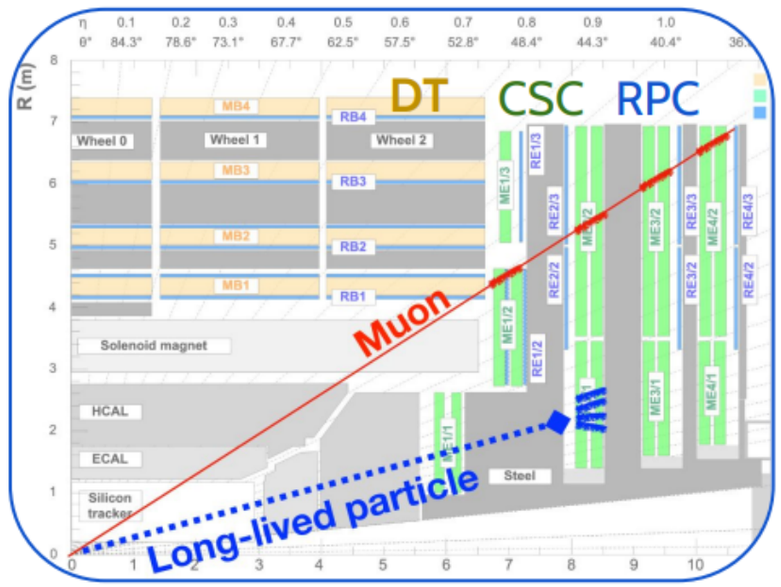
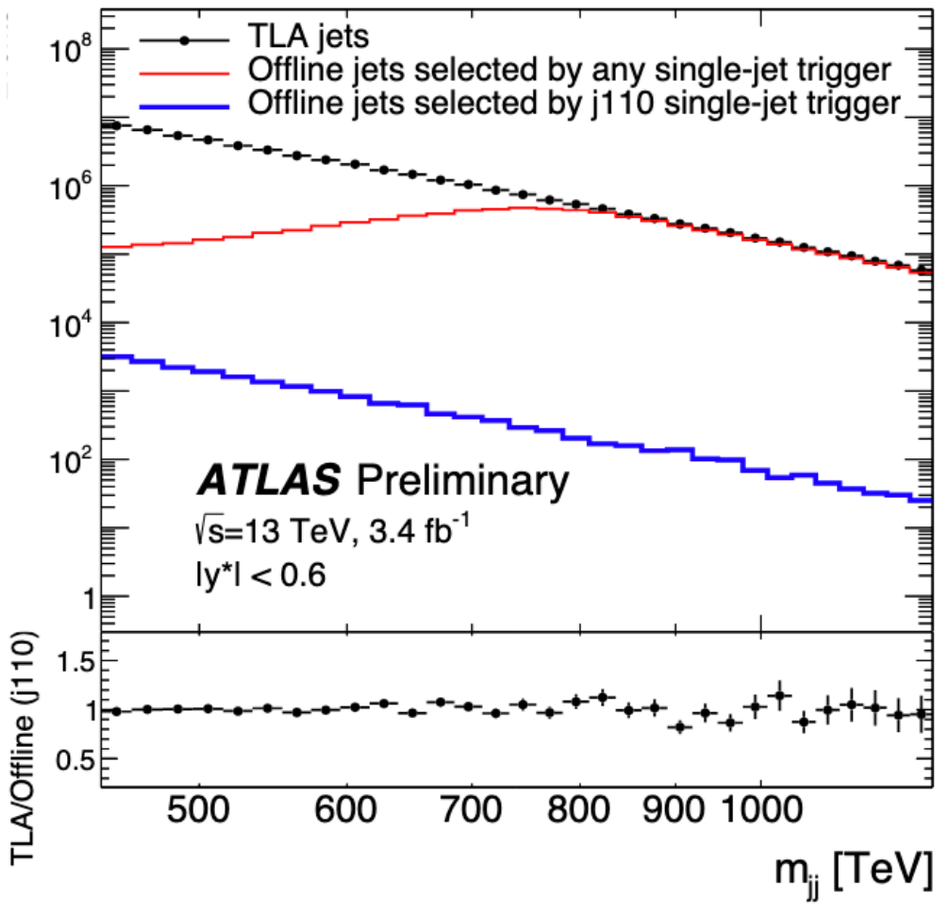


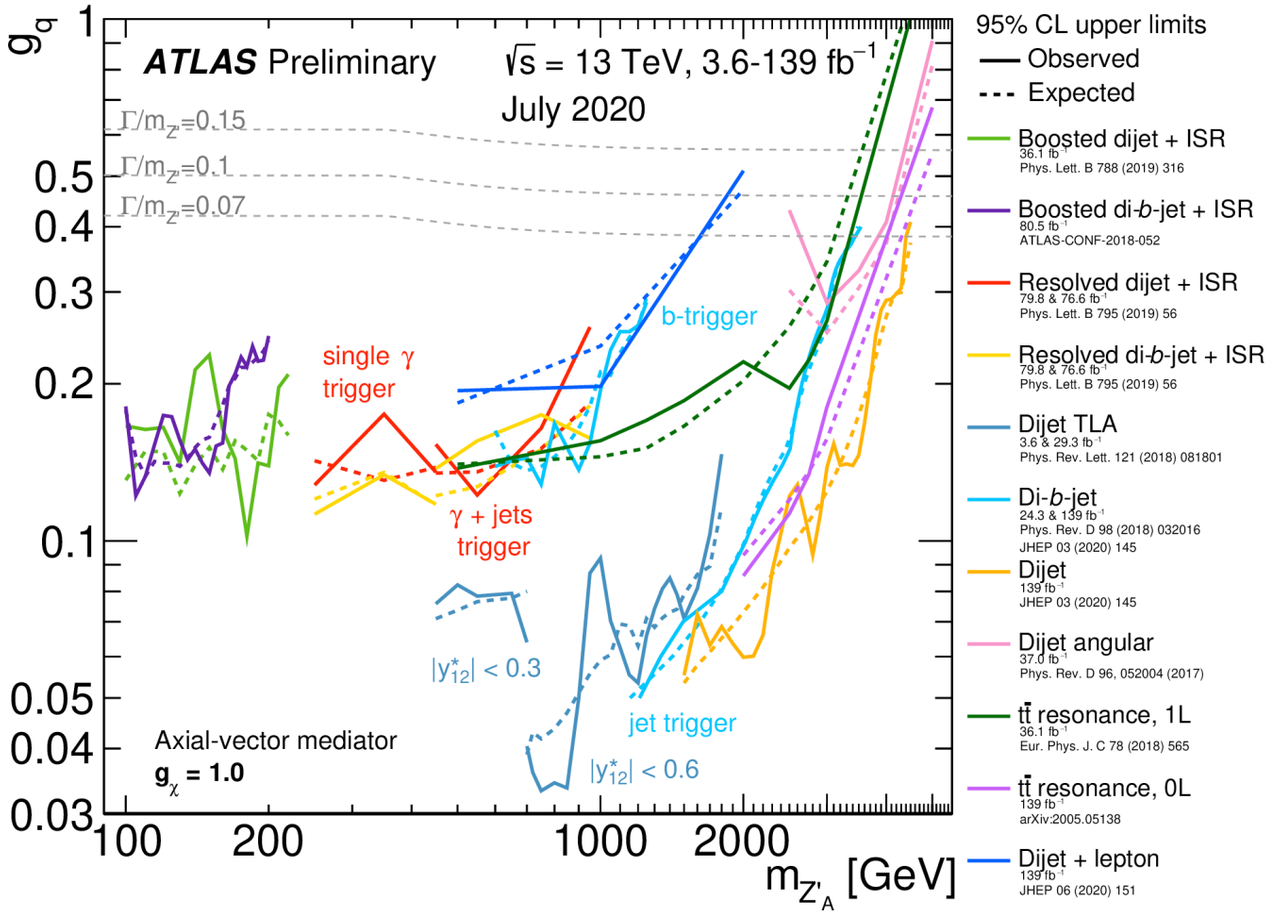


Unconventional Data Taking

- Novel idea to **circumvent bandwidth limitation** w/ **partial event building**
- Going beyond the 1-kHz limit in two ways:
  - **"data scouting"** → saving only objects reco'd at trigger level
  - **"data parking"** → offline reconstruction is delayed.

ATLAS-CONF-2016-030

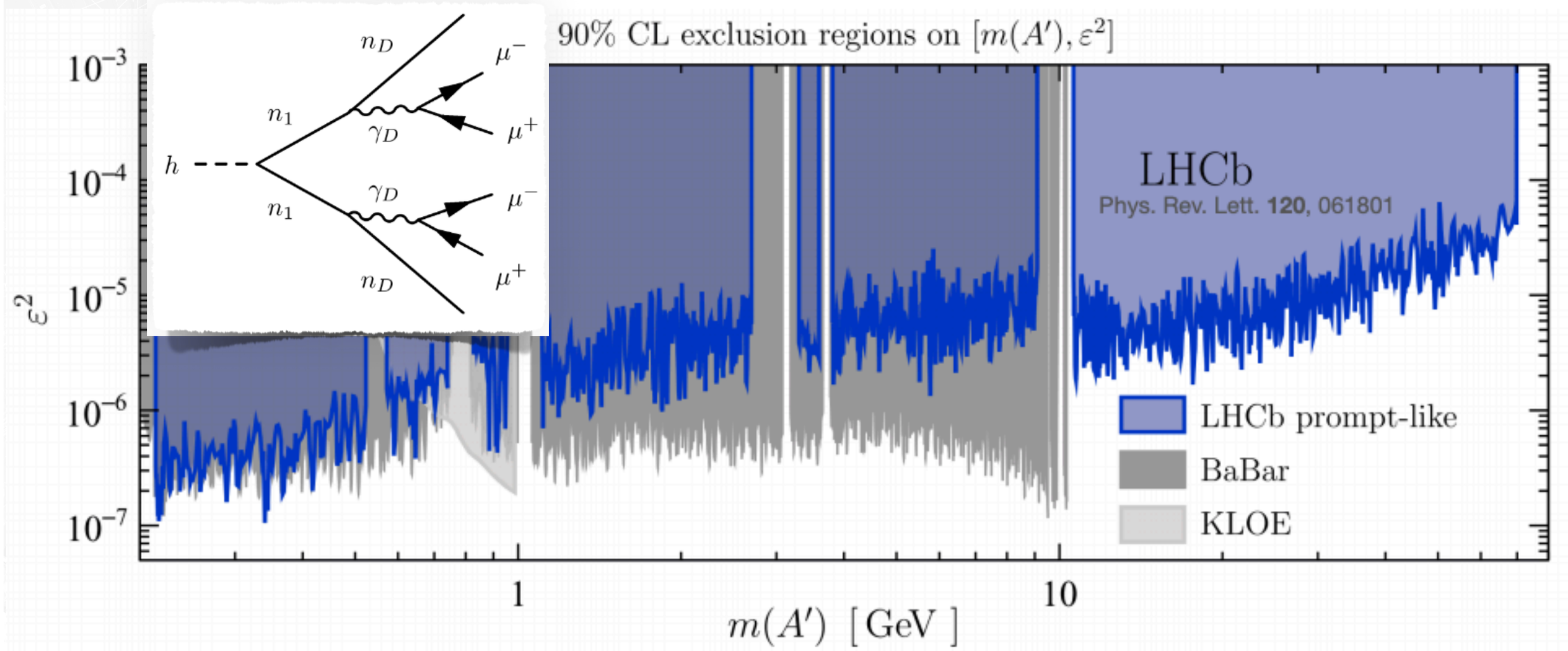




ATLAS EXOTICA Summary Plots 2021

Keep an eye on the other side of the ring

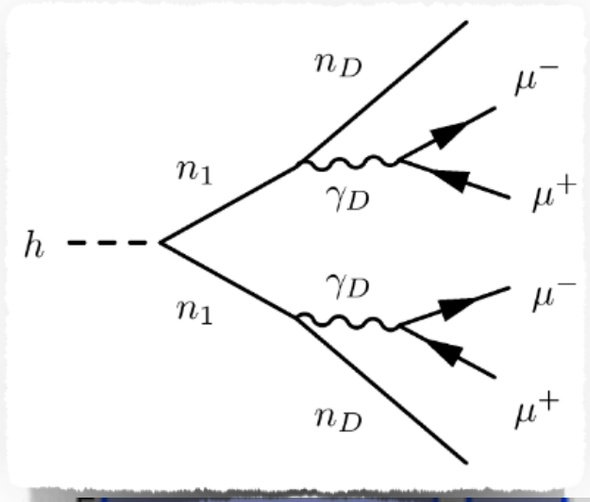
- Most spectacular example of vector portal address SM problems: dark photon



PhysRevLett.120.061801

- If epsilon < 10^{-5} A' **can be long-lived**
- Main **challenge for ATLAS/CMS is triggering** and discriminating backgrounds

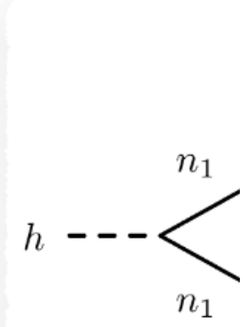
Muon Scouting at CMS

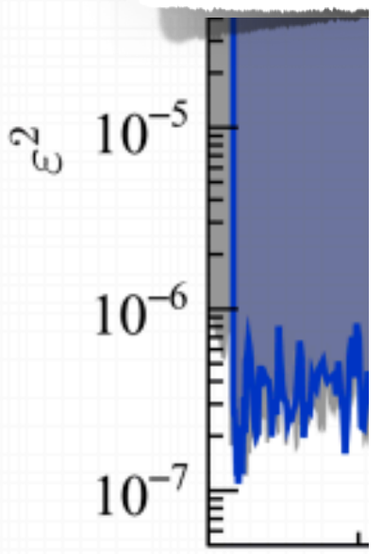


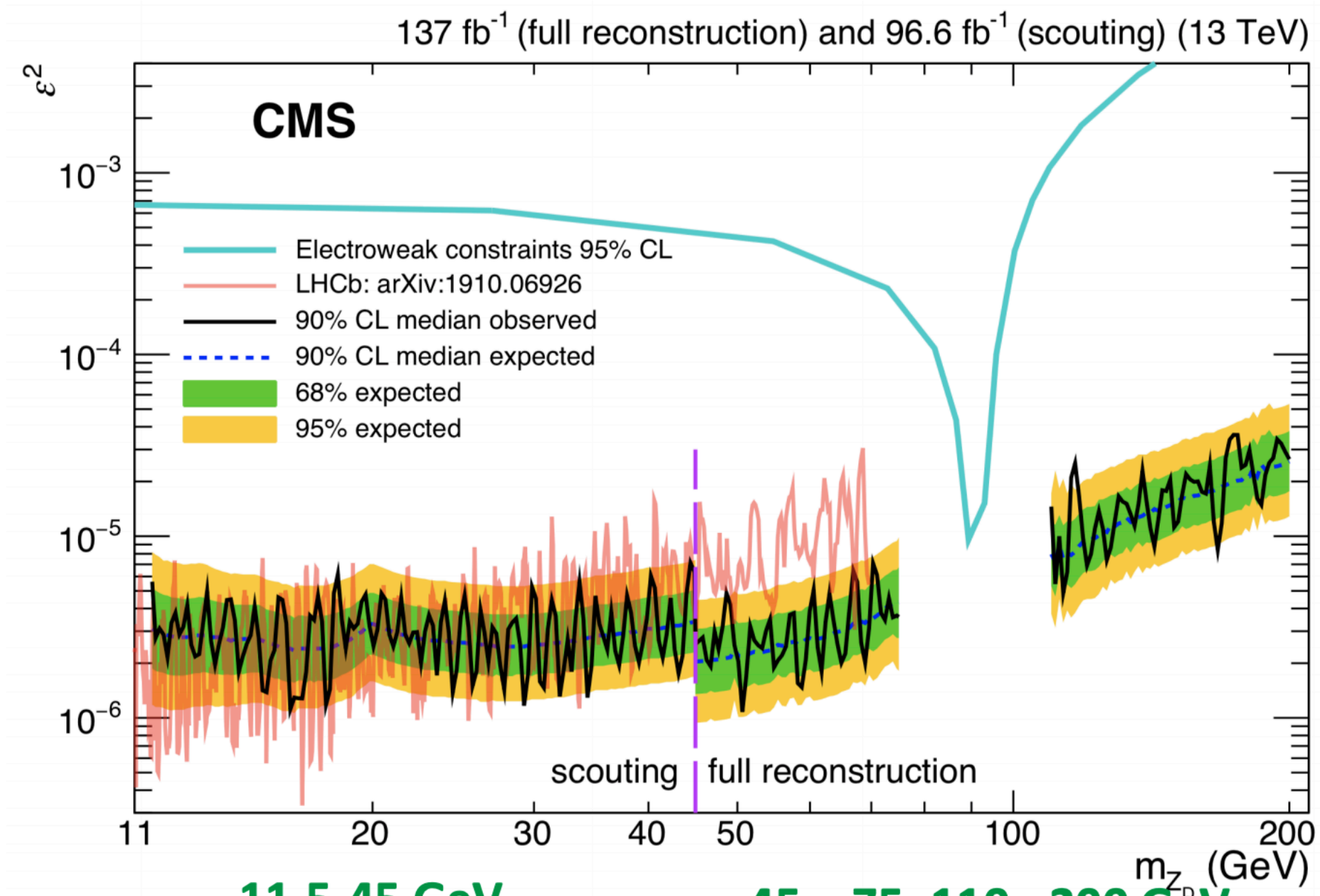
Scouting

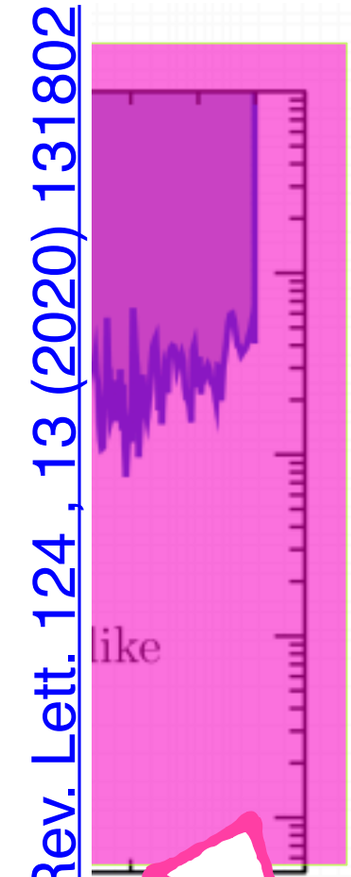
Standard Trigger

Muon Scouting at CMS









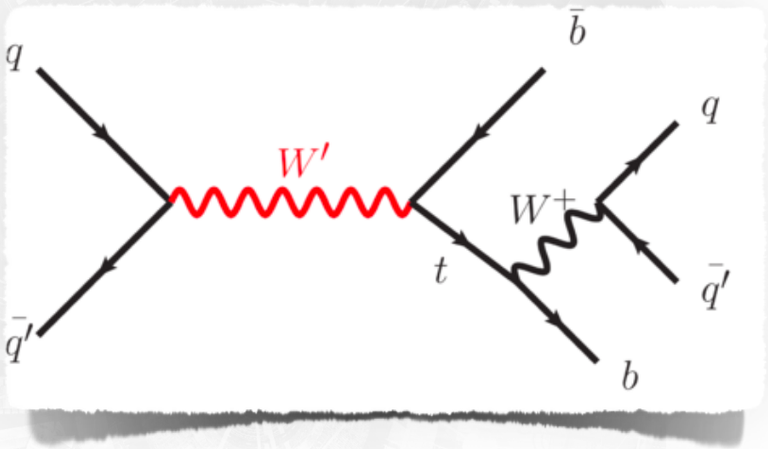
11.5-45 GeV
scouting

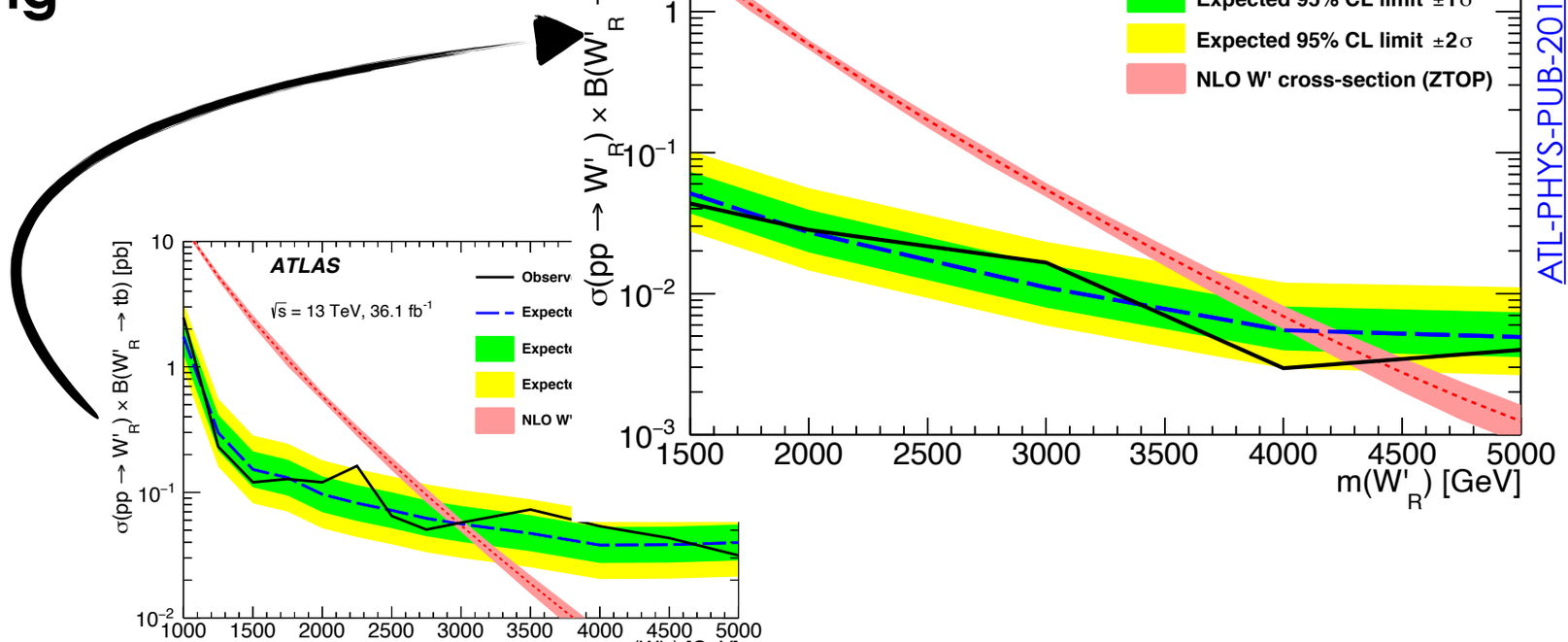
45 – 75, 110 - 200 GeV:
full reconstruction

lard
ger

Novel analysis techniques

- Multivariate **jet tagger using deep neural network**





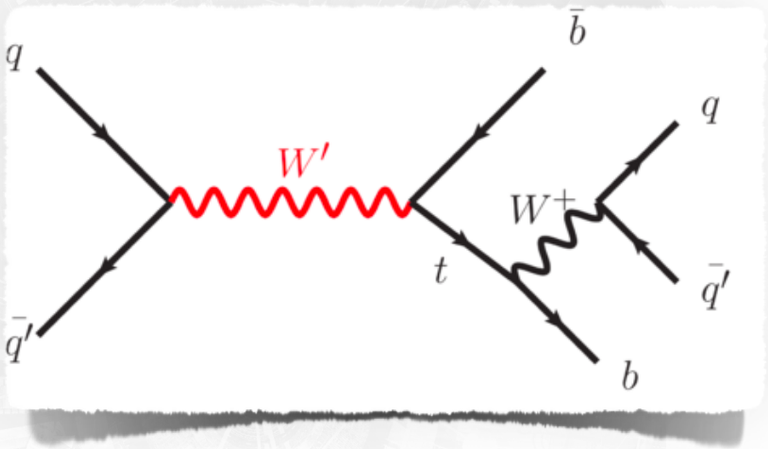
ATL-PHYS-PUB-2017-013 ATLAS-CONF-2021-043
ATLAS-CONF-2017-064

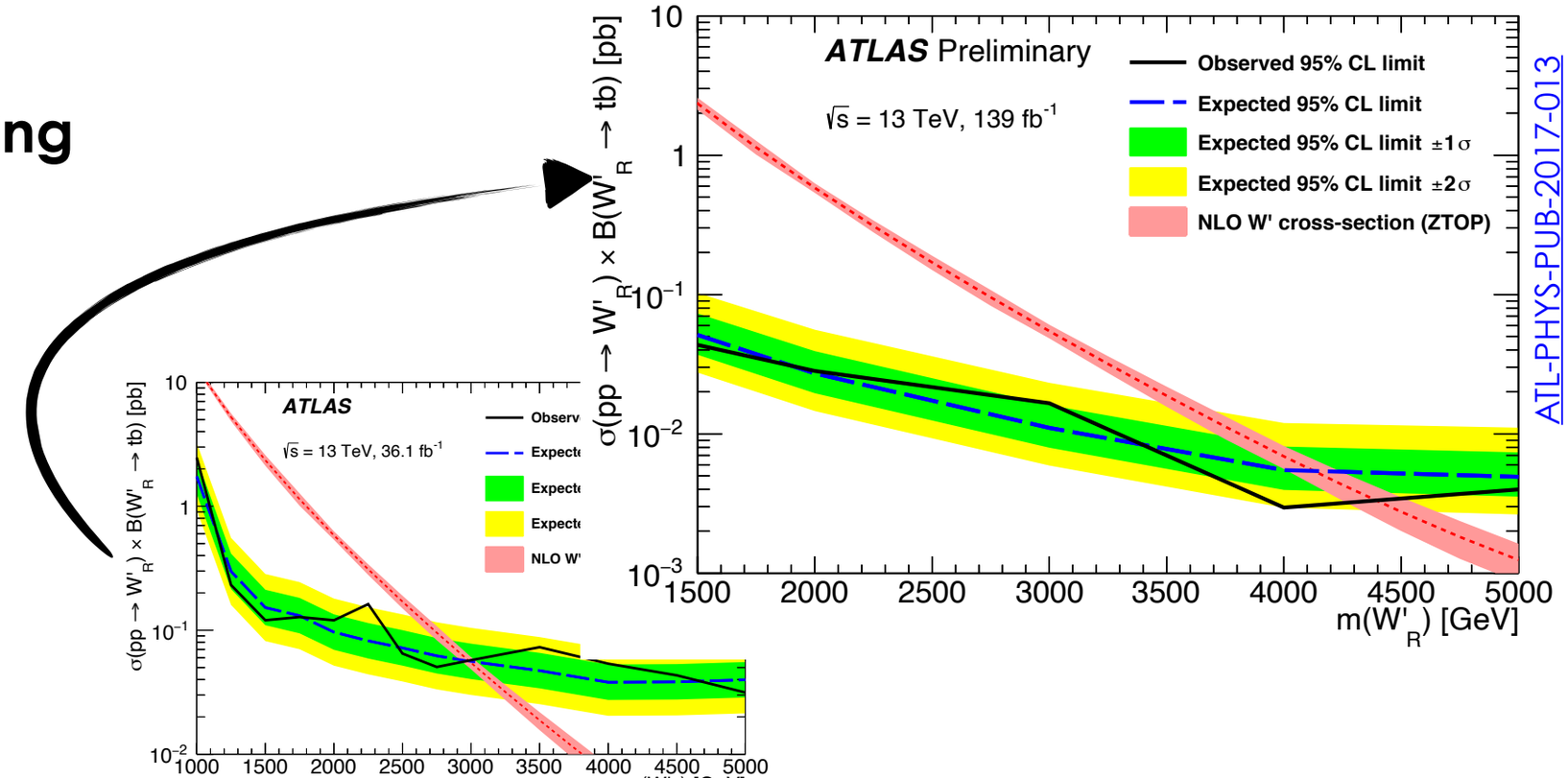
- Large large impact parameter **tracking**

ATL-PHYS-PUB-2021-012 ATL-PHYS-PUB-2017-014
EXOT-2018-57

Novel analysis techniques

- Multivariate **jet tagger using deep neural network**





ATL-PHYS-PUB-2017-013 ATLAS-CONF-2021-043
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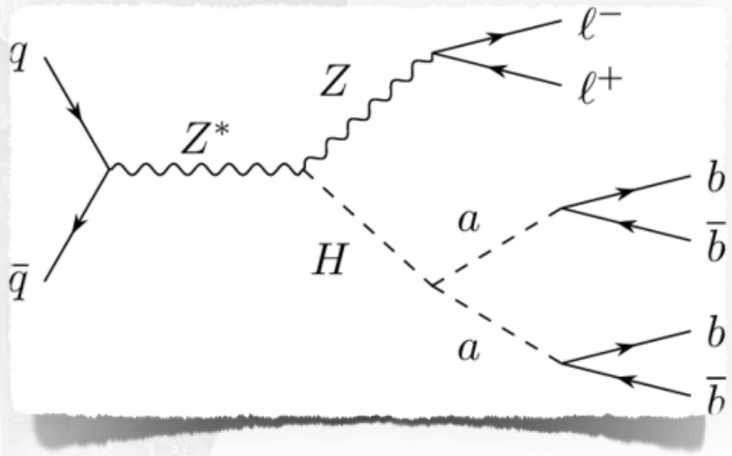
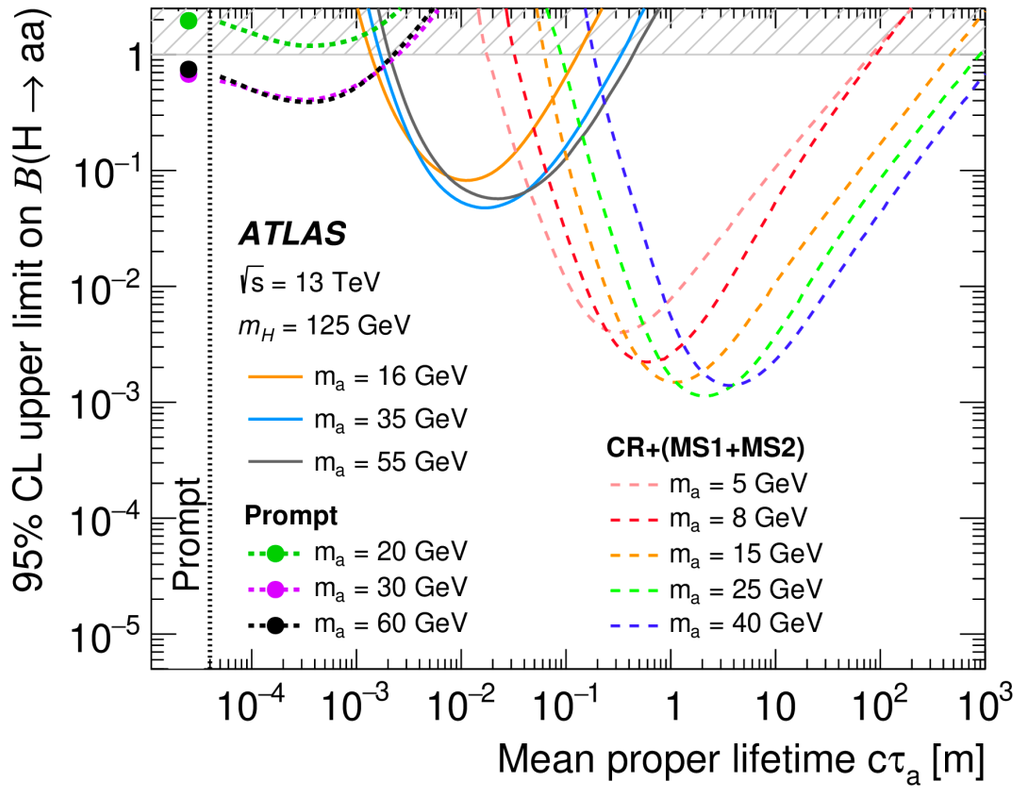
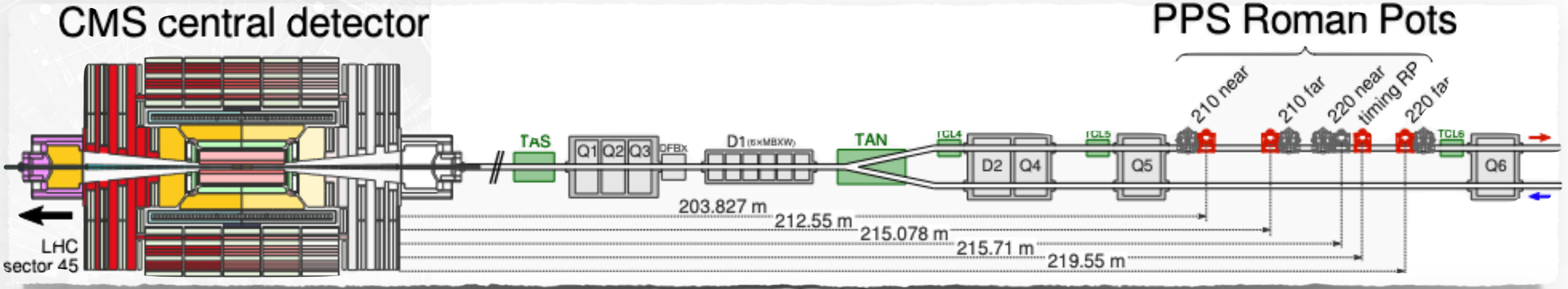
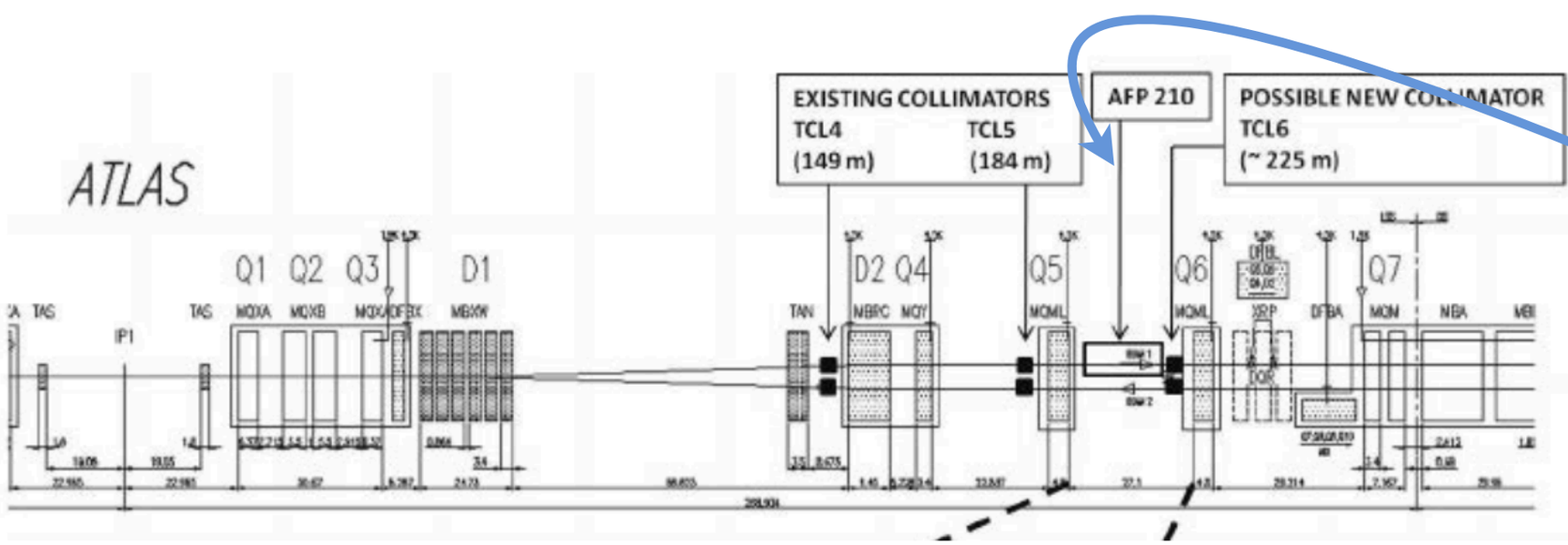


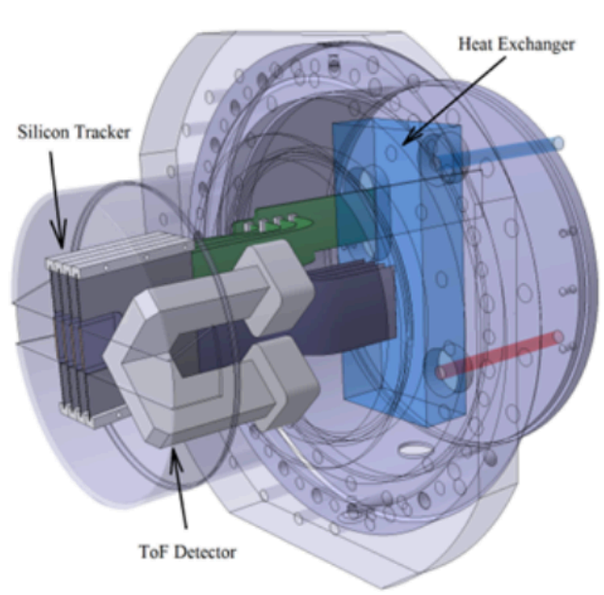


ATL-PHYS-PUB-2021-012 ATL-PHYS-PUB-2017-014
EXOT-2018-57

New forward detectors have their say



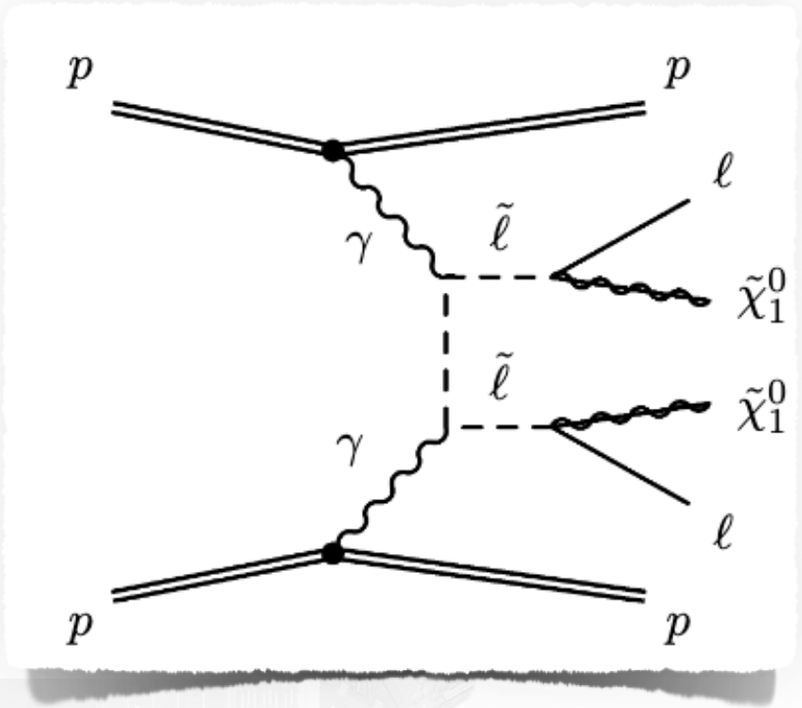


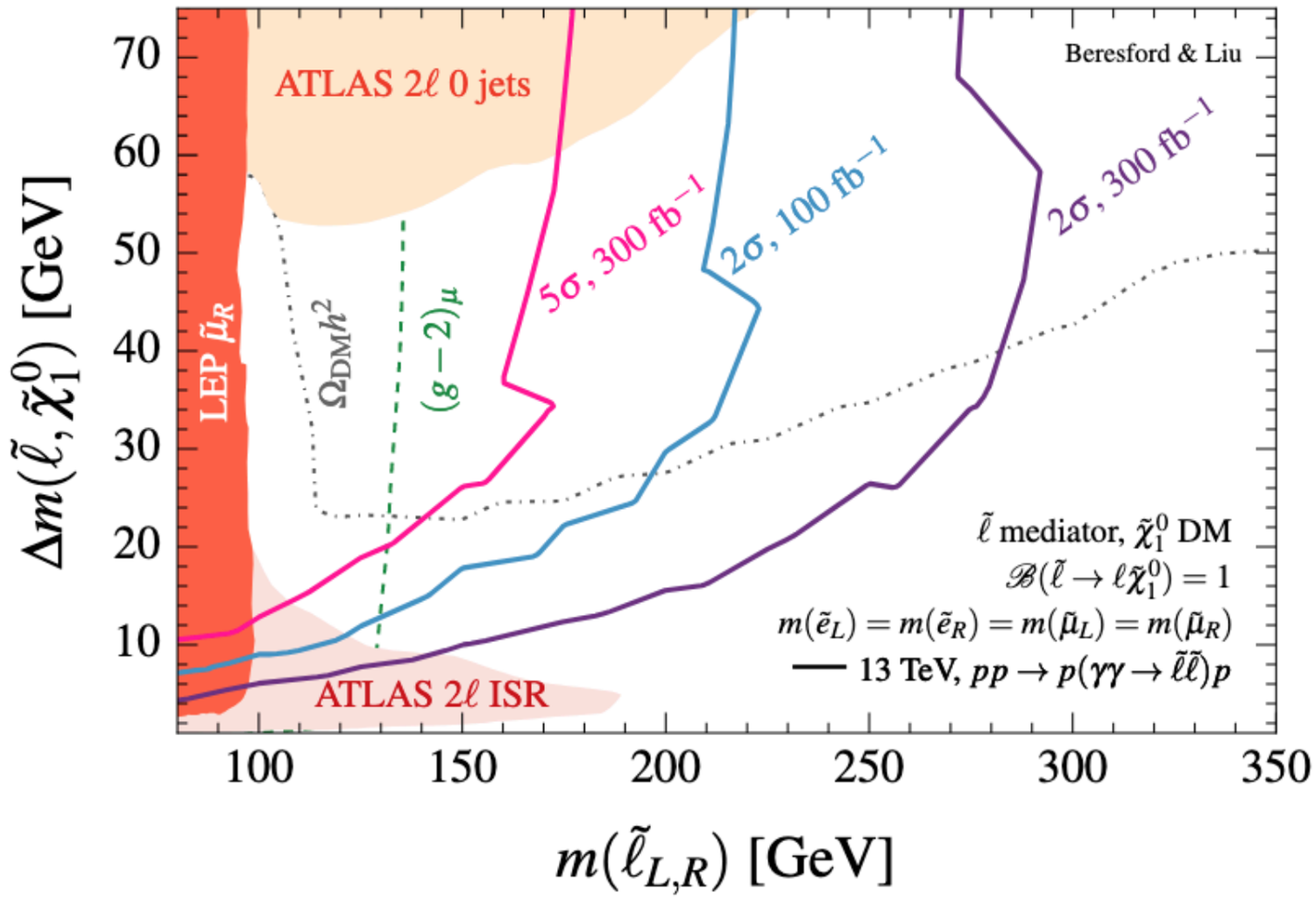


- Significant **extension to the physics reach** by tagging and measuring momentum and emission angle of very forward protons

New Physics in Photon Collisions at LHC

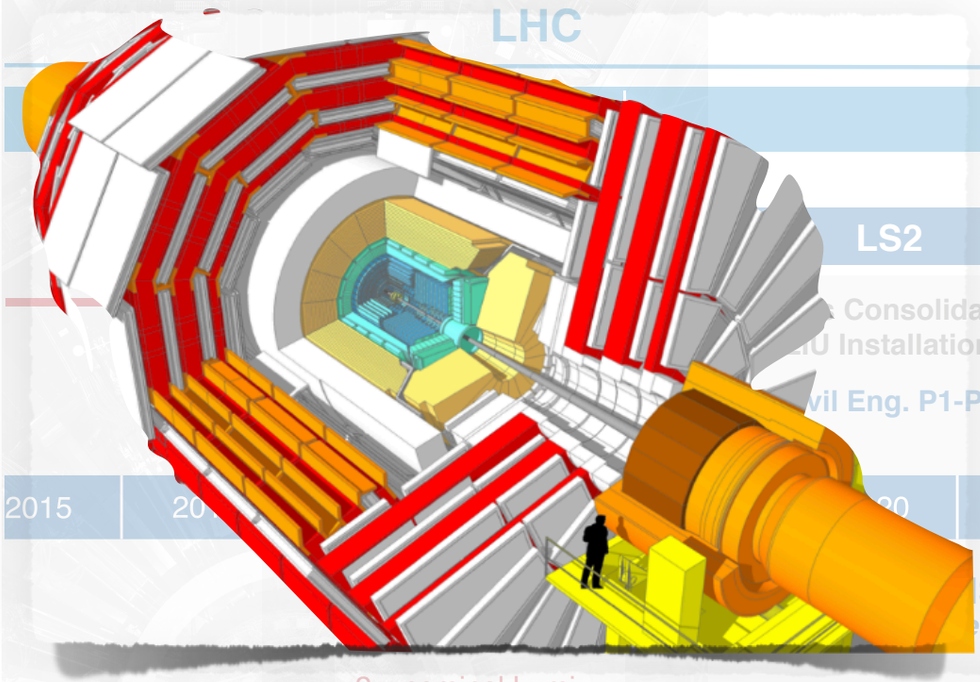
- Forward detectors offer a **unique opportunity to probe γγ and gluon-gluon collisions**
- **Complete measurement of the final state**
- Example: Inelastic Dark Matter or Split SUSY

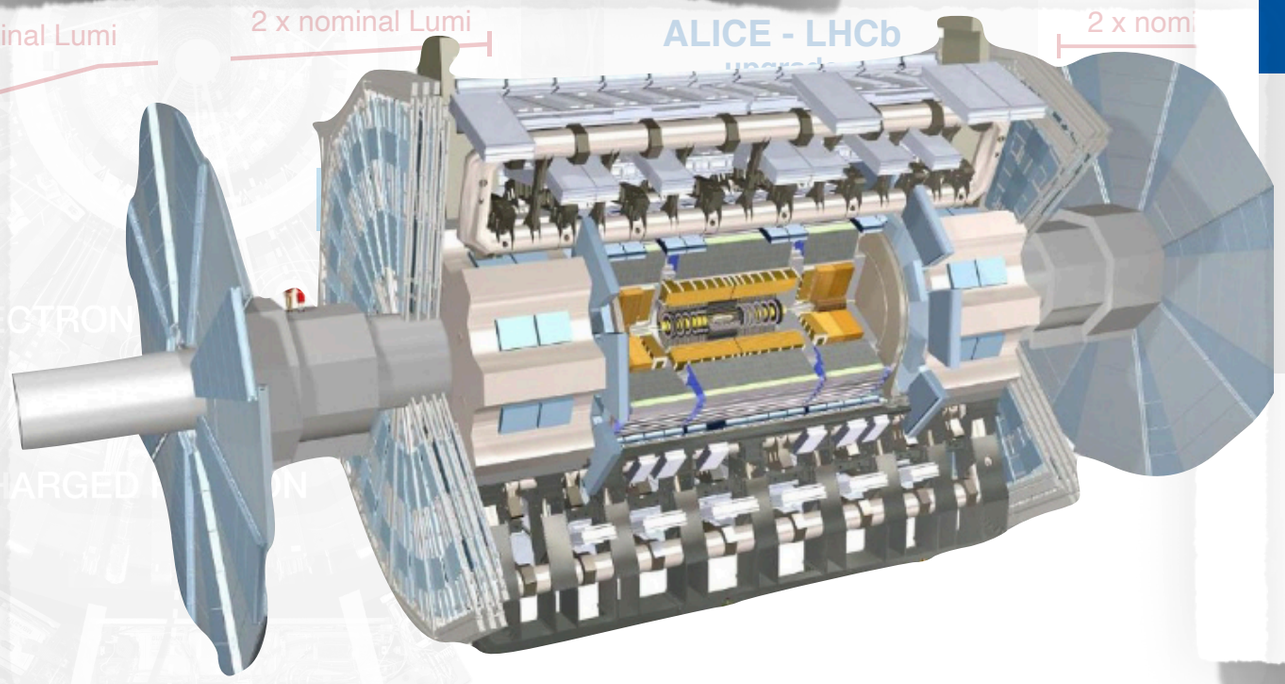




arXiv:1811.06465

Looking forward for High Lumi





HL-LHC

Run 4 - 5...

LS3

14 TeV energy

HL-LHC installation

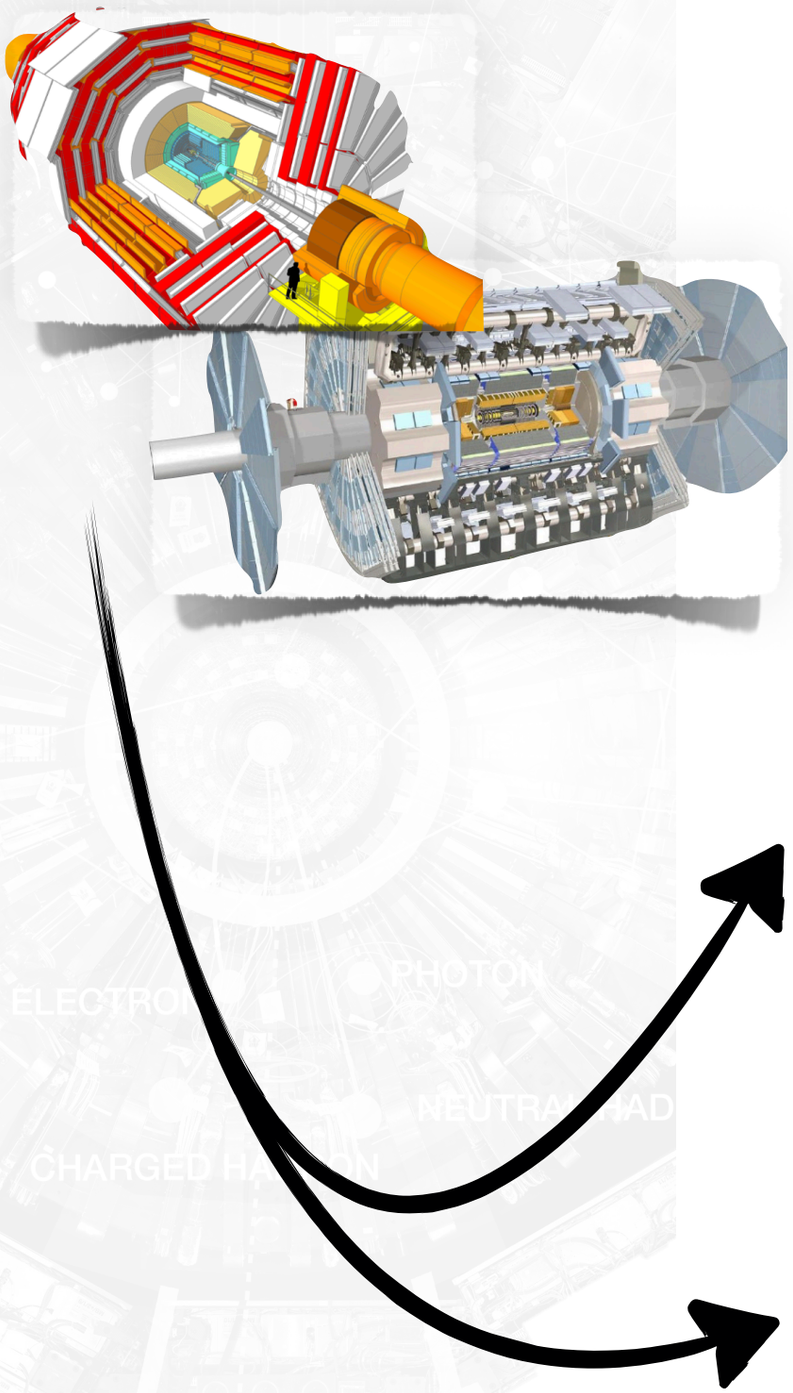
2025 | 2026 | 2027 | 2040

5 to 7.5 x nominal Lumi

ATLAS - CMS
HL upgrade

integrated luminosity **3000 fb^{-1}** **4000 fb^{-1}**

HL LHC Physics Opportunities



- **<u>Large data sample</u>**:

- Lower experimental uncertainties

- **<u>New tools for searches</u>**:

- timing information
- extended tracking for forward boosted physics
- new trigger strategies

- **<u>Common Effort</u>**

CERN-LPCC-2018-05

European Strategy

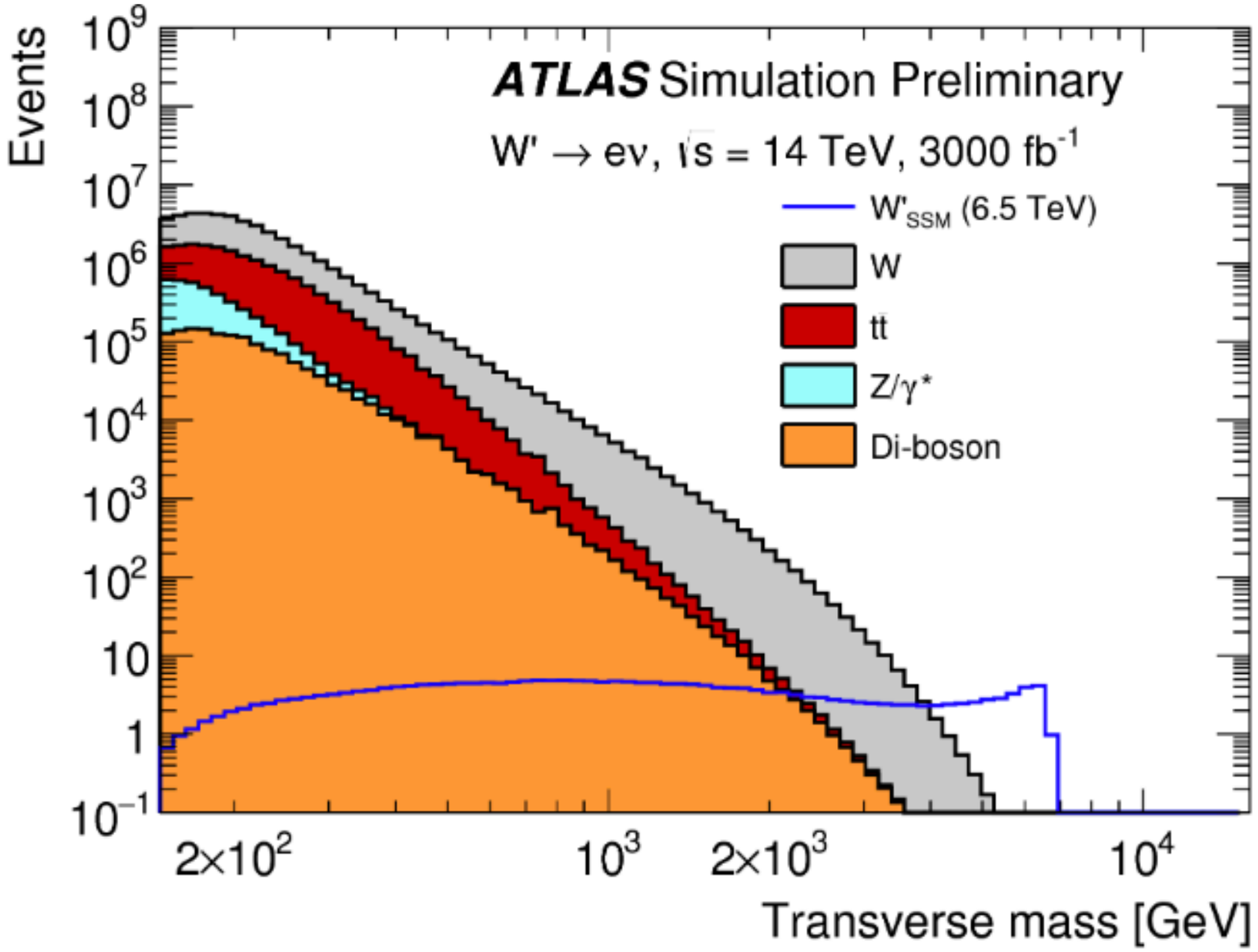
SnowMass2021

Accumulating data

- **High mass sensitivity** dominated by statistics and object performance at high energy

- **Leptonic channels** (Z'/W') reach 6-8 TeV mass sensitivity

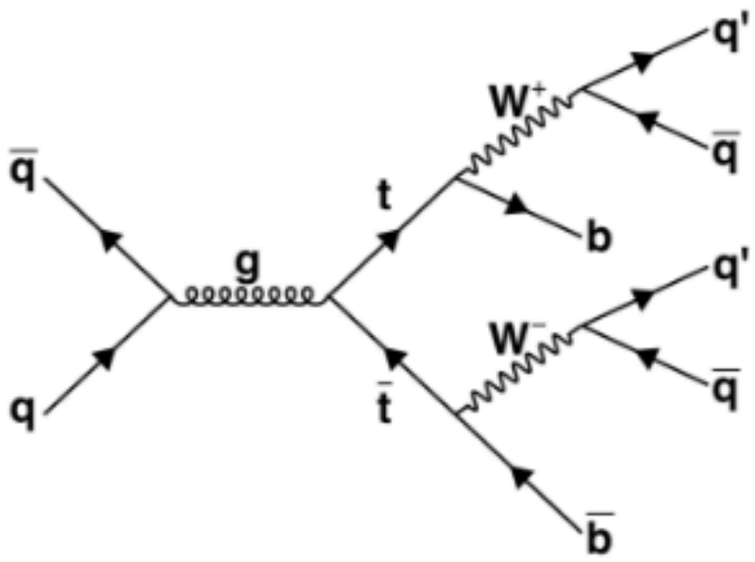
- **1-2.5 TeV better than Run 2**

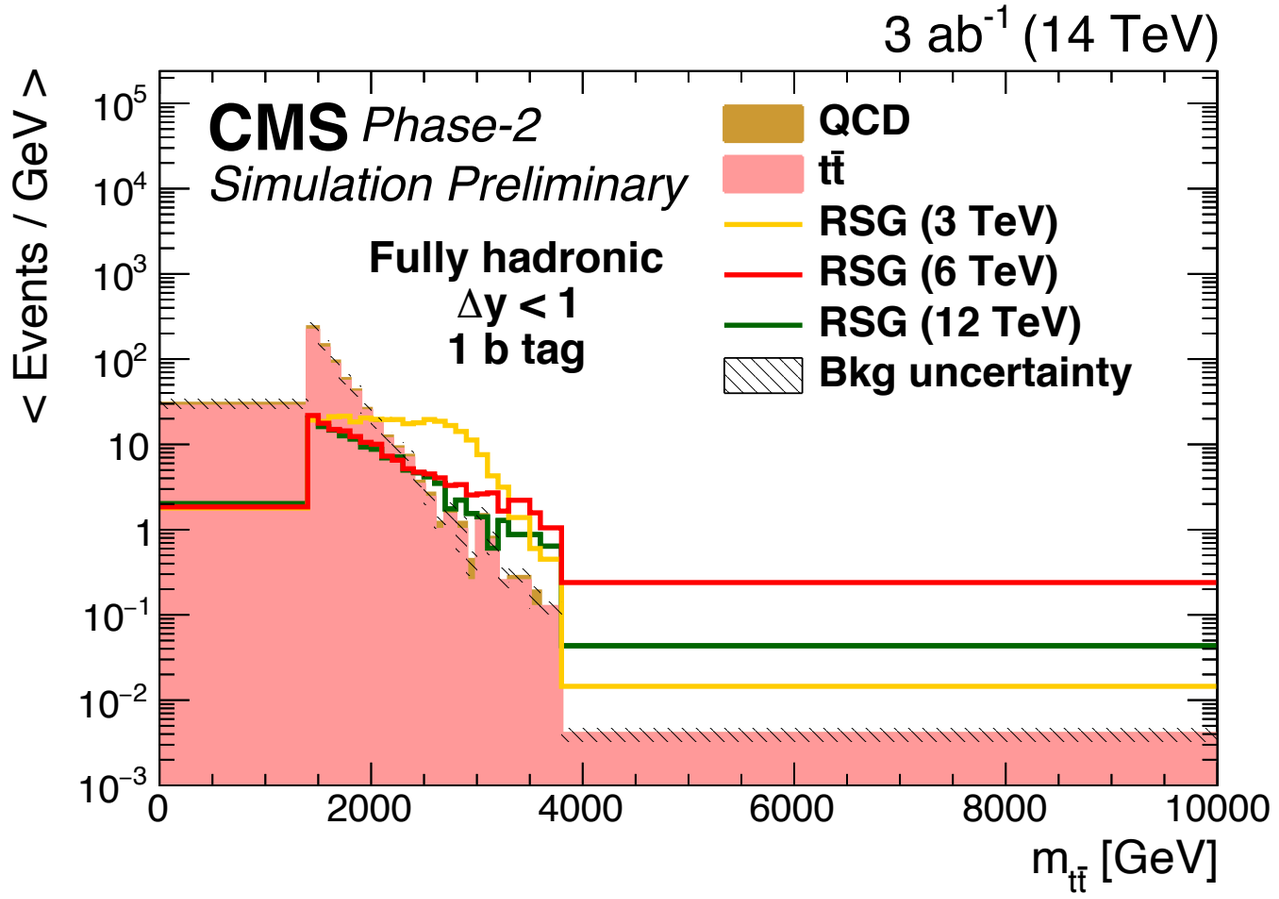


Accumulating data

- **High mass sensitivity** dominated by statistics and object performance at high energy

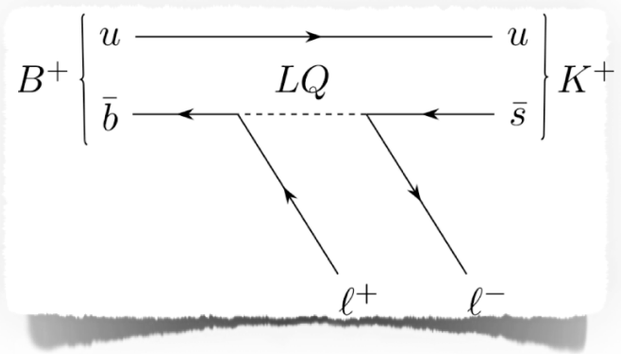
- **Hadronic channels** dominated by top final states
  - Phase2 **improved b-tagging**
  - reach **6 TeV** mass sensitivity

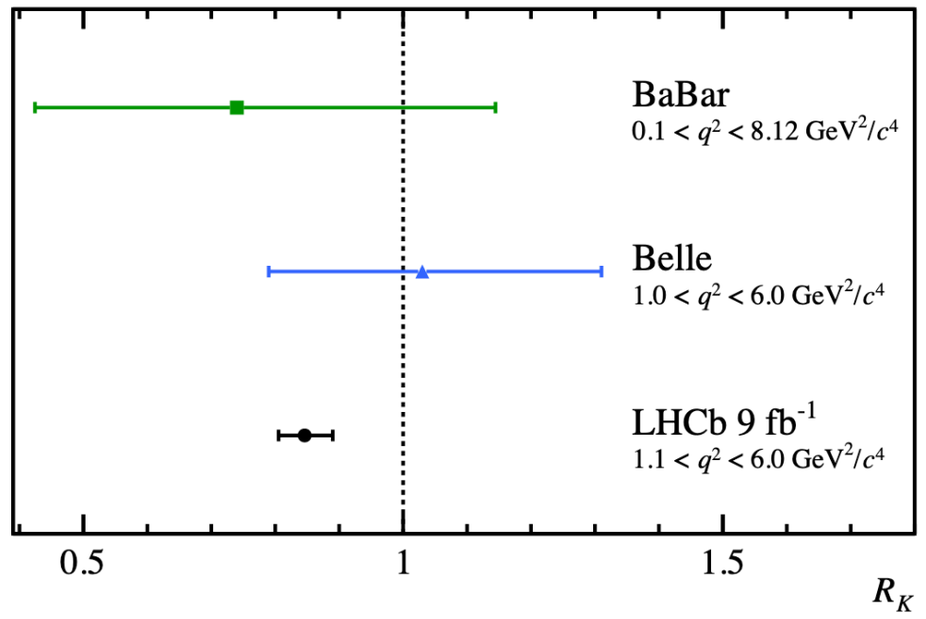




Being inspired by Run 2

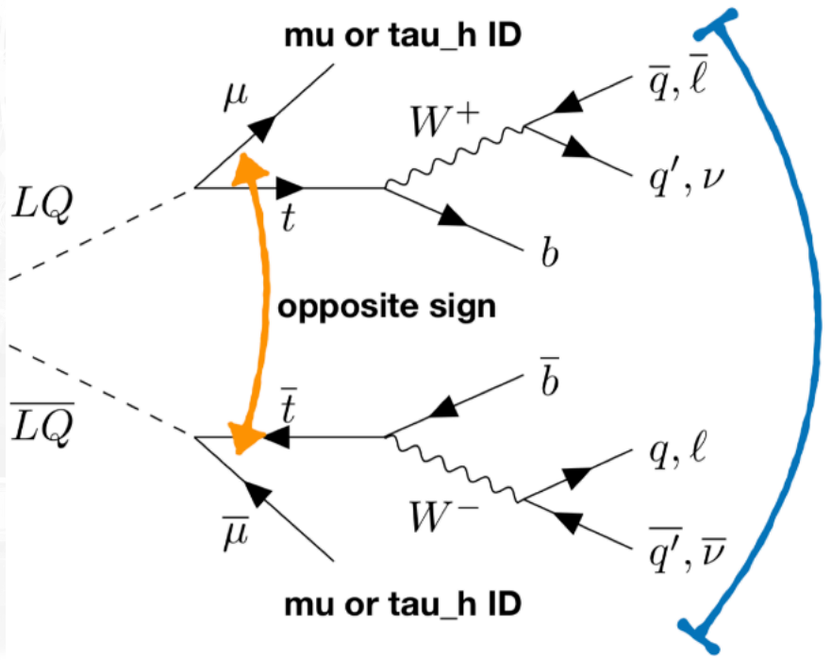
- Pattern of **interlinked anomalies** emerged in experimental studies of **LFU**



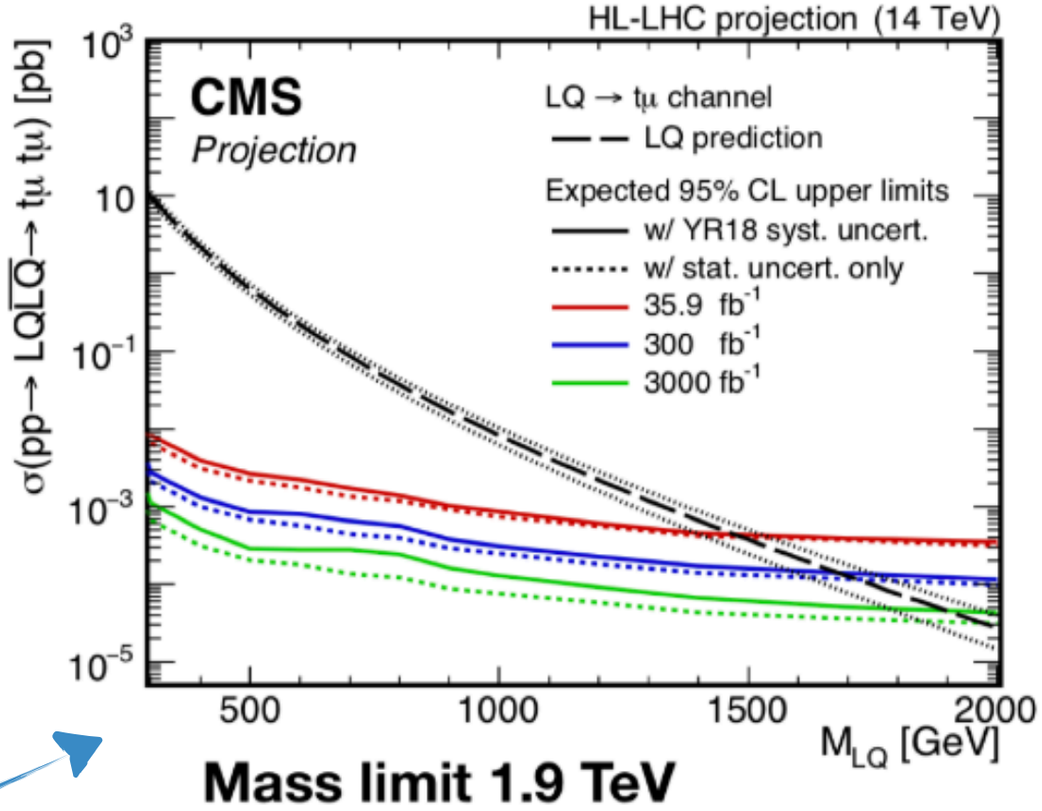


arXiv:2103.11769

- Renewed interest in Models with **third generation LeptoQuarks**



Probe all combinations of jets, lepton, pTmiss
Choose combination that minimizes chi2-like variable

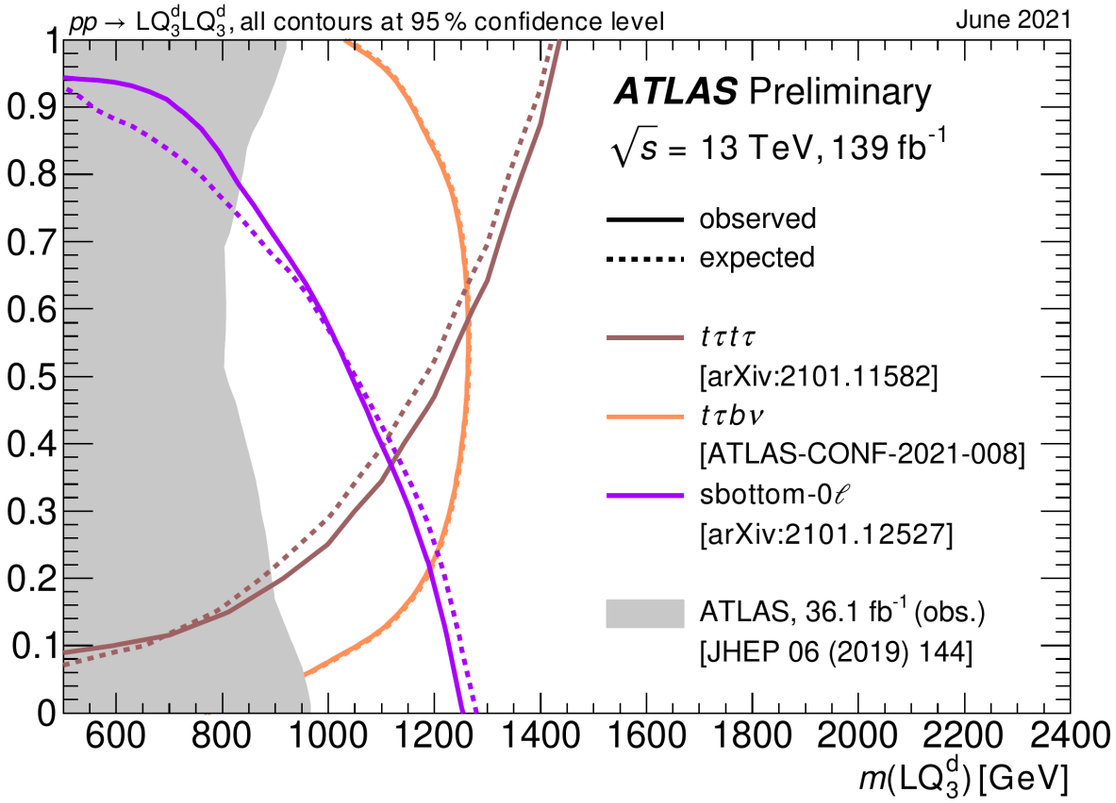


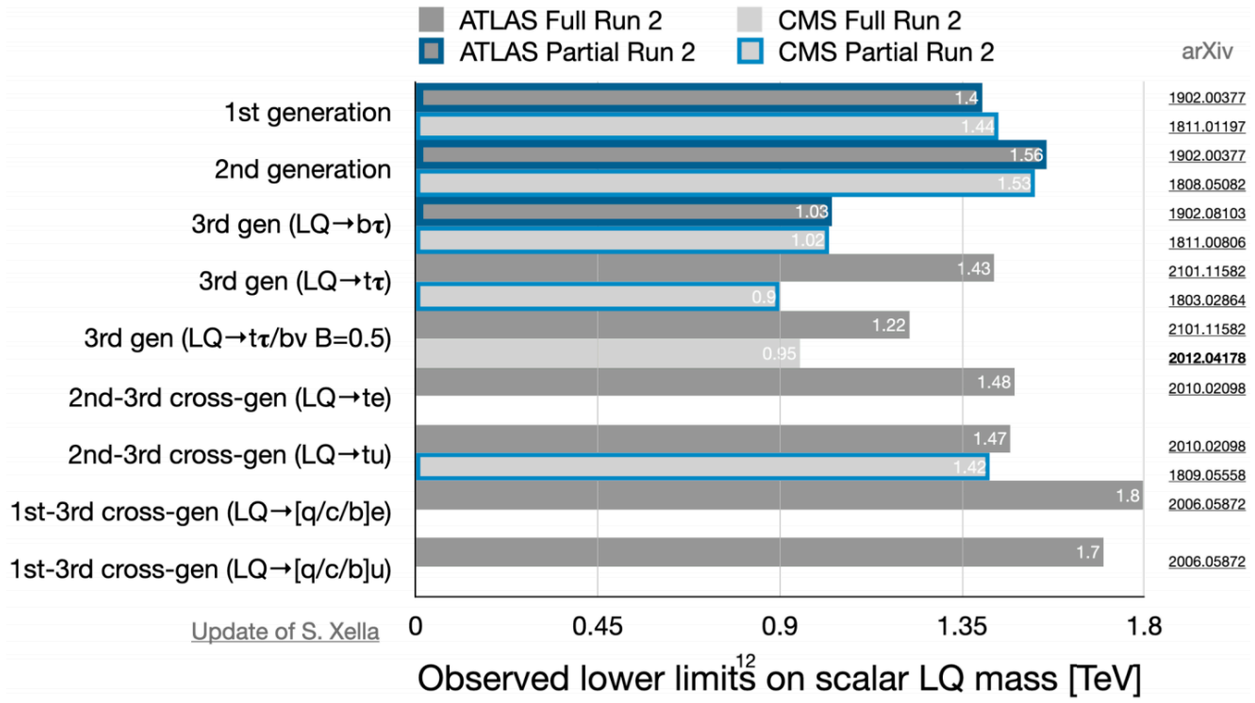
CMS-PAS-FTR-18-008

Being inspired by Run 2

- Pattern of **interlinked anomalies** emerged in experimental studies of **LFU**

- Broad program underway, for both scalar and vector LQs



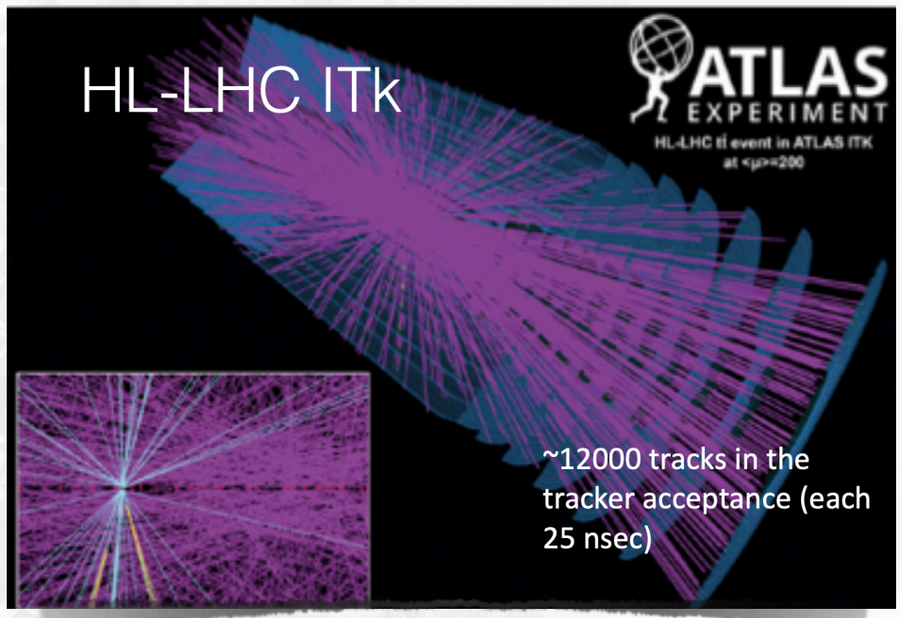


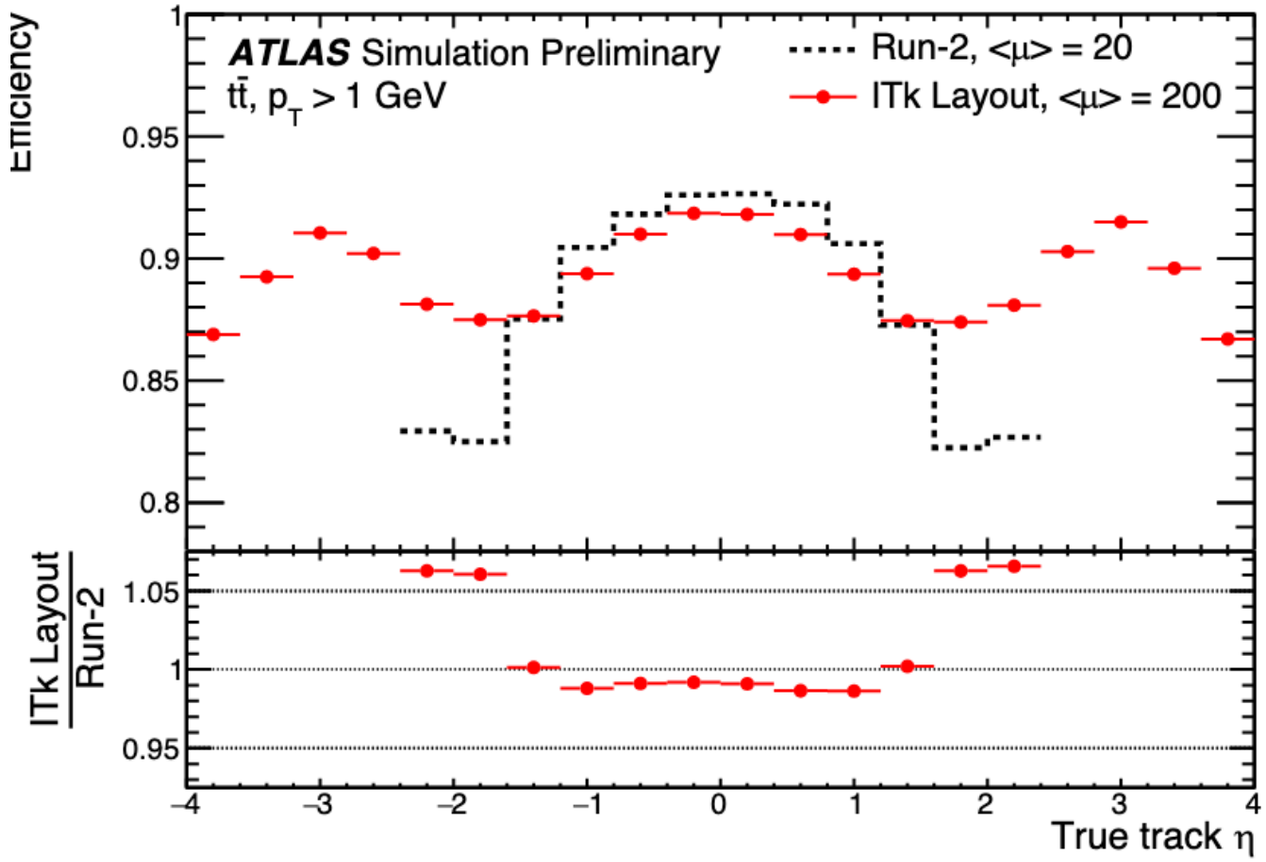
ATL-PHYS-PUB-2021-017

LHCP2021

ATLAS ITk Silicon Tracker upgrade

- Nearly 13 m^2 of pixels and 165 m^2 of strips with **improved coverage and novel readout electronics**
- Improves **tracking and b-tagging** performance compared to Run 2

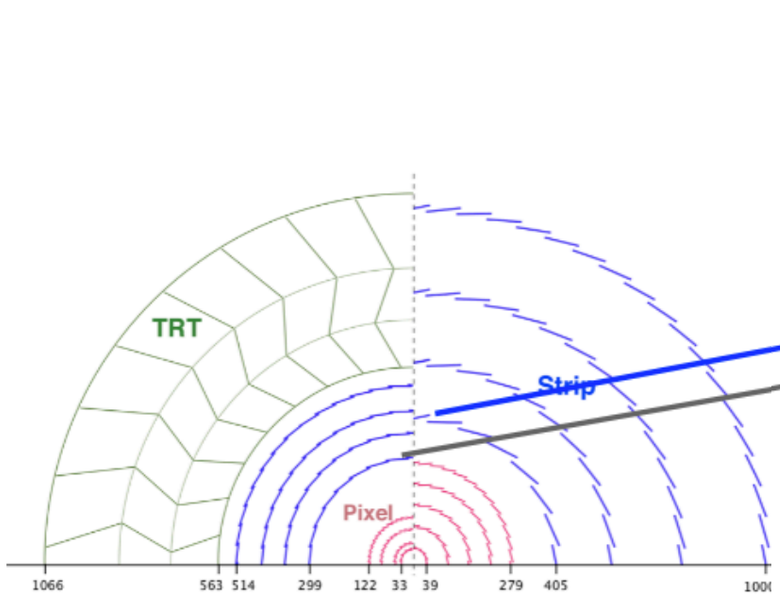


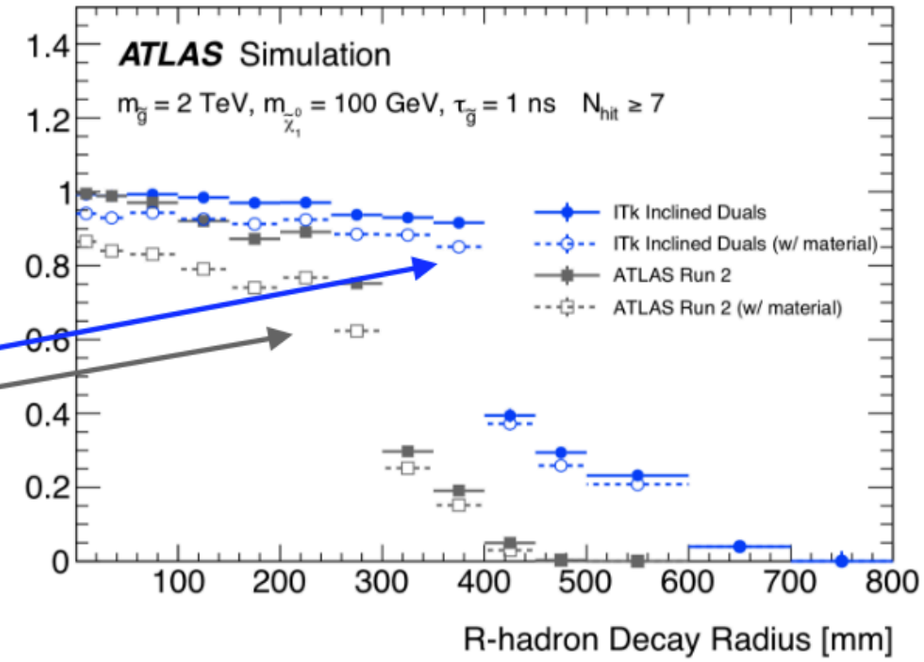


ATL-ITK-SLIDE-2018-073

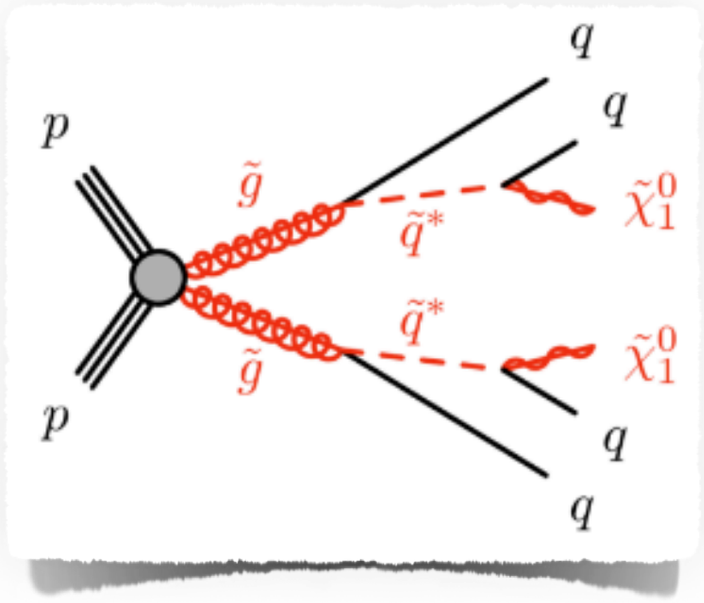
Displaced Tracks at HL-LHC

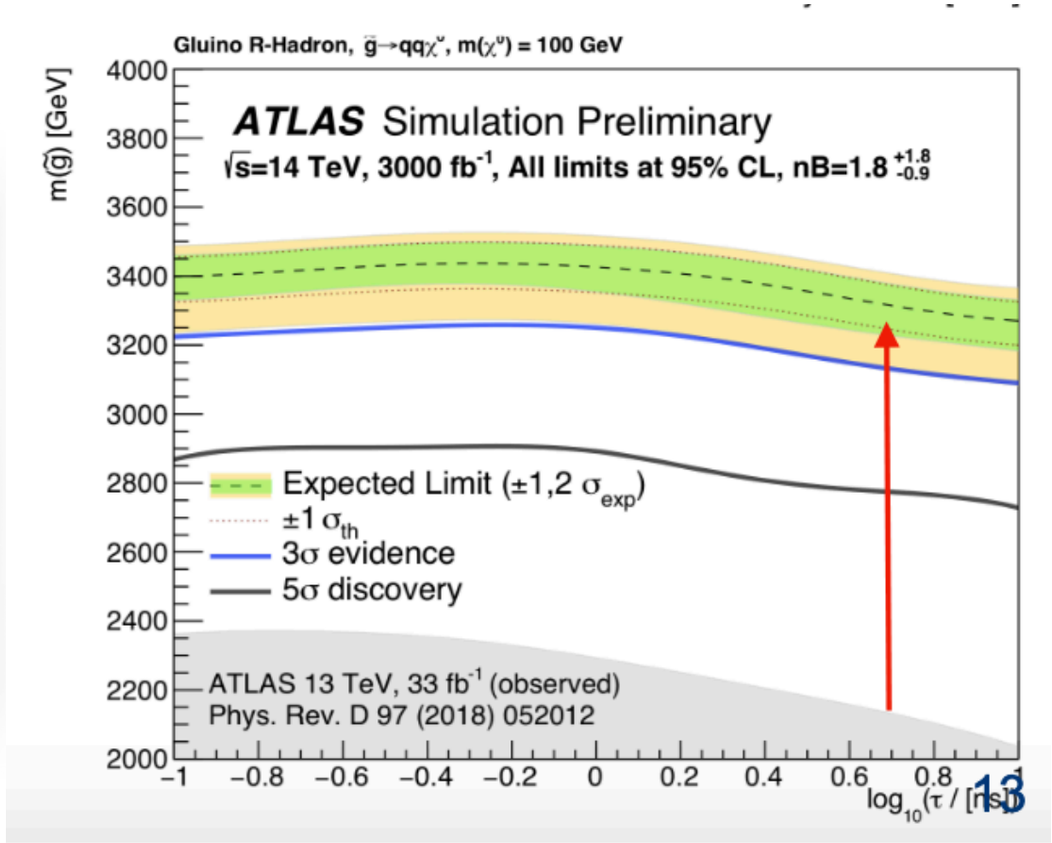
- Higher **reco efficiency** with ITk detector
- Improved geometry and l**arger volume w/ lower material budget**





- Sensitive to **long-lived particles with τ ~10 ps-10 ns** decaying to multiple charged particles

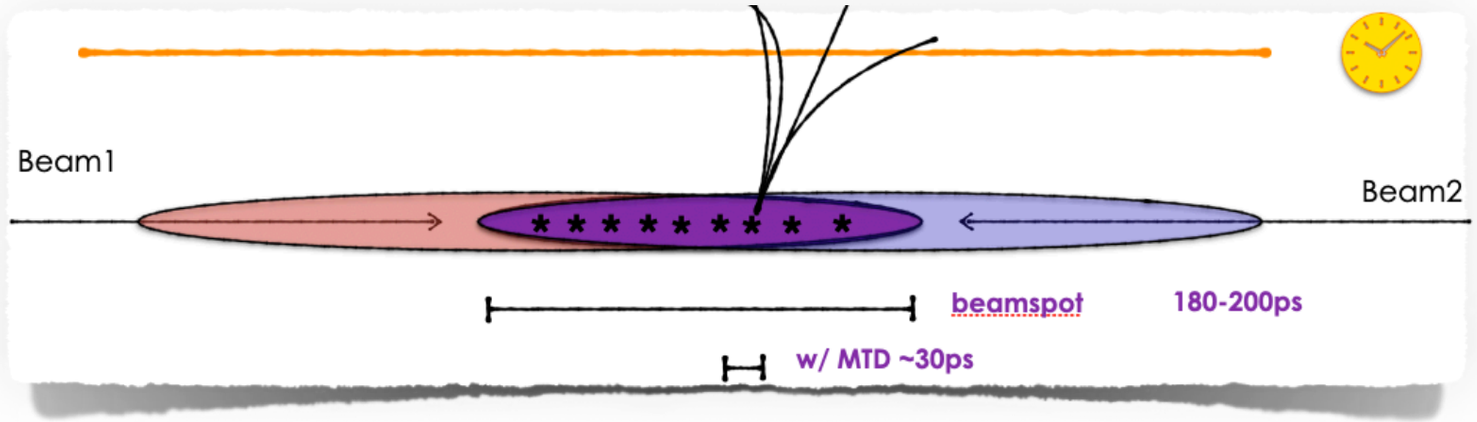




ATL-PHYS-PUB-2018-033

CMS New MIP Timing Detector

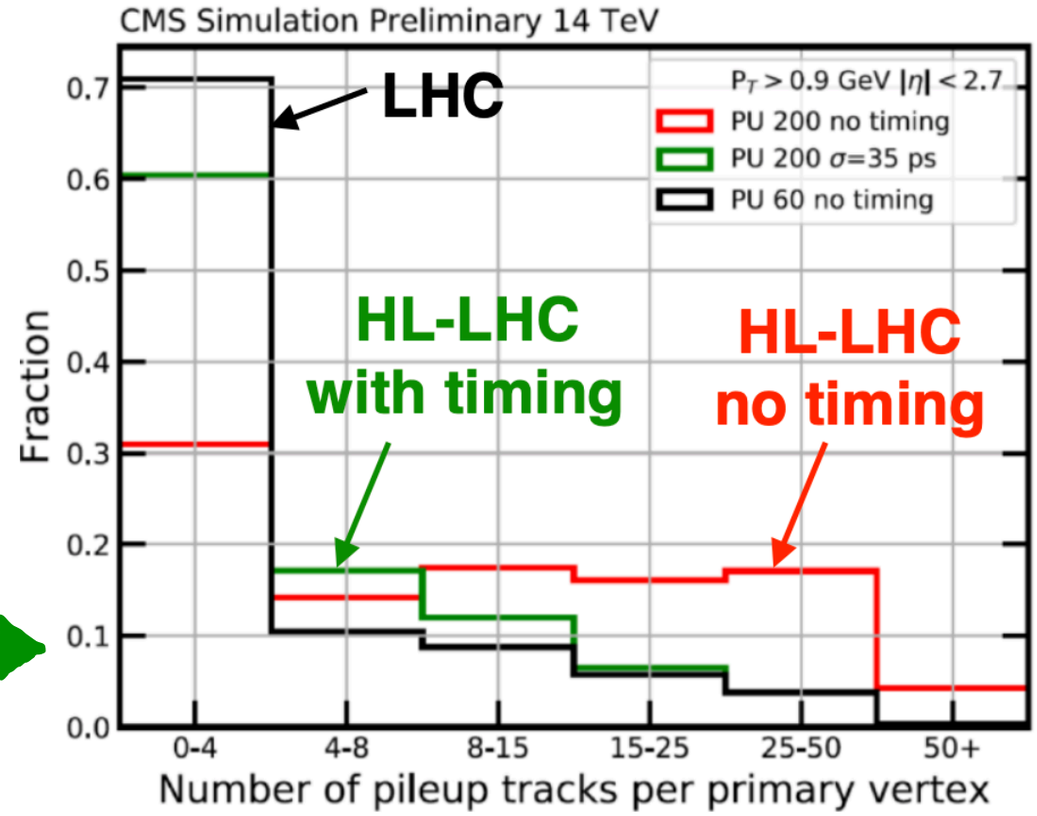
- Significant **PU contamination** and whole **event reconstruction degradation at HL-LHC**



- New **Hermetic timing detector** with various technologies optimized for different radiation levels

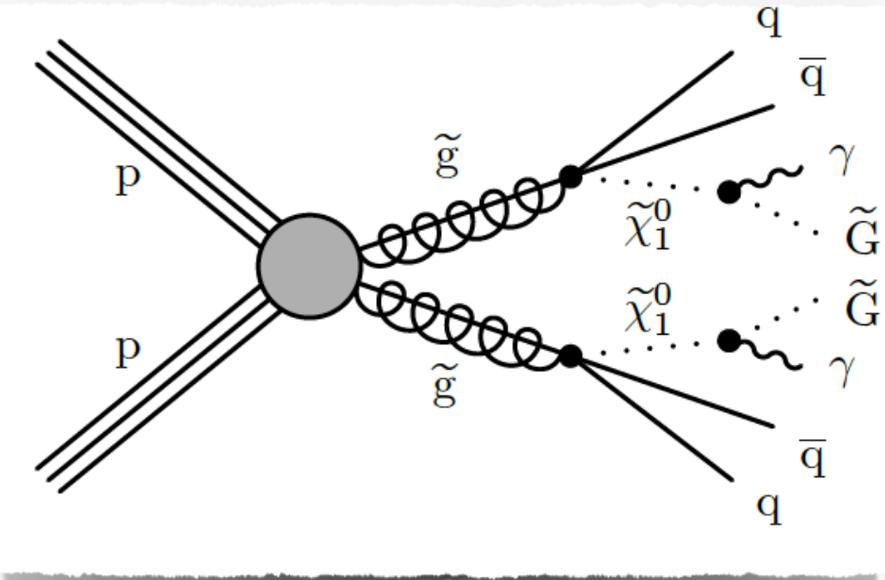
- Require time compatibility within O(30ps) for **track vertex association**

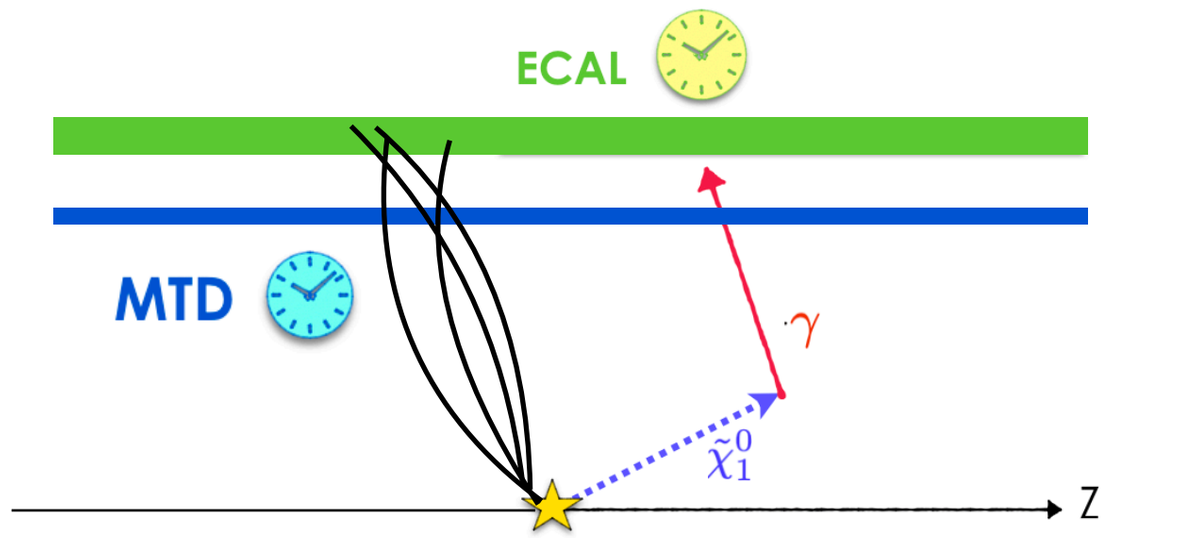
  - Effectively **reduce actual pileup** to level of the current LHC well handled by CMS detector



CERN-LHCC-2019-003

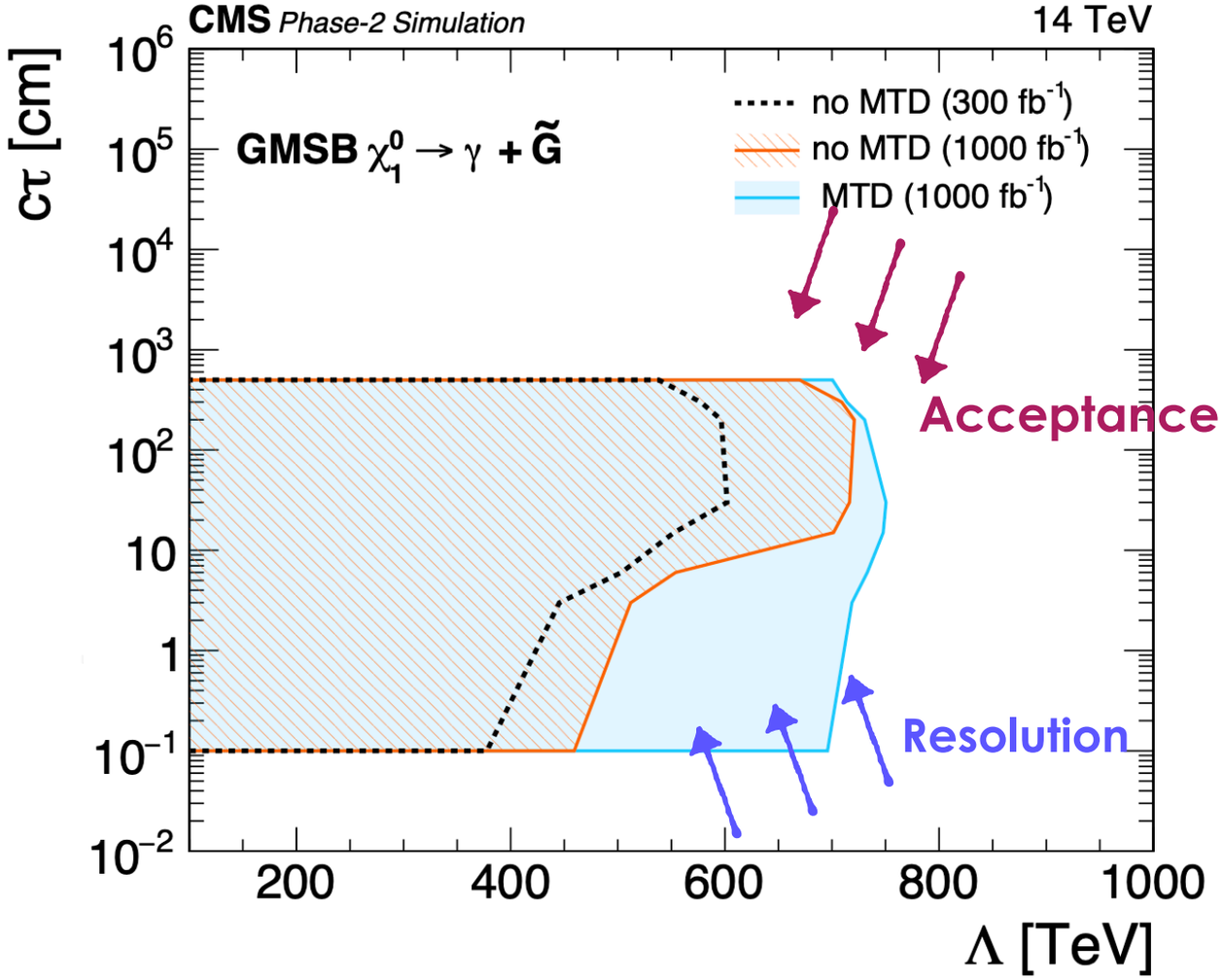
Displaced Photons w/ MTD





- Exploit **MTD to reduce BS timing information** crucial to **evaluate photons TOF w/ ECAL**

- Sensitivity of the analysis is explored requiring **at least one displaced photon and making a 0 background assumption.**

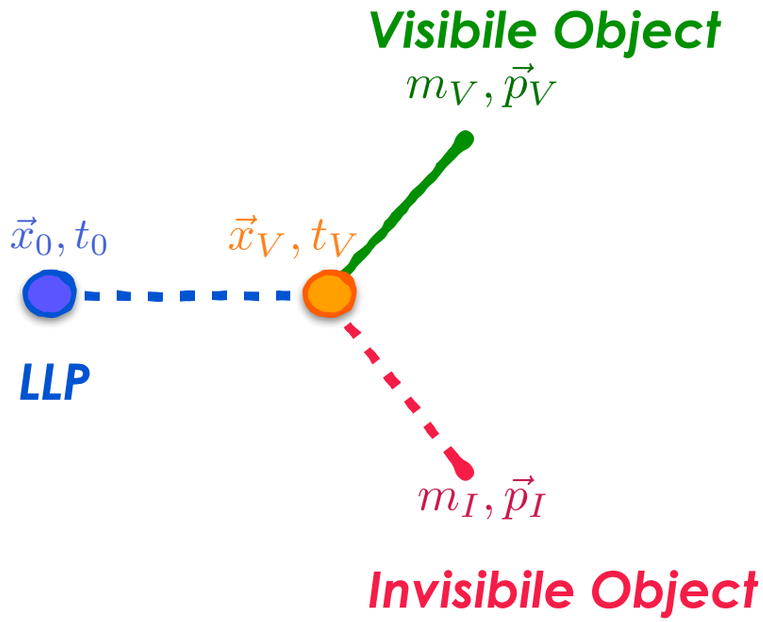


CERN-LHCC-2019-003

Being creative with timing

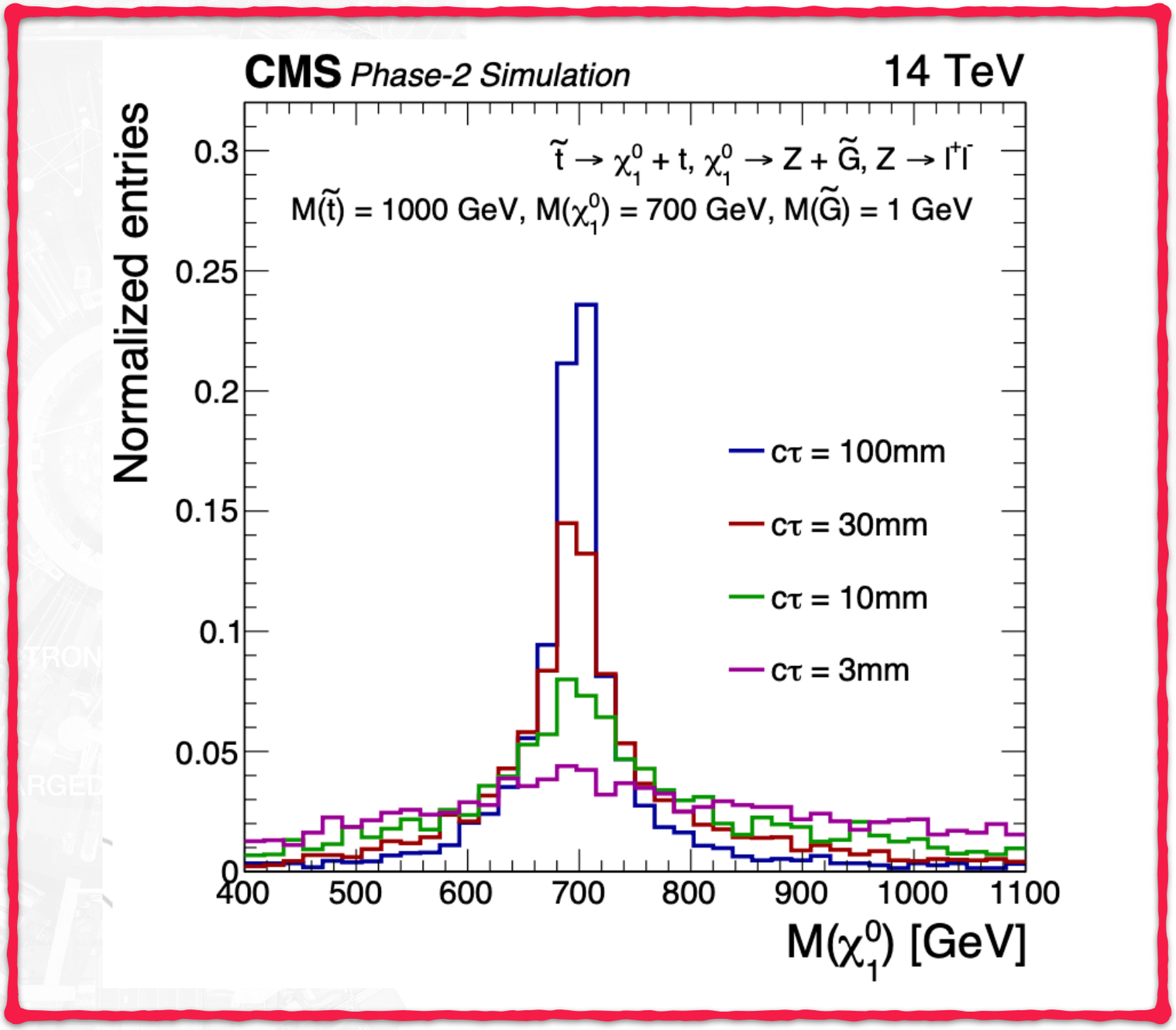
- **Reconstructed vertex to measure the TOF** of LLPs

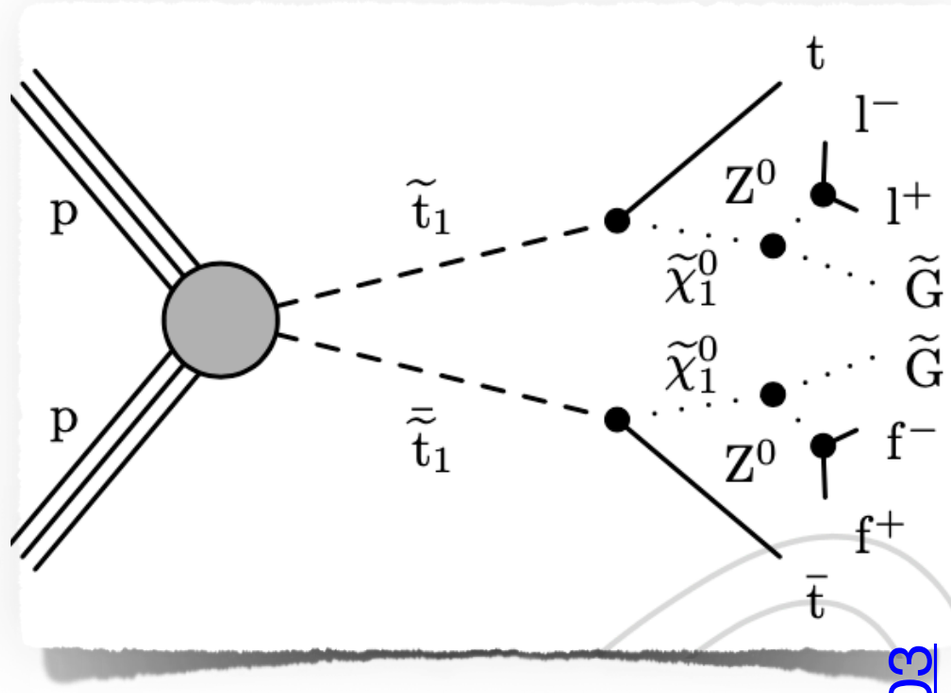
- **Kinematic closure:** direct measurement of the **LLP mass**



Neutralino mass reconstruction

- **Stop production with LL neutralino** decaying into Z and Gravitino

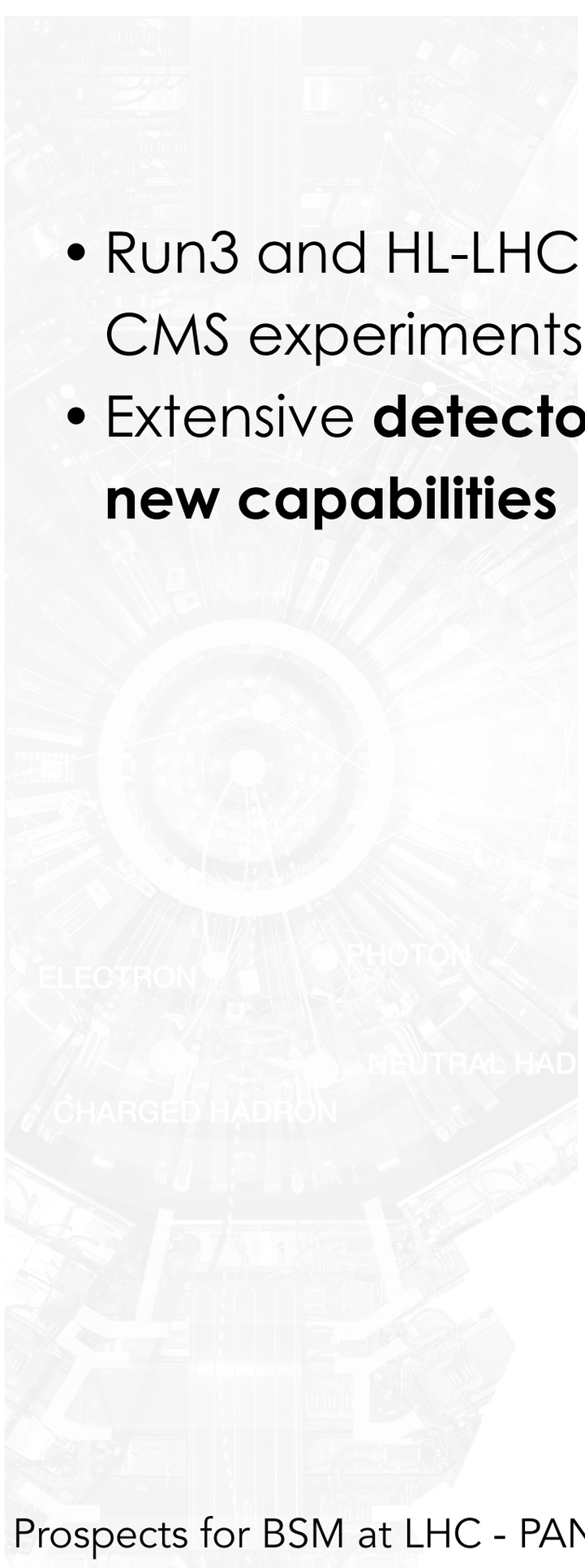




CERN-LHCC-2019-003

Conclusions

- Run3 and HL-LHC will significantly **increase physics reach** of ATLAS/ CMS experiments
- Extensive **detector upgrades** will **preserve performance** and provide **new capabilities**



Conclusions

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Non Conventional Signatures

Dedicated trigger algorithms

Unique object reconstruction, discriminating variables, or data processing

Re-defined analyses strategies w/ atypical backgrounds

Conclusions

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Dedicated trigger algorithms

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Looking for Forward for Run 3 and for Pilot Run in October!

ies, or data processing

Re-defined analyses strategies w/ atypical backgrounds