Muon Registration at the CMS Experiment

V. Shalaev and S. Shmatov

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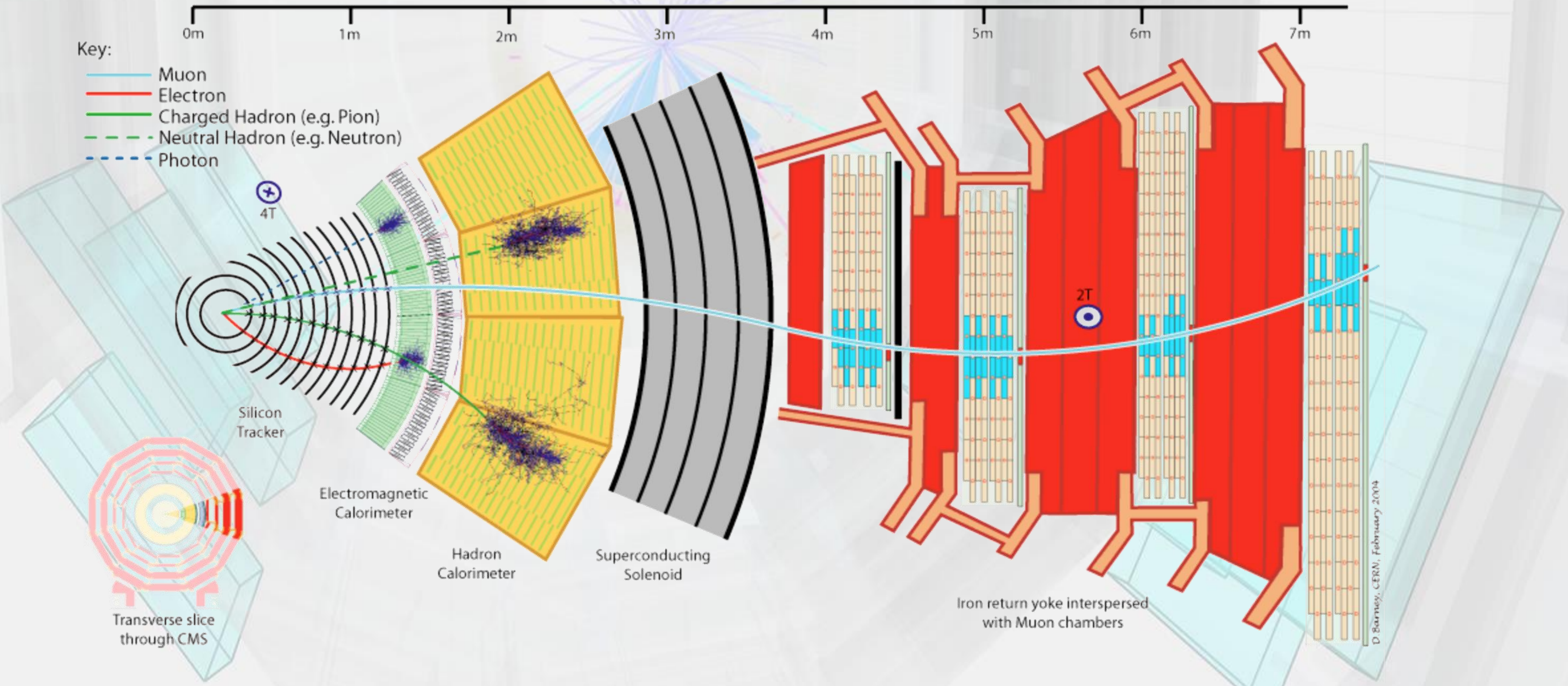
The Conference of Nuclear Physics Section of the Physical Sciences Department of the Russian Academy of Sciences

Tracking on CMS: Tasks and Challenges



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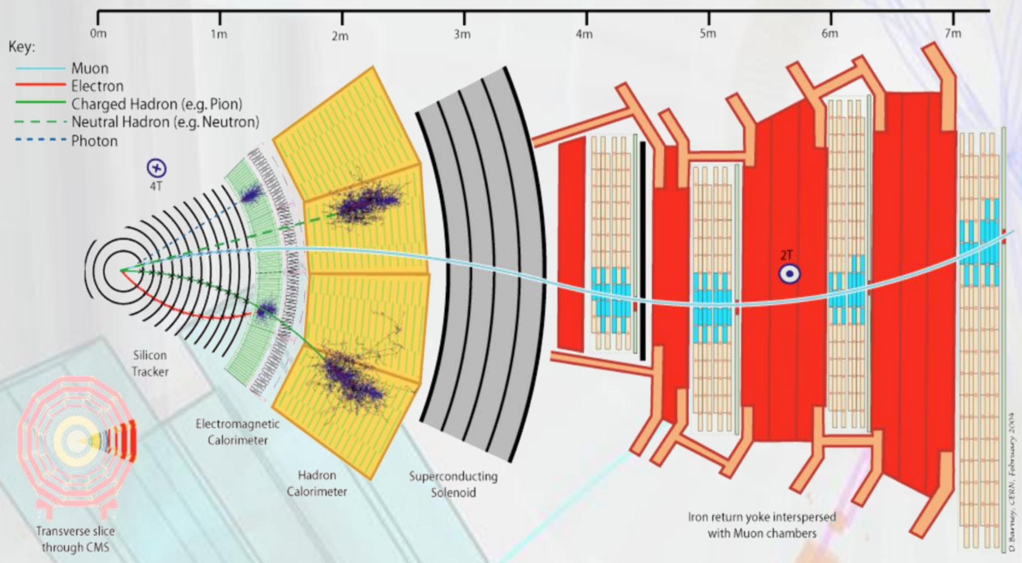

<u>Conditions</u>: $L_{inst} \sim 10^{34}\ cm^{-2}s^{-1}$

- Bunch crossing (BX) every **25 ns**
- ~**20-30** pp-collisions per BX
- ~ **30** charged particles per pp-collision

~**600-900** charged particles per BX or $\mathbf{10^{11}}$ per second

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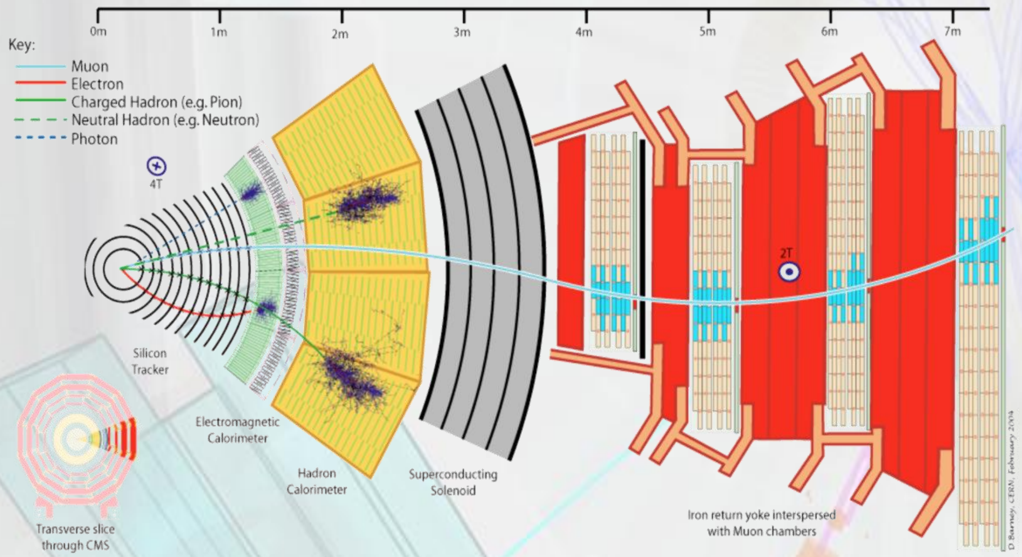

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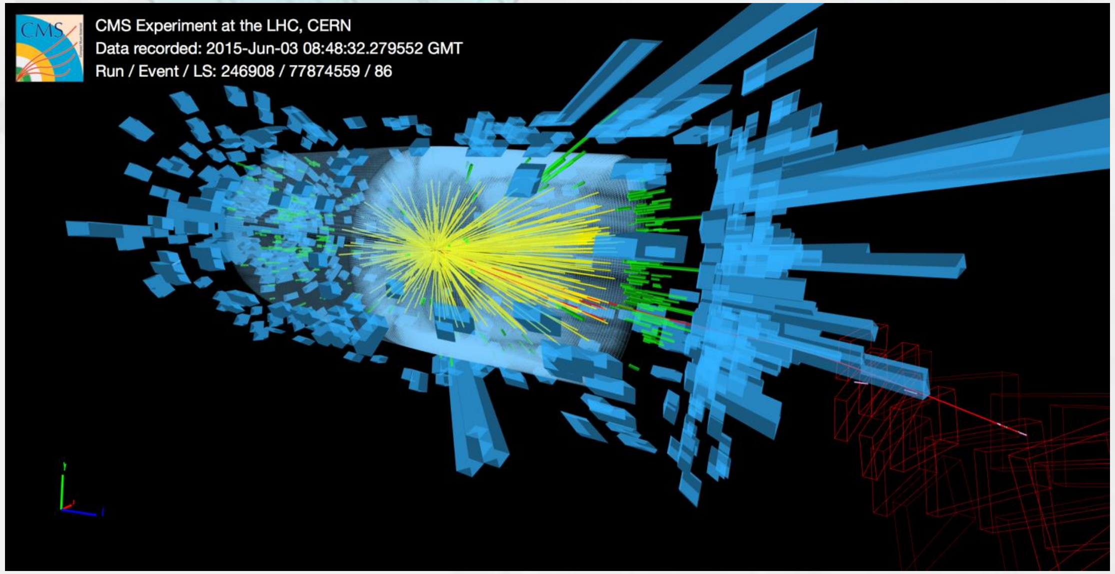

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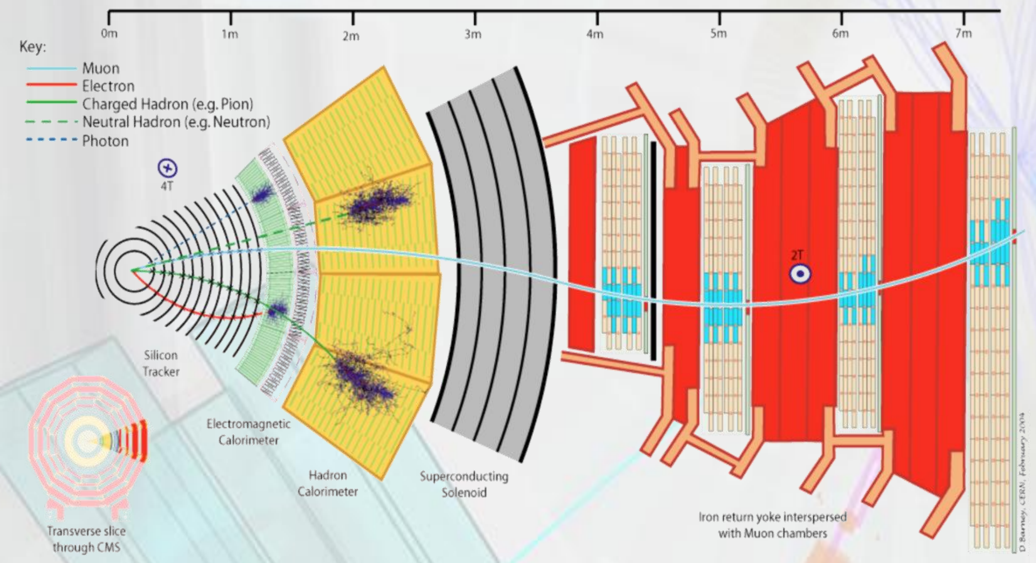

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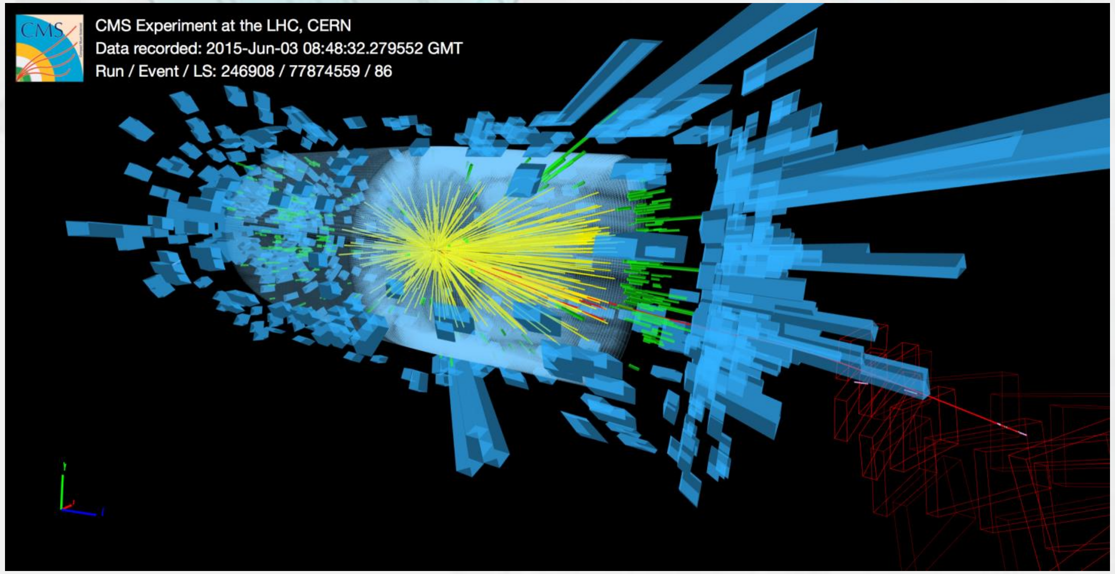

Requirements: fast and accurate

- High efficiency
- Low fake rate
- Precise track parameters
- Quickly!

Tracks Reconstruction. Muon Case

Common steps of reconstruction:

1. **Clustering and Seeding** – using combination of hits to provide track candidate
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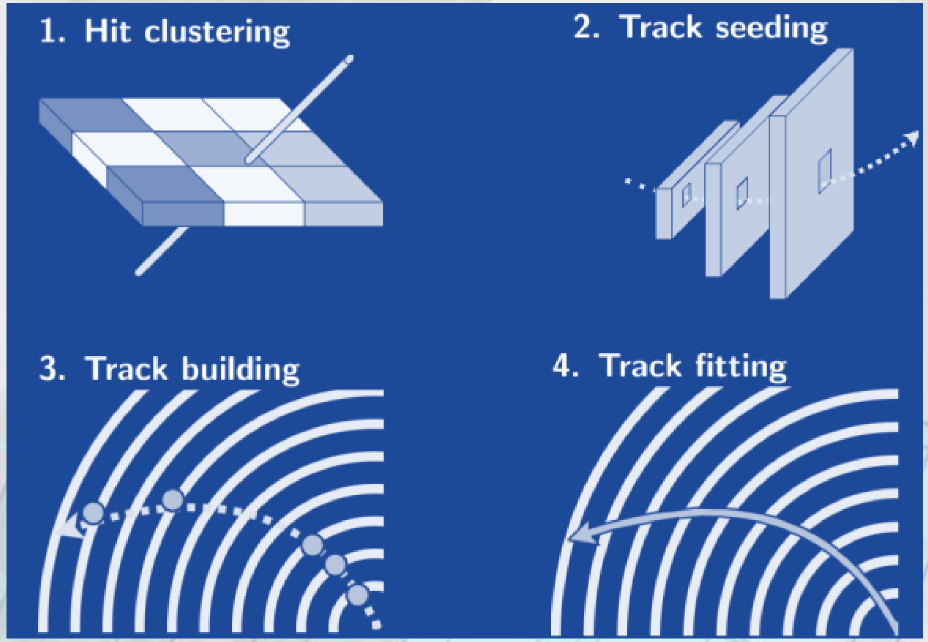
3. **Final fit** – adding vertex, taking into account detector defects, smoothing trajectory, final estimation of parameters and uncertainties



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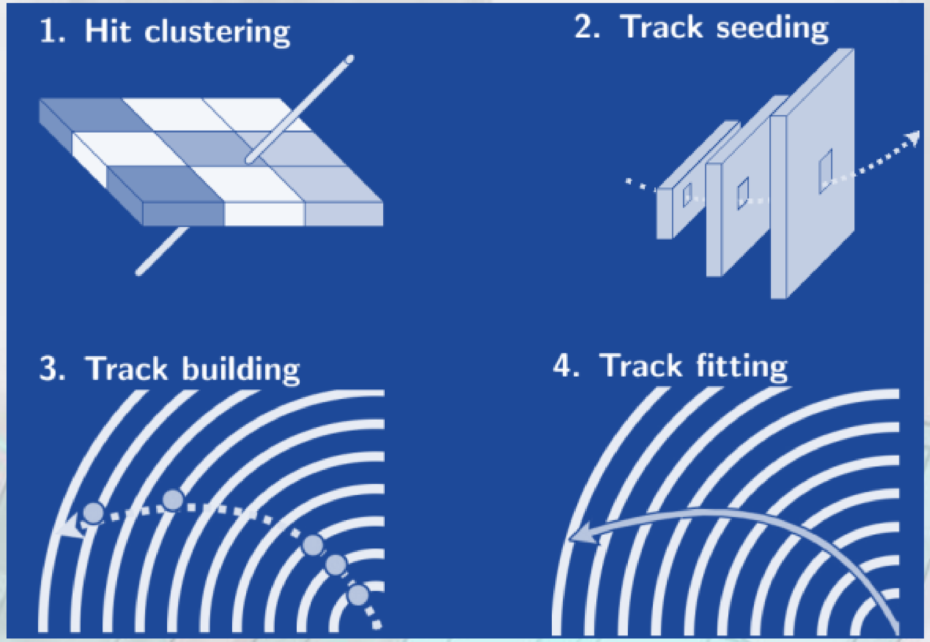

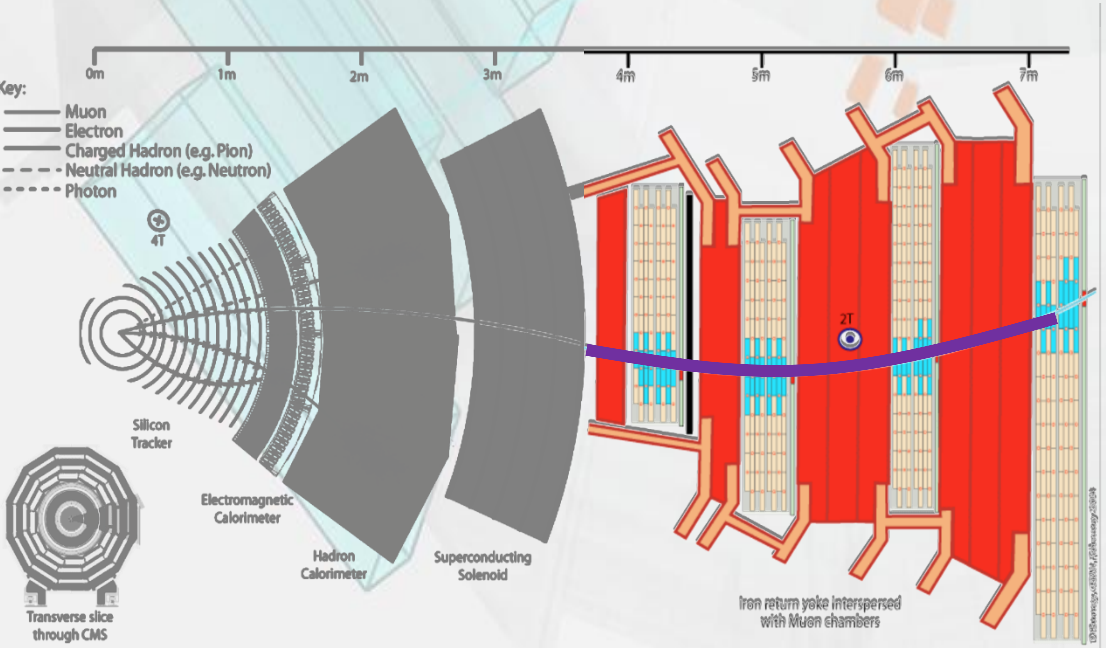

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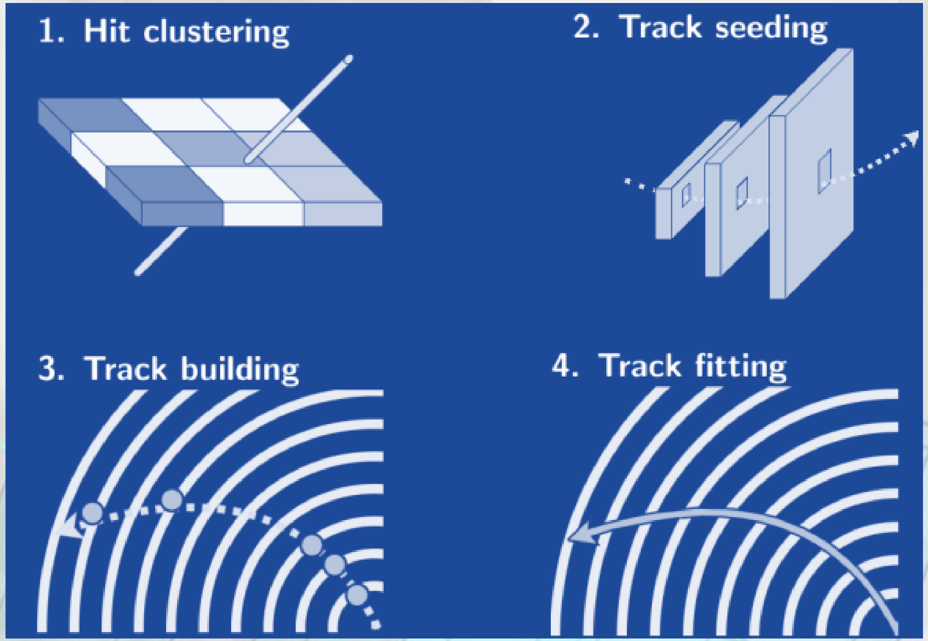

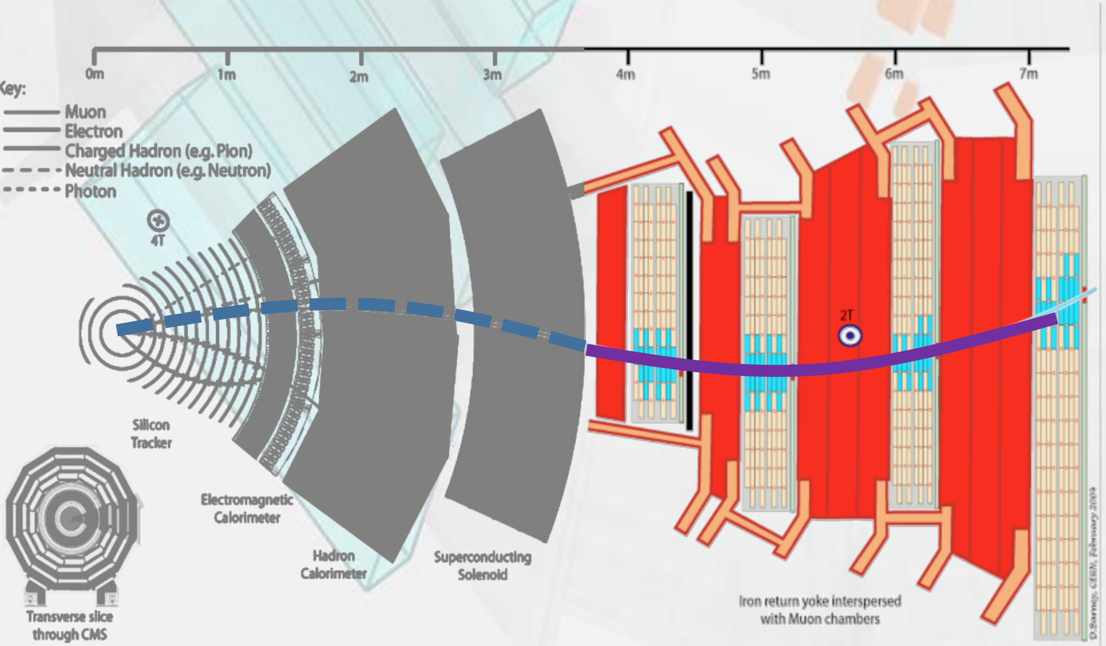

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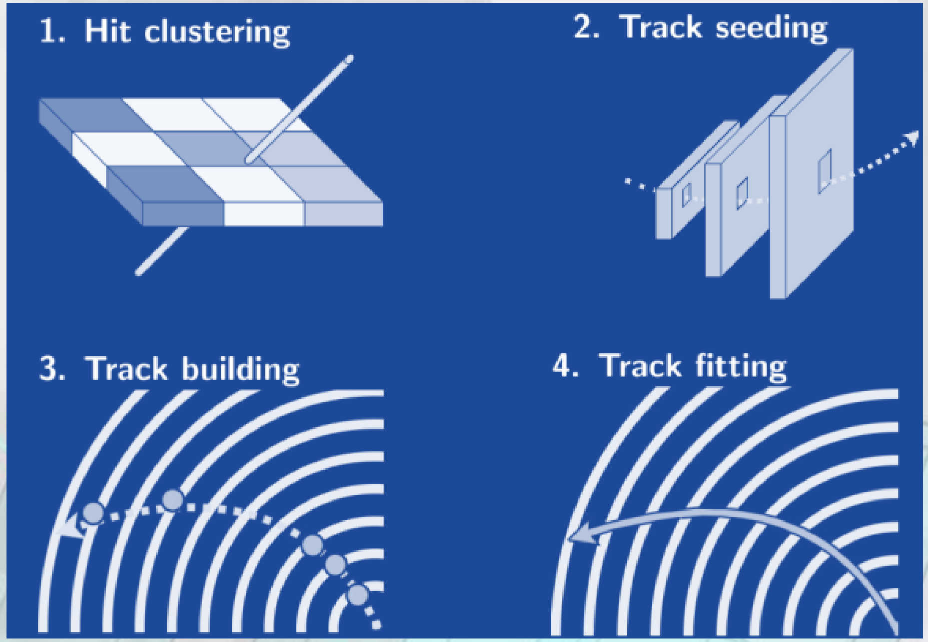

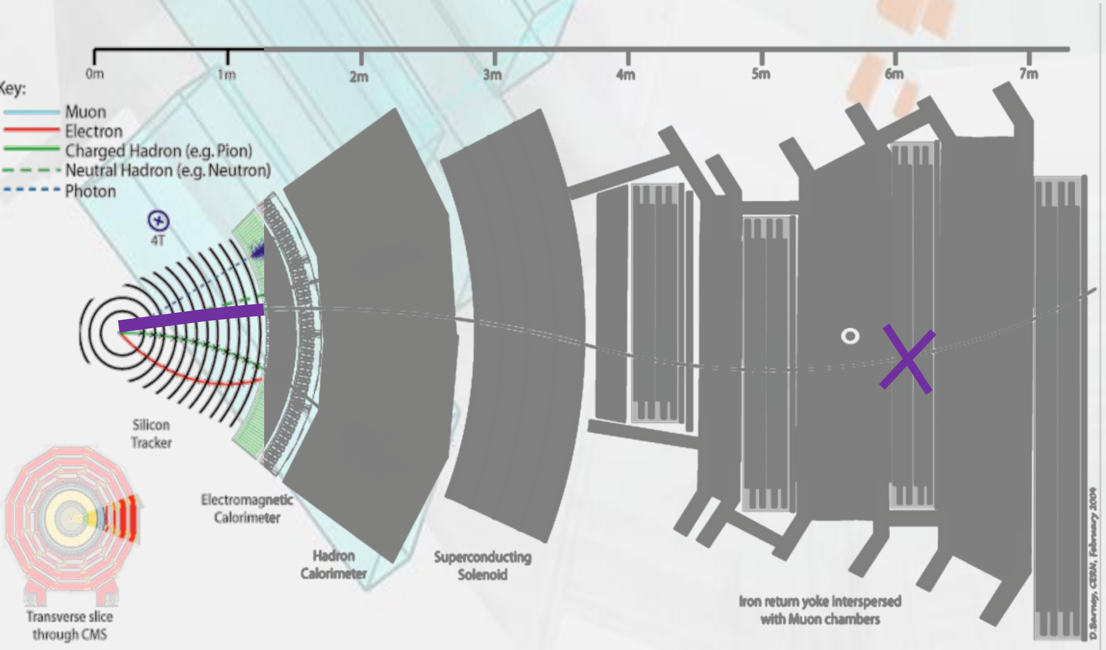

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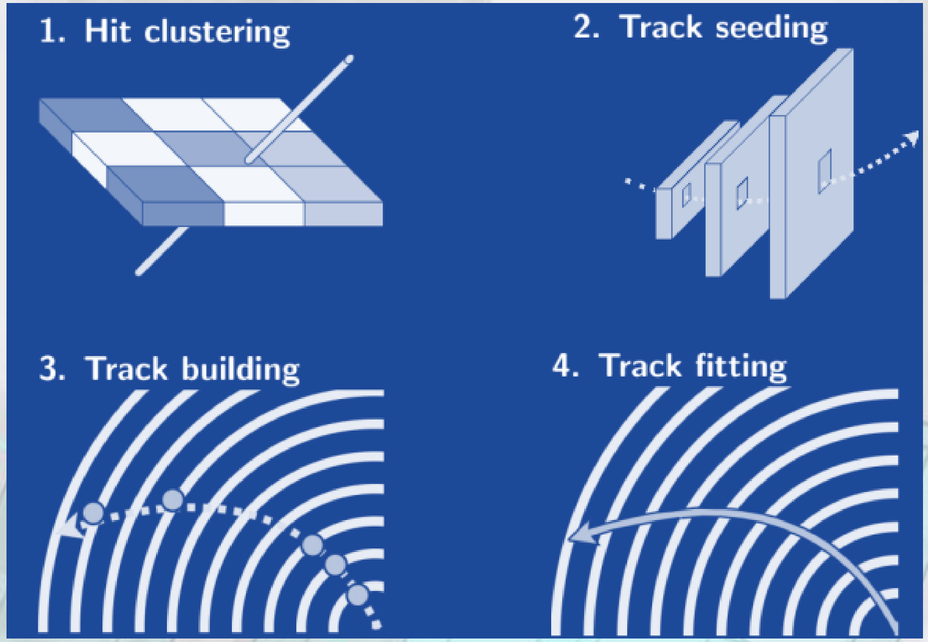

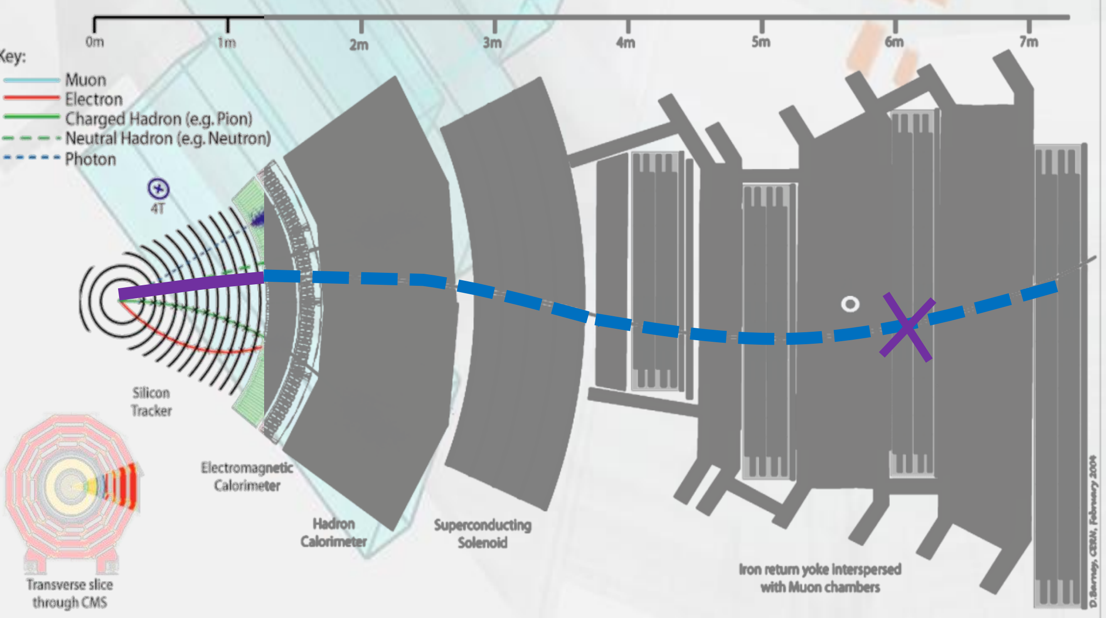

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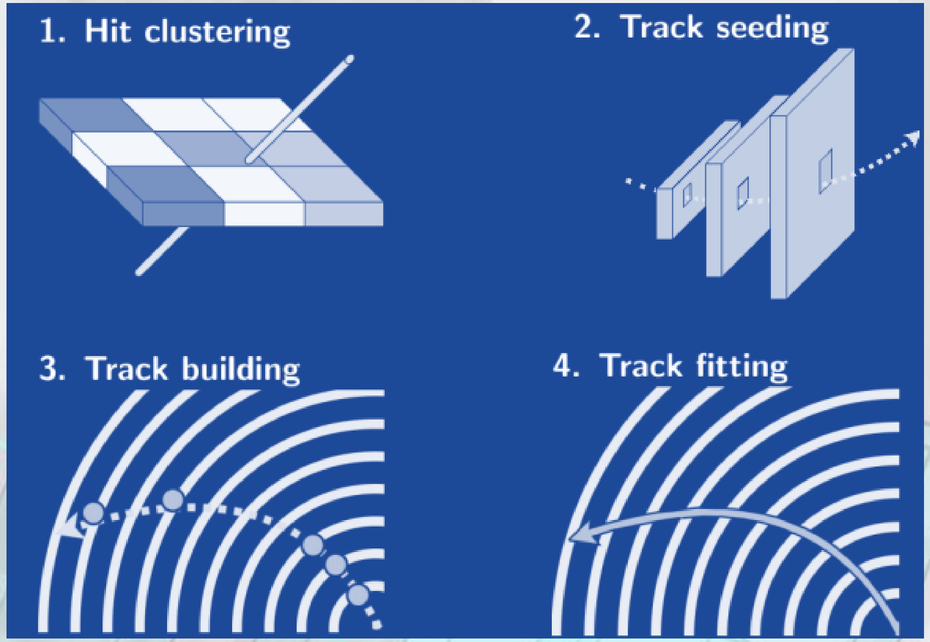

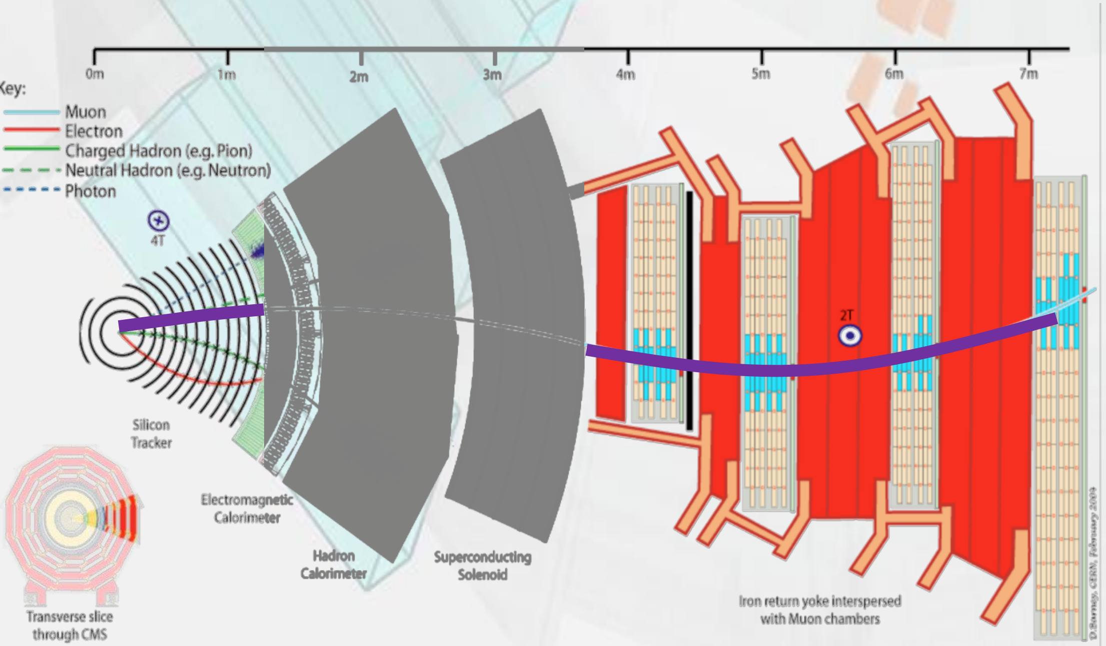

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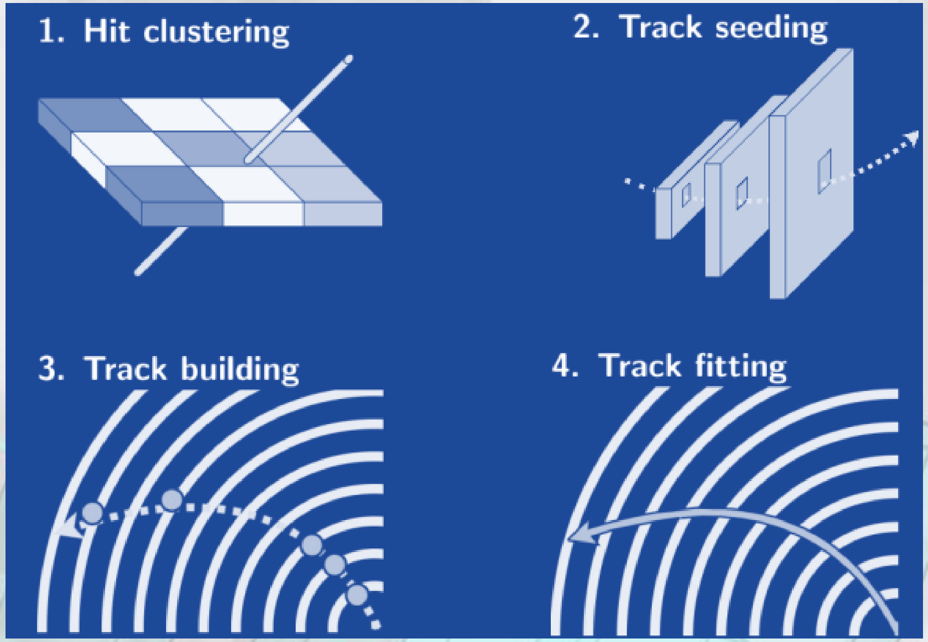

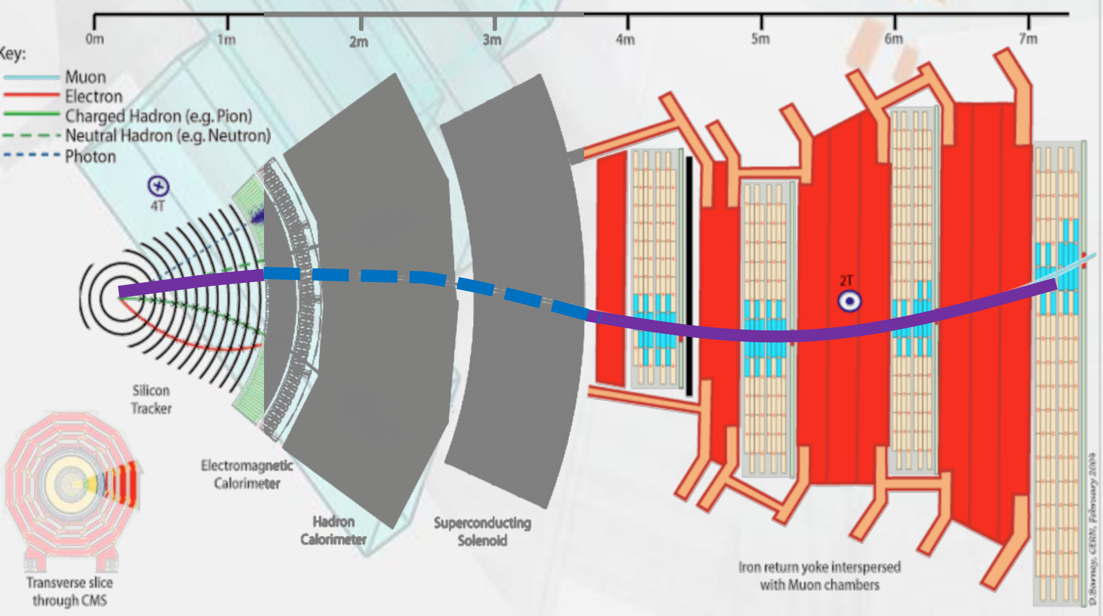

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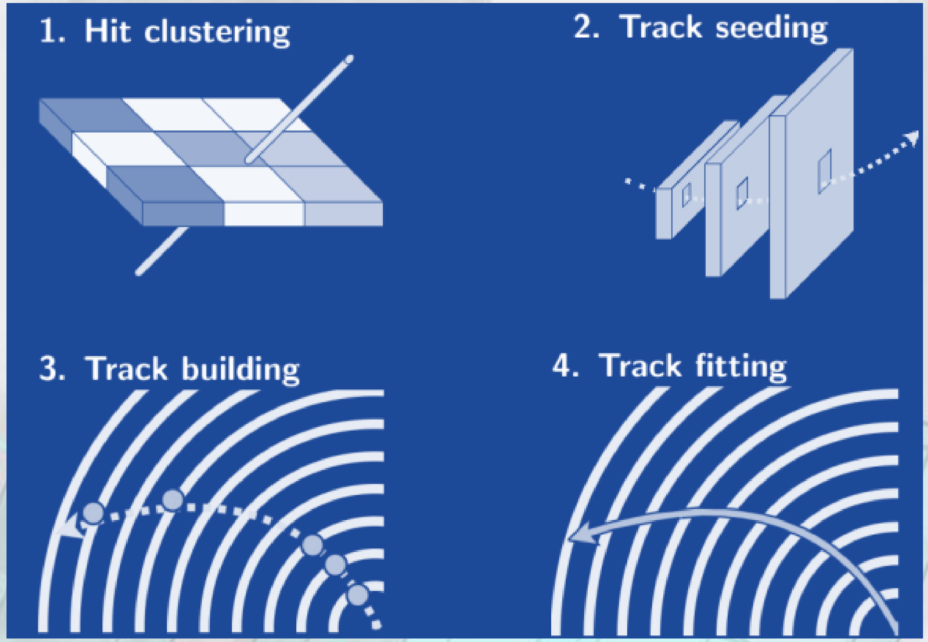

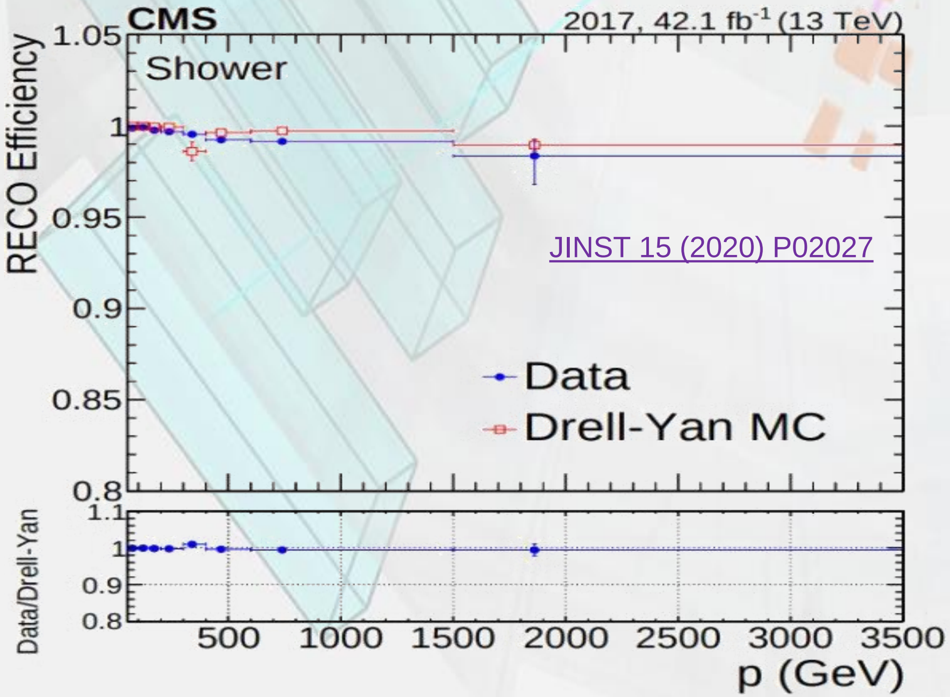

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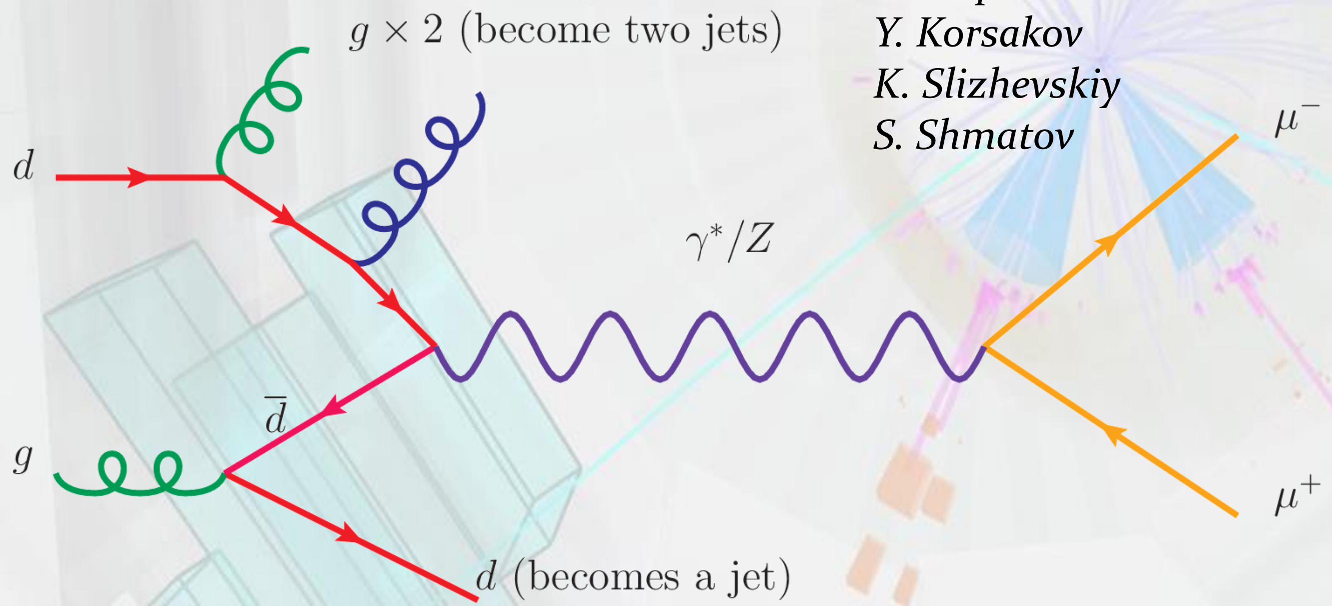
Muon Reconstruction efficietncy ~99%!

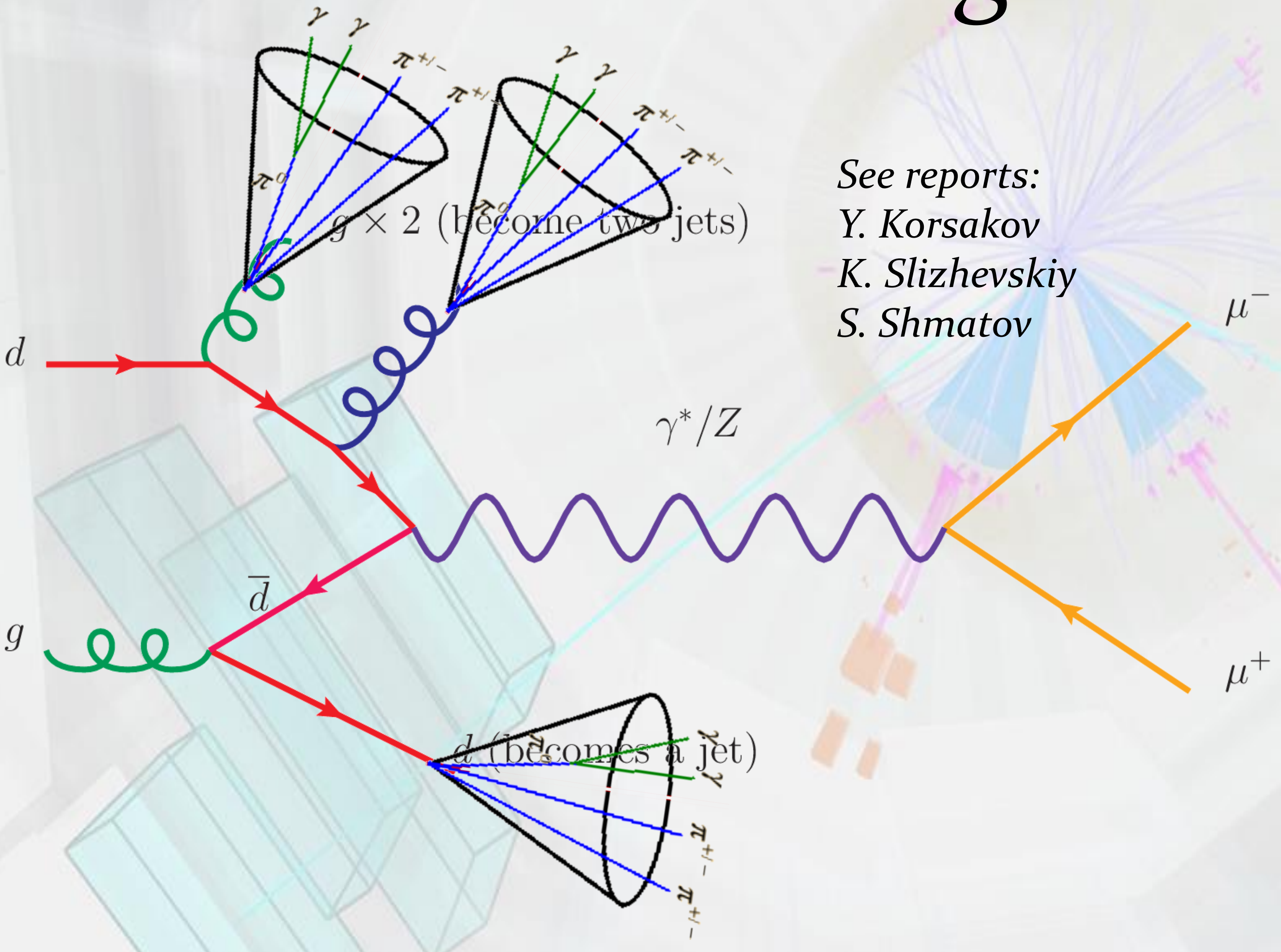
How to Find the Right Muon. Isolation

See reports:
Y. Korsakov
K. Slizhevskiy
S. Shmatov



How to Find the Right Muon. Isolation

Muons from QCD are dominate.
Needs to distinguish signal muons. How?



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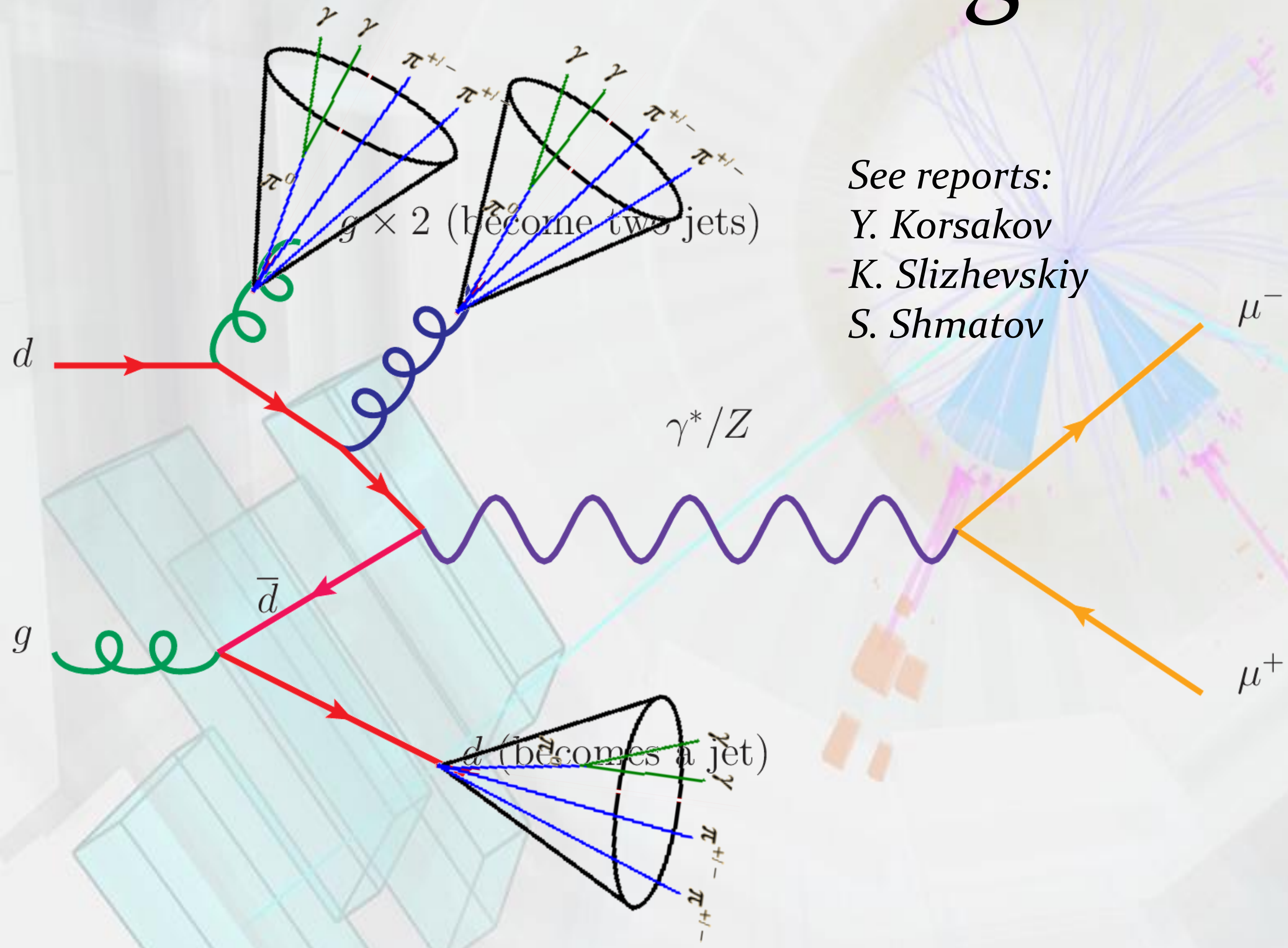

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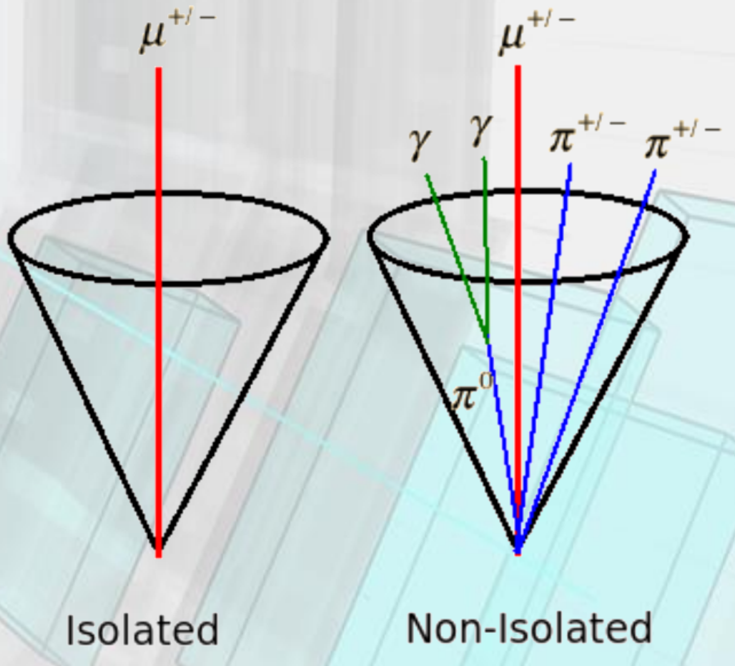

- **Tracker isolation** – only silicon tracker is used
- **Combined isolation** – silicon tracker and calorimeters are used
- **Particle flow isolation** – all subdetectors are used

$$\Delta R = \sqrt{\Delta\varphi^2 + \Delta\eta^2} < 0.4$$

$$\frac{\sum p_T^{\Delta R} - p_T^{\mu}}{\sum p_T^{\Delta R}} < 0.15$$

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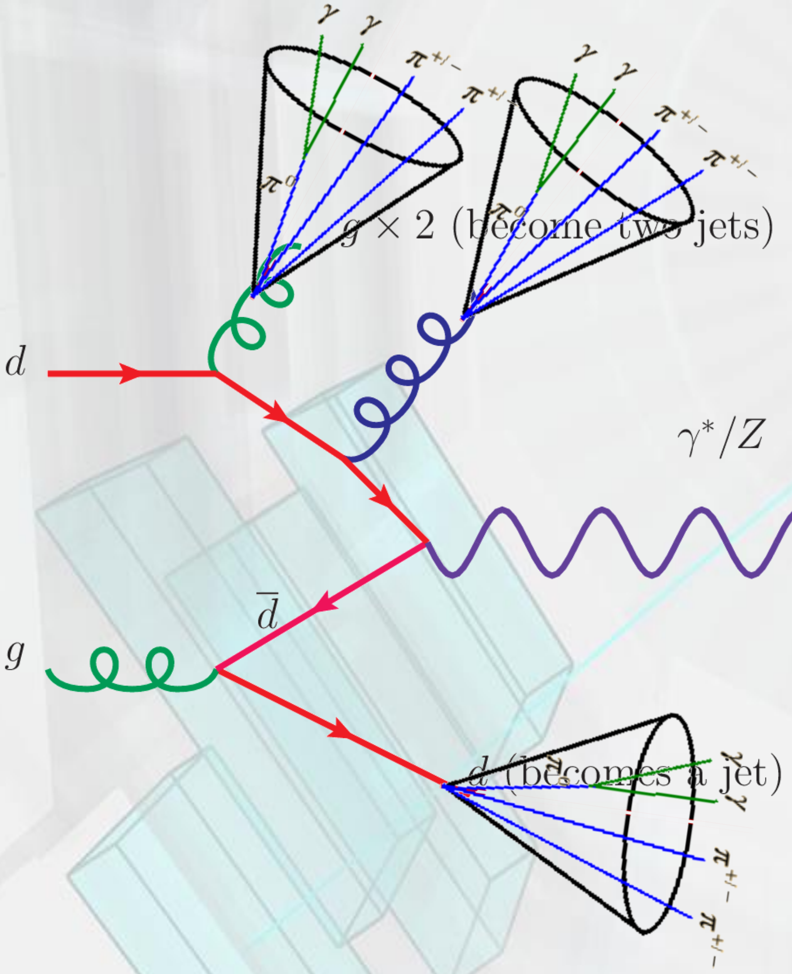

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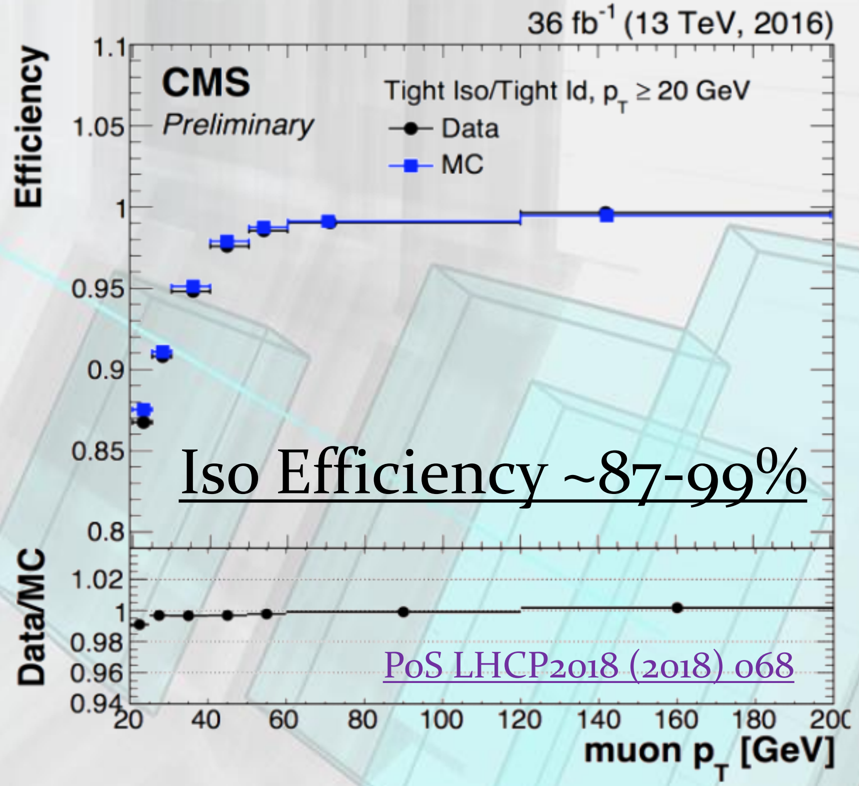

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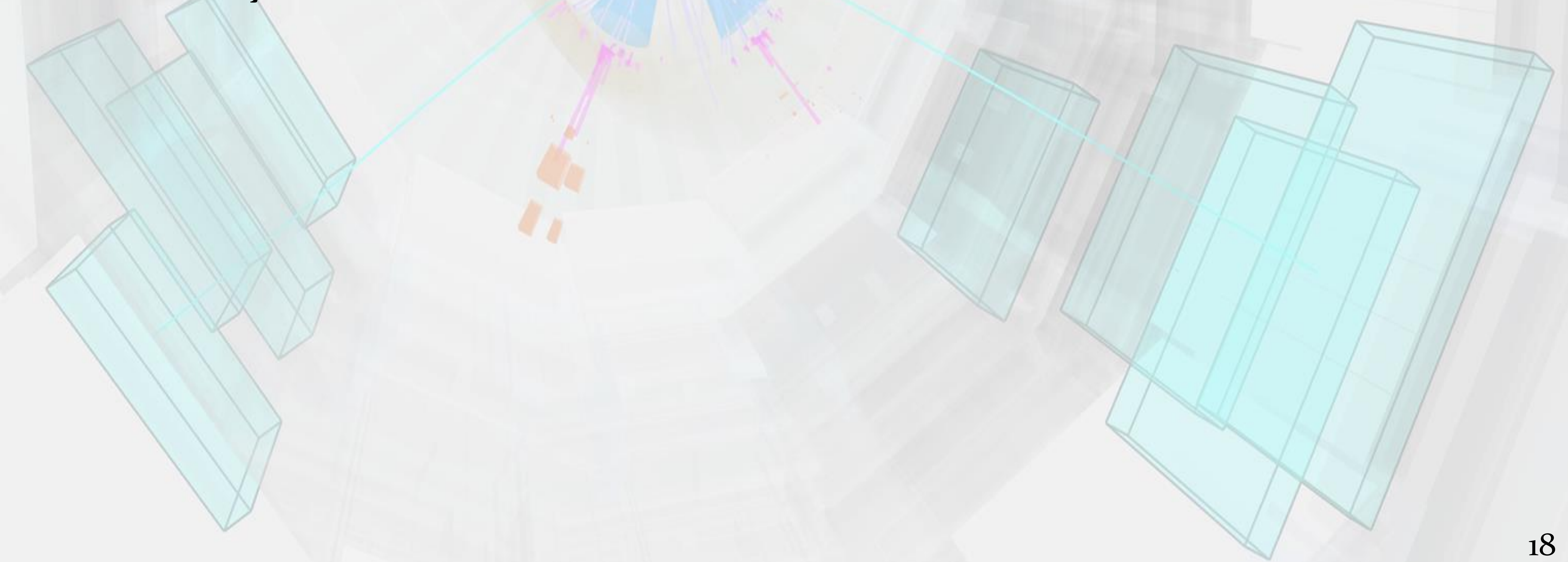
Triggering

Conditions: $L_{inst} \sim 10^{34}\ cm^{-2}s^{-1}$

- 40 MHz
- ~400 Tb per second

Extremely overloaded!



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Level 1 Trigger (L1)

- **Local trigger** – collect signals from muon stations
- ↑ **Regional trigger** – ranking of objects in one detector subsystem
- ↑ **Global trigger**– making decision, forming data stream

30 kHz

High Level Trigger (HLT)

- Use information from silicon tracker
- ↑ Vertex snap
- ↑ Apply Isolation Criteria
- ↑ Fitting
- ↑ Make a decision

100 Hz / 100 Mb/s

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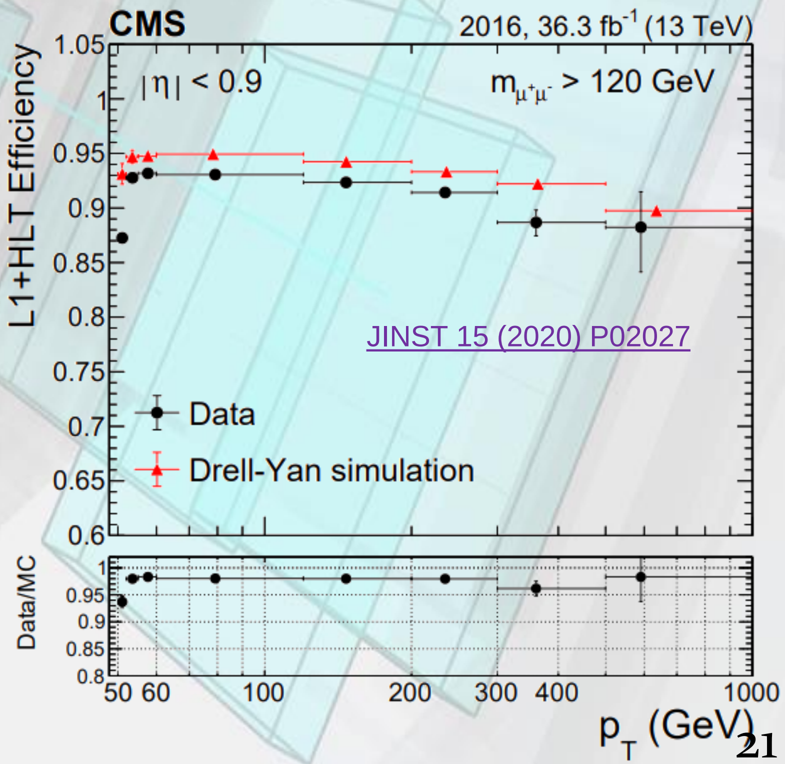
<u>Trigger Efficiency ~93-98%</u>



JINST 15 (2020) P02027

Muon Identification

Electroweak precision measurements requires high quality muon tracks.
Special Identification algorithms are used

Tight Muon

The candidate is reconstructed as a Global Muon	
χ^2/ndof of the global-muon track fit < 10	To suppress hadronic punch-through and muons from decays in flight
At least one muon chamber hit included in the global-muon track fit	
Muon segments in at least two muon stations	To suppress accidental track-to-segment matches
Its tracker track has transverse impact parameter $d_{xy} < 2$ mm w.r.t. the primary vertex, $d_z < 5$ mm	To suppress cosmic muons and further suppress muons from decays in flight and tracks from pileup
Number of pixel hits > 0. number of tracker layers with hits >5	To guarantee a good p_T measurement, for which some minimal number of measurement points in the tracker is needed

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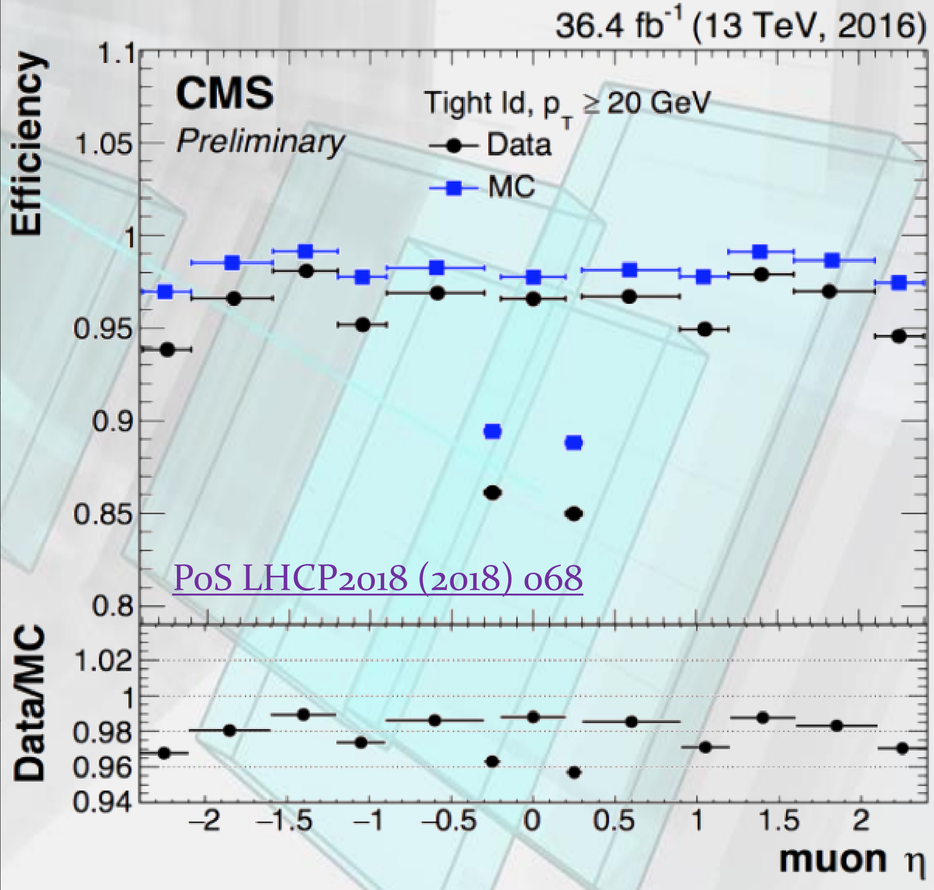
Identification efficiency >95%!



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Conclusions

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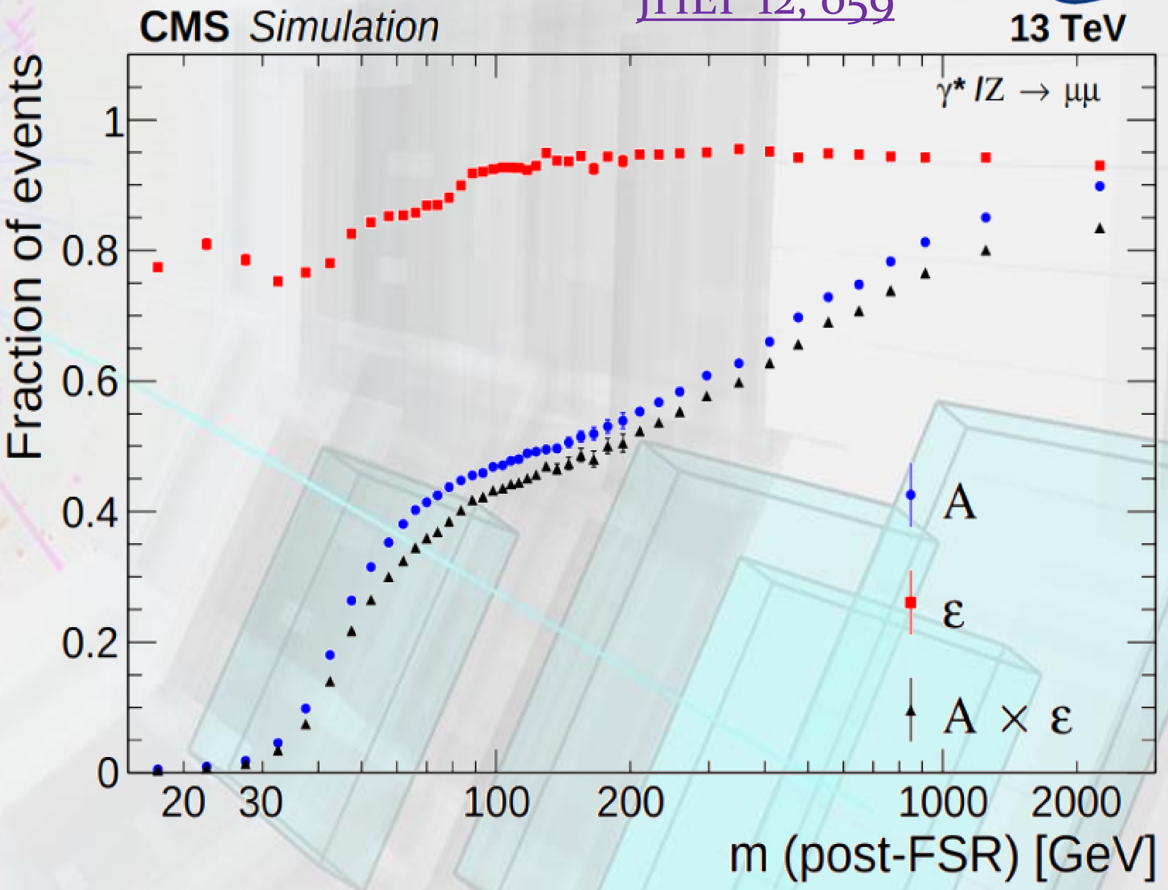

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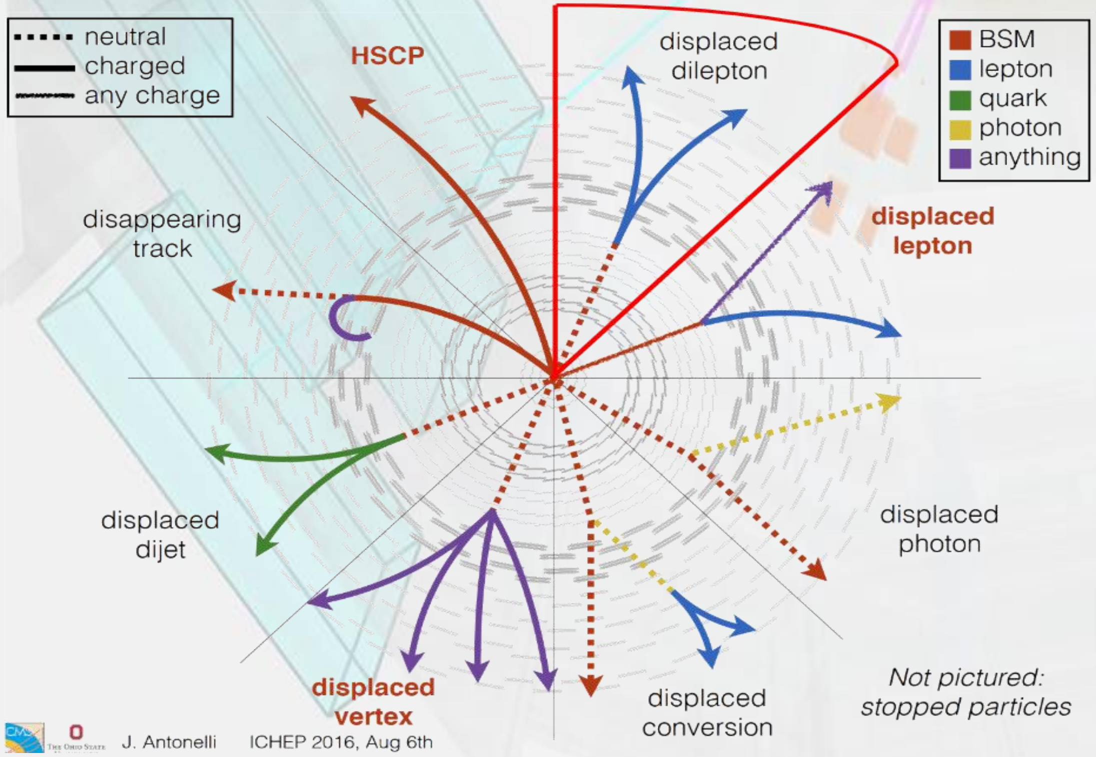

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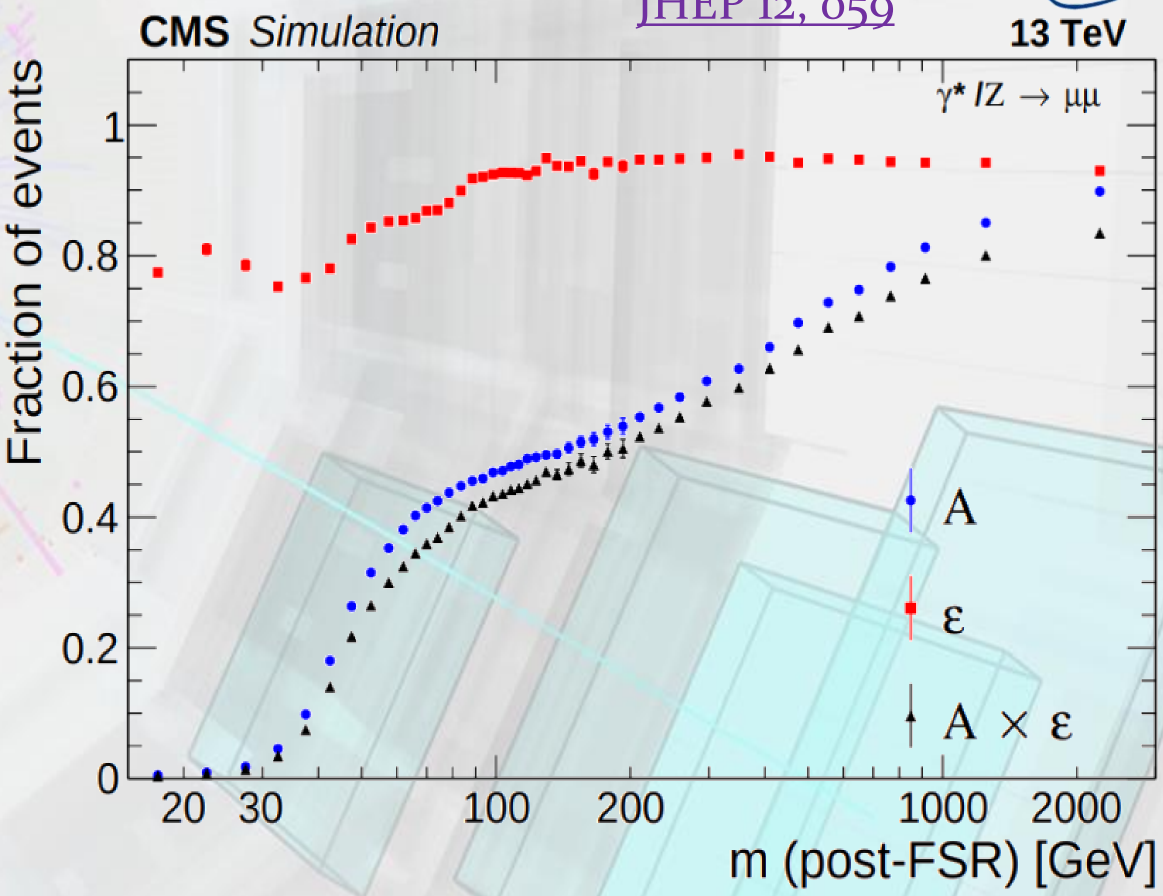

New technics and algorithms (like mkFIT , DNN etc.) are coming. New methods of registration exotic experimental signatures is under the process