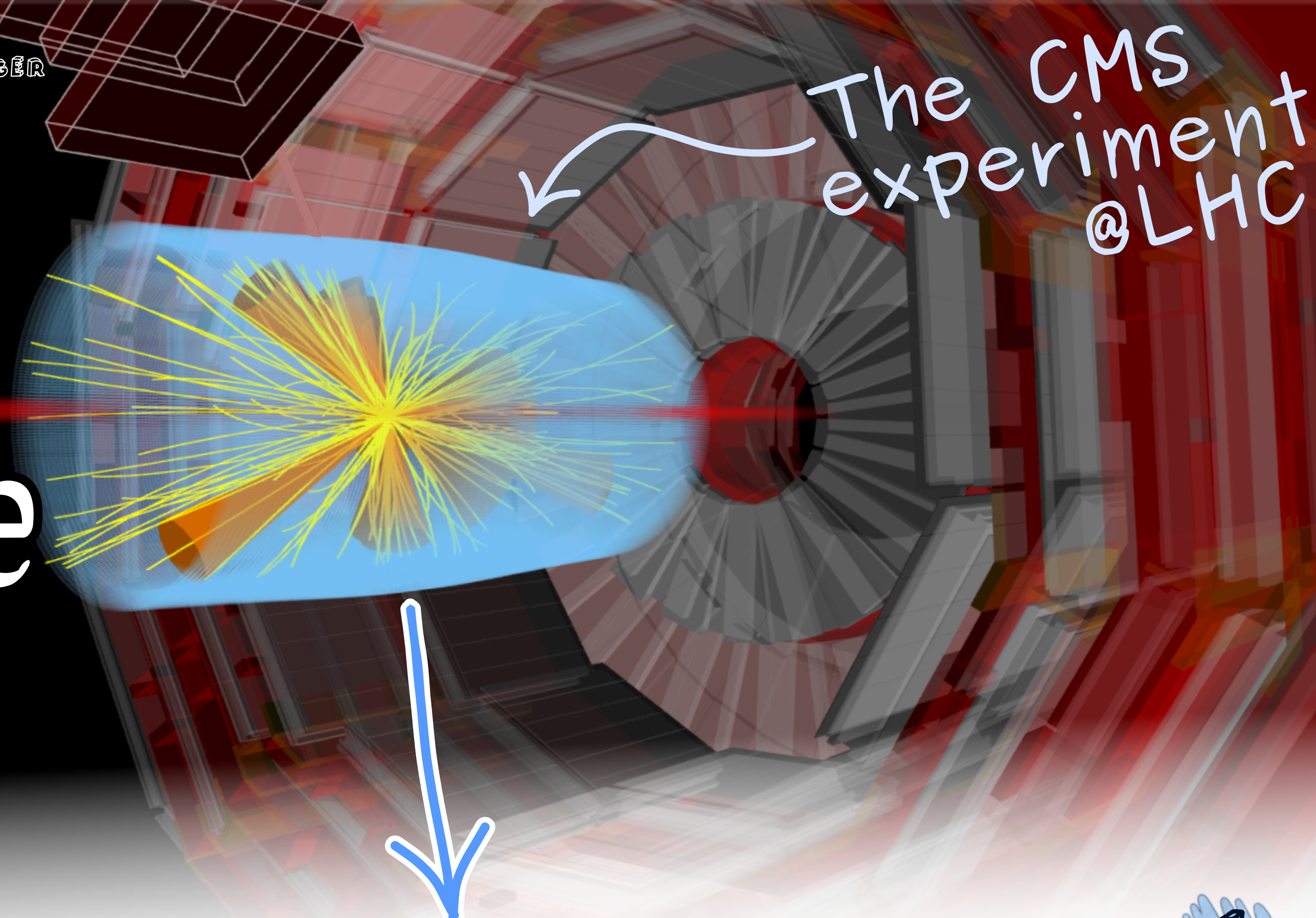


# Pixels for the subatomic universe

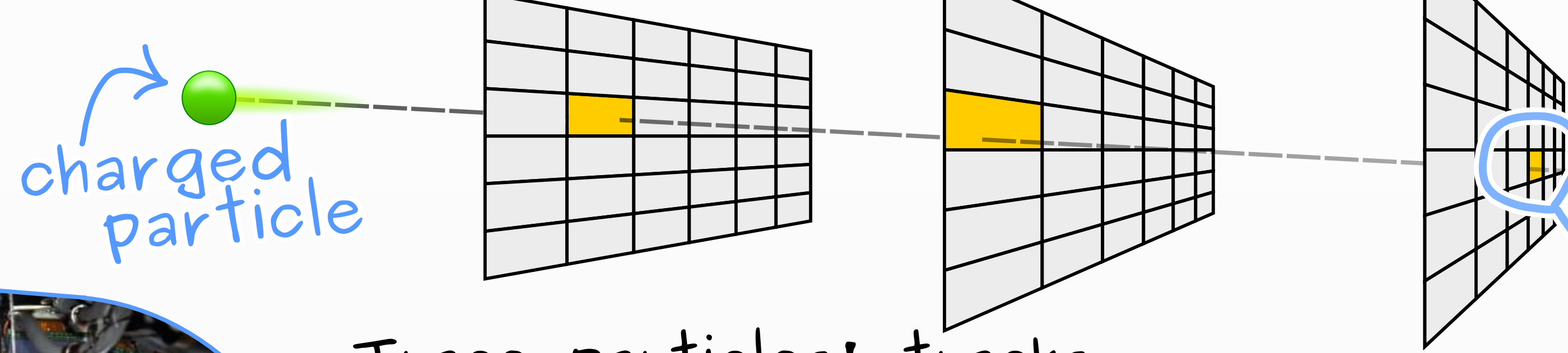


PROF. BEN KILMINSTER'S GROUP

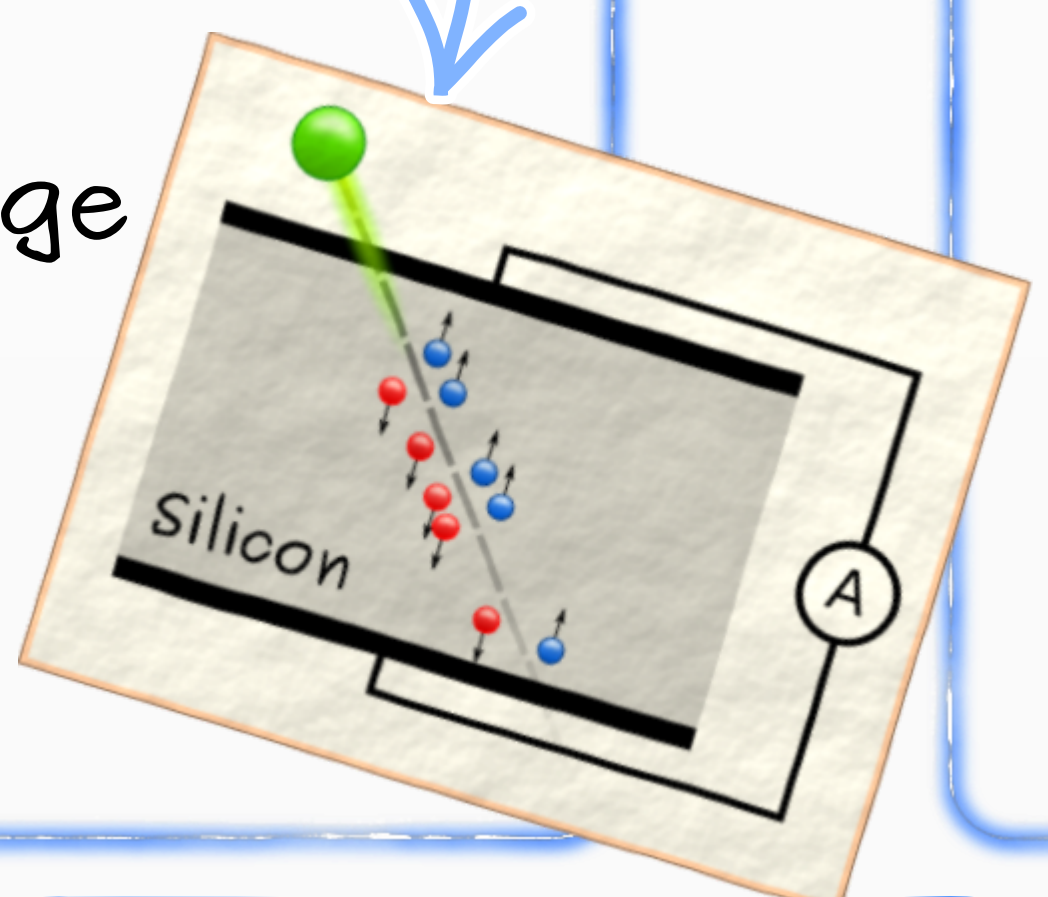
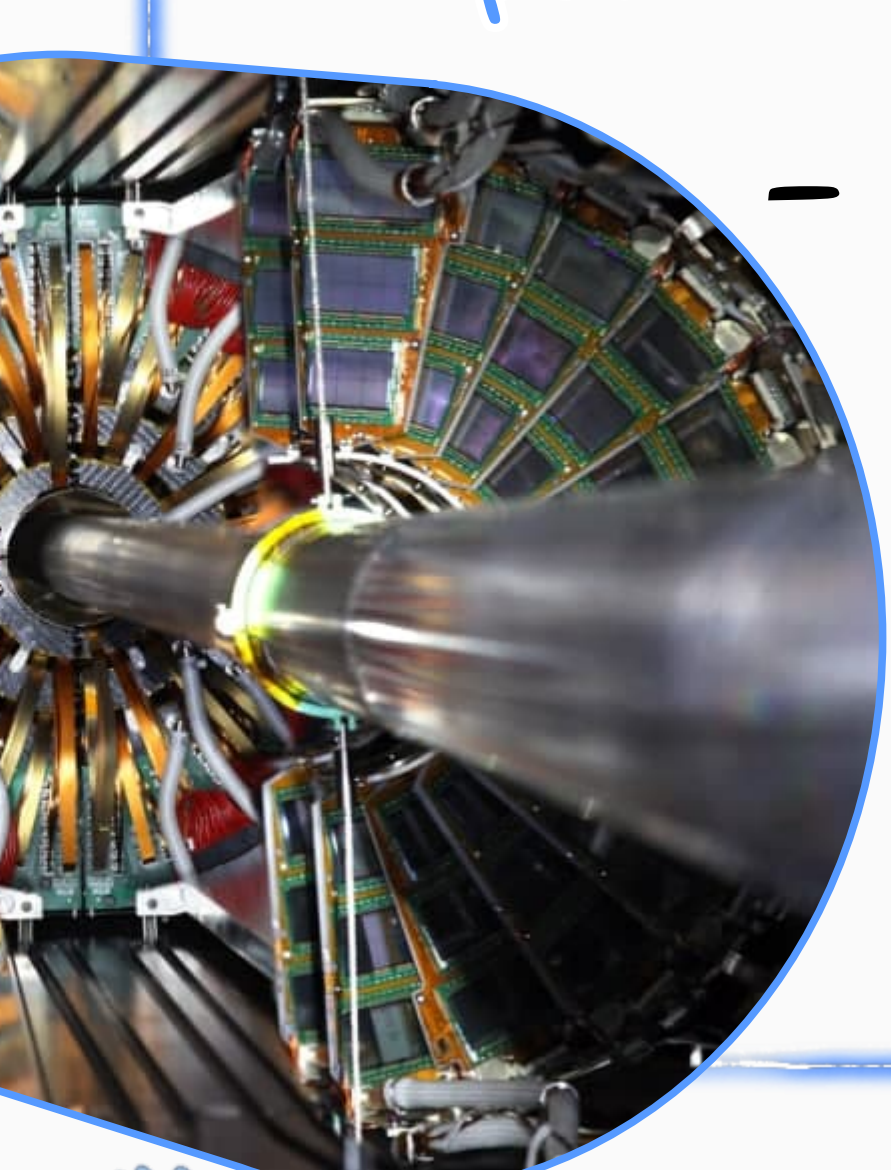
The CMS experiment @LHC



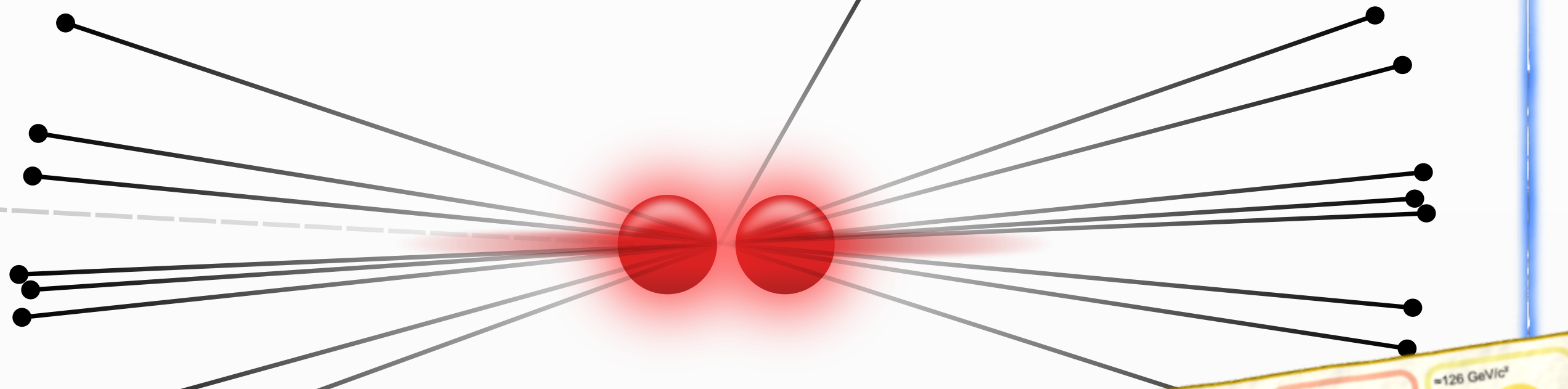
## 2 Pixel detector (the tracker)



- Trace particles' tracks
- Measure momentum and charge
- Identify point of collision
- Find decays of b-quarks



## 1 protons collide

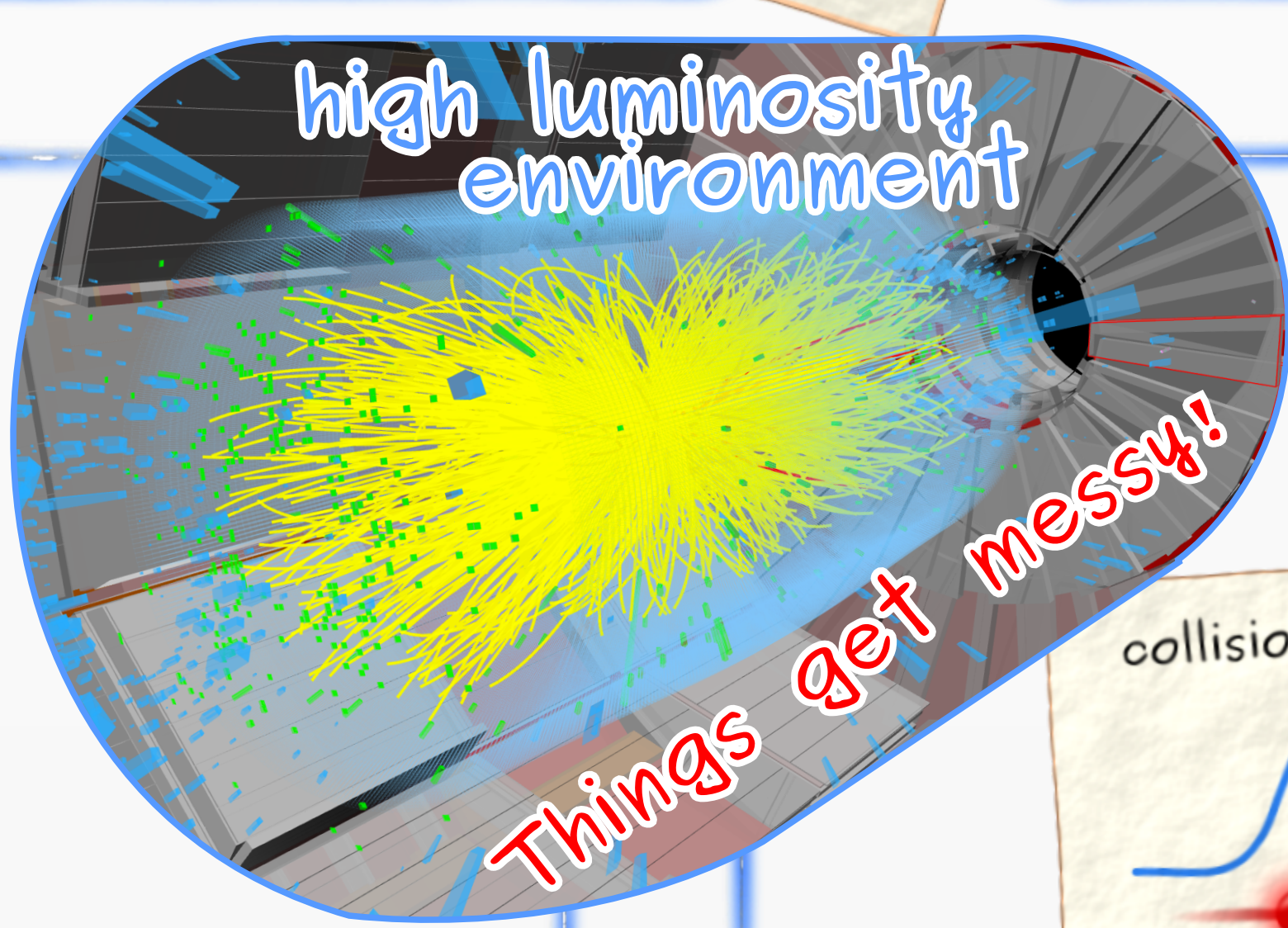


hadrons + leptons + photons etc...

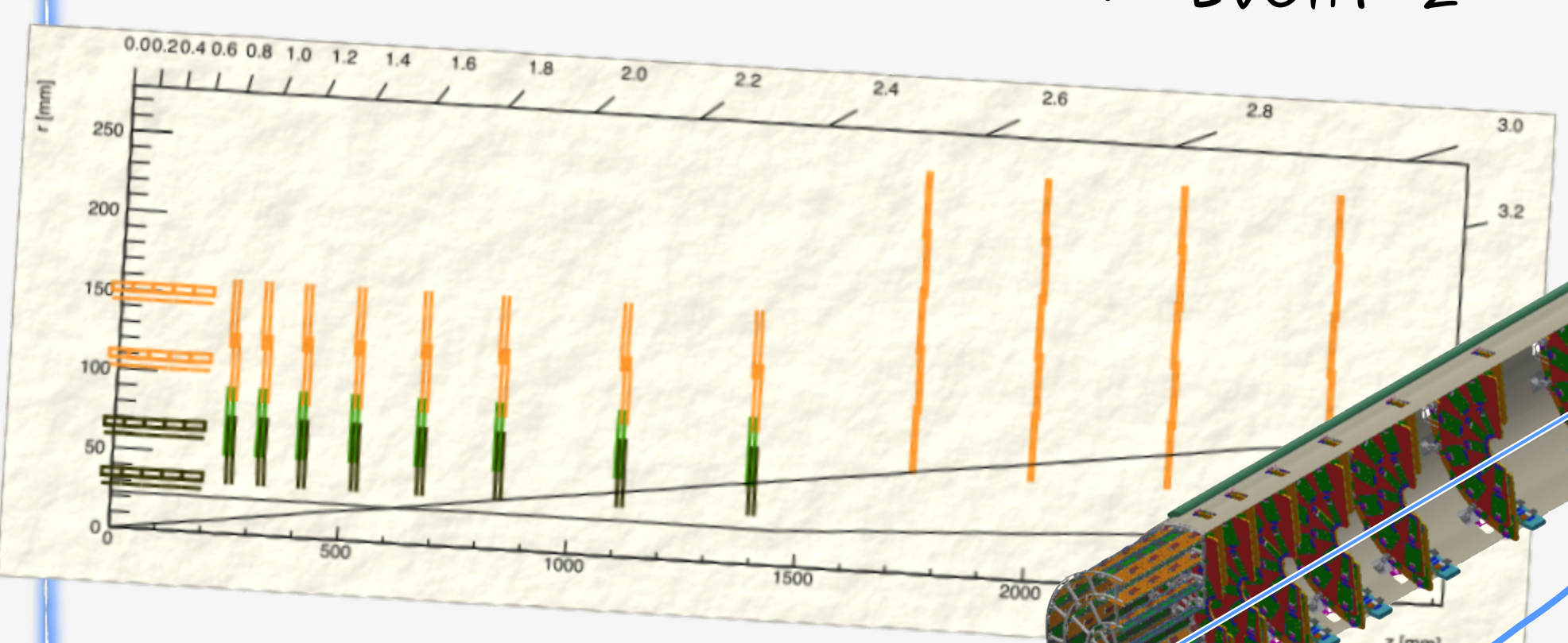
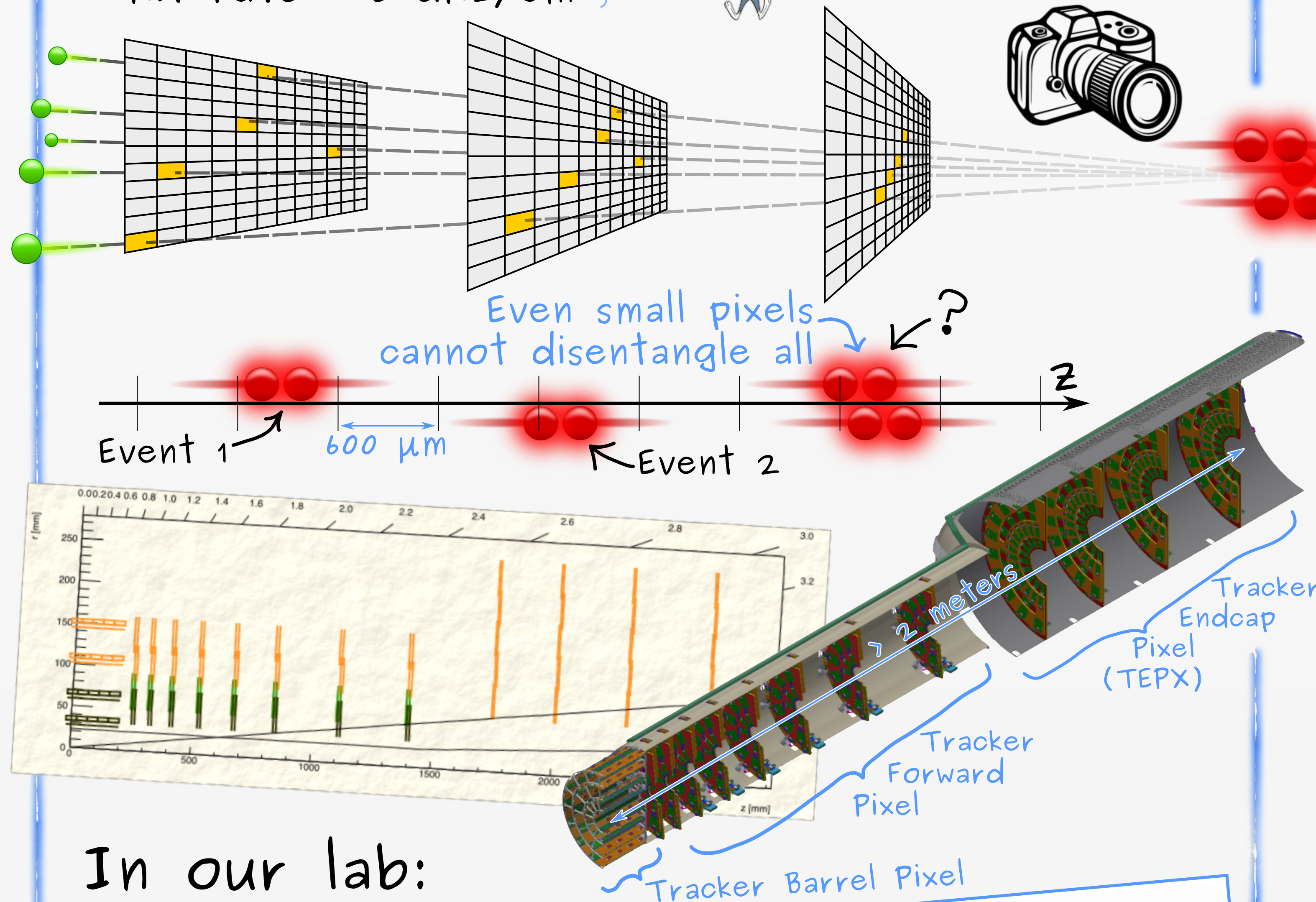
mass = +2.3 MeV/c <sup>2</sup> charge = +2/3	mass = +1.275 GeV/c <sup>2</sup> charge = +2/3	mass = +173.07 GeV/c <sup>2</sup> charge = +2/3	mass = 0 charge = 0	mass = +126 GeV/c <sup>2</sup> charge = 0
<b>u</b> up	<b>c</b> charm	<b>t</b> top	<b>g</b> gluon	<b>H</b> Higgs boson
mass = +4.8 MeV/c <sup>2</sup> charge = -1/3	mass = +95 MeV/c <sup>2</sup> charge = -1/3	mass = +4.18 GeV/c <sup>2</sup> charge = -1/3	mass = 0 charge = 0	mass = 0 charge = 0
<b>d</b> down	<b>s</b> strange	<b>b</b> bottom	<b>γ</b> photon	<b>Z</b> Z boson
mass = 0.511 MeV/c <sup>2</sup> charge = -1	mass = 105.7 MeV/c <sup>2</sup> charge = -1	mass = 1.777 GeV/c <sup>2</sup> charge = -1	mass = 91.2 GeV/c <sup>2</sup> charge = 0	mass = 80.4 GeV/c <sup>2</sup> charge = ±1
<b>e</b> electron	<b>μ</b> muon	<b>τ</b> tau	<b>W</b> W boson	<b>Z</b> Z boson
mass = +2.2 eV/c <sup>2</sup> charge = 0	mass = +1.88 MeV/c <sup>2</sup> charge = 0	mass = +1.777 GeV/c <sup>2</sup> charge = 0	mass = 80.4 GeV/c <sup>2</sup> charge = ±1	mass = 80.4 GeV/c <sup>2</sup> charge = ±1
<b>ν<sub>e</sub></b> electron neutrino	<b>ν<sub>μ</sub></b> muon neutrino	<b>ν<sub>τ</sub></b> tau neutrino	<b>W</b> W boson	<b>Z</b> Z boson

## 3 3D-TRACKING

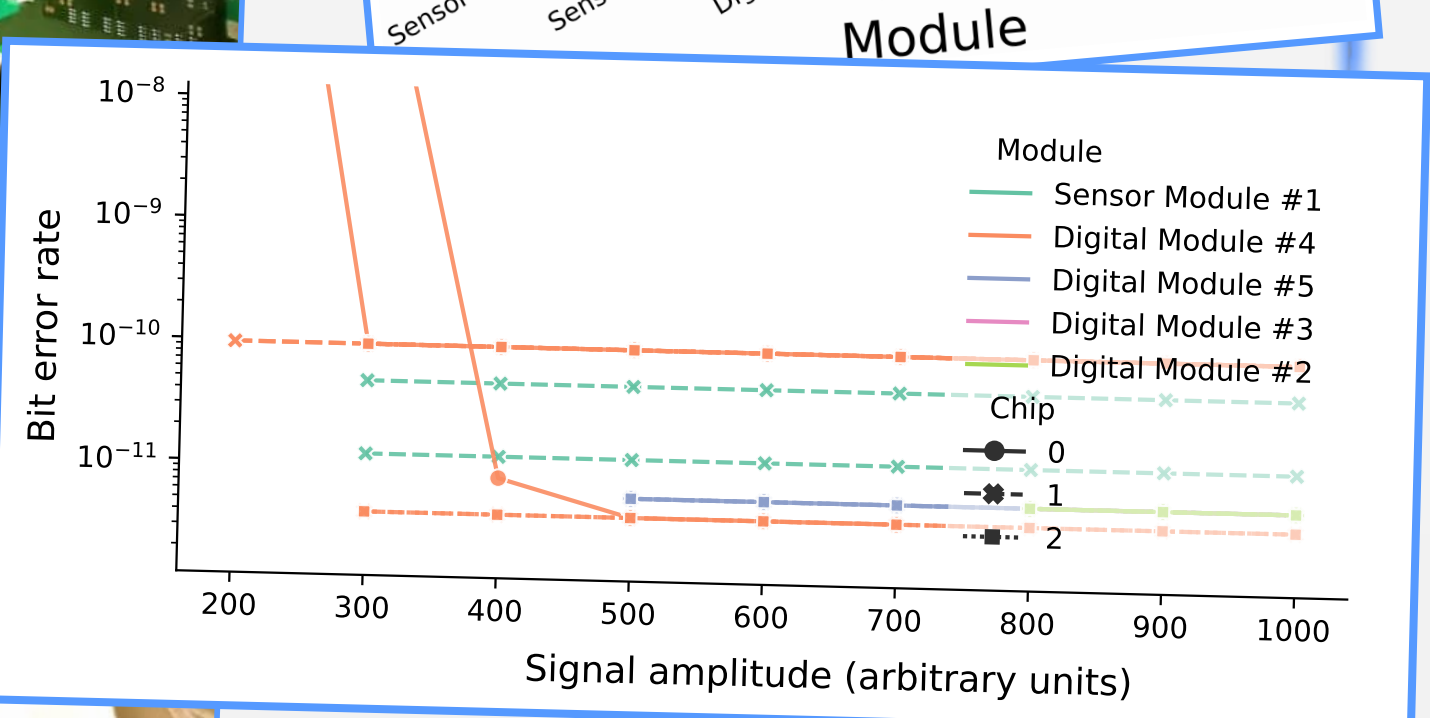
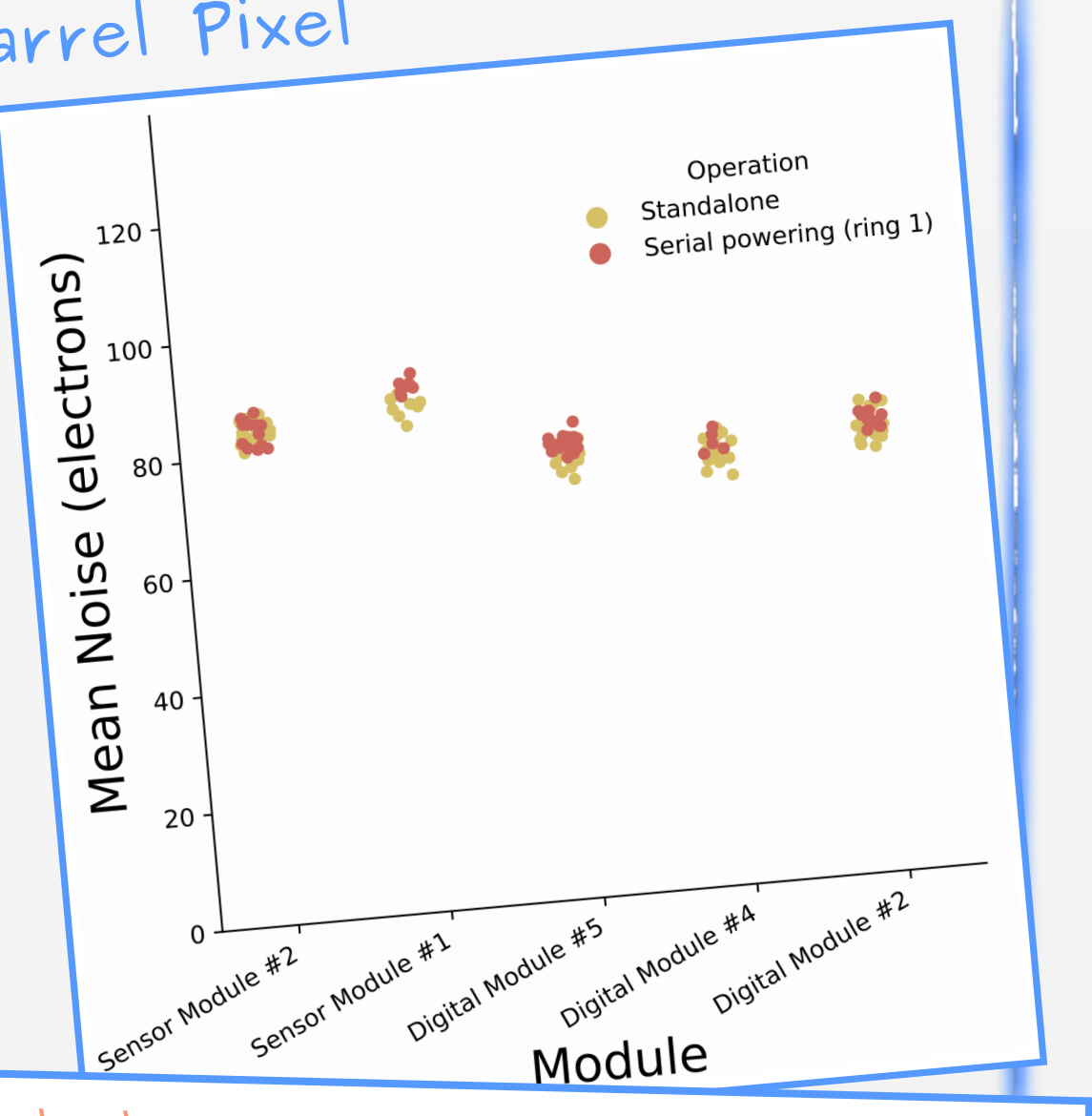
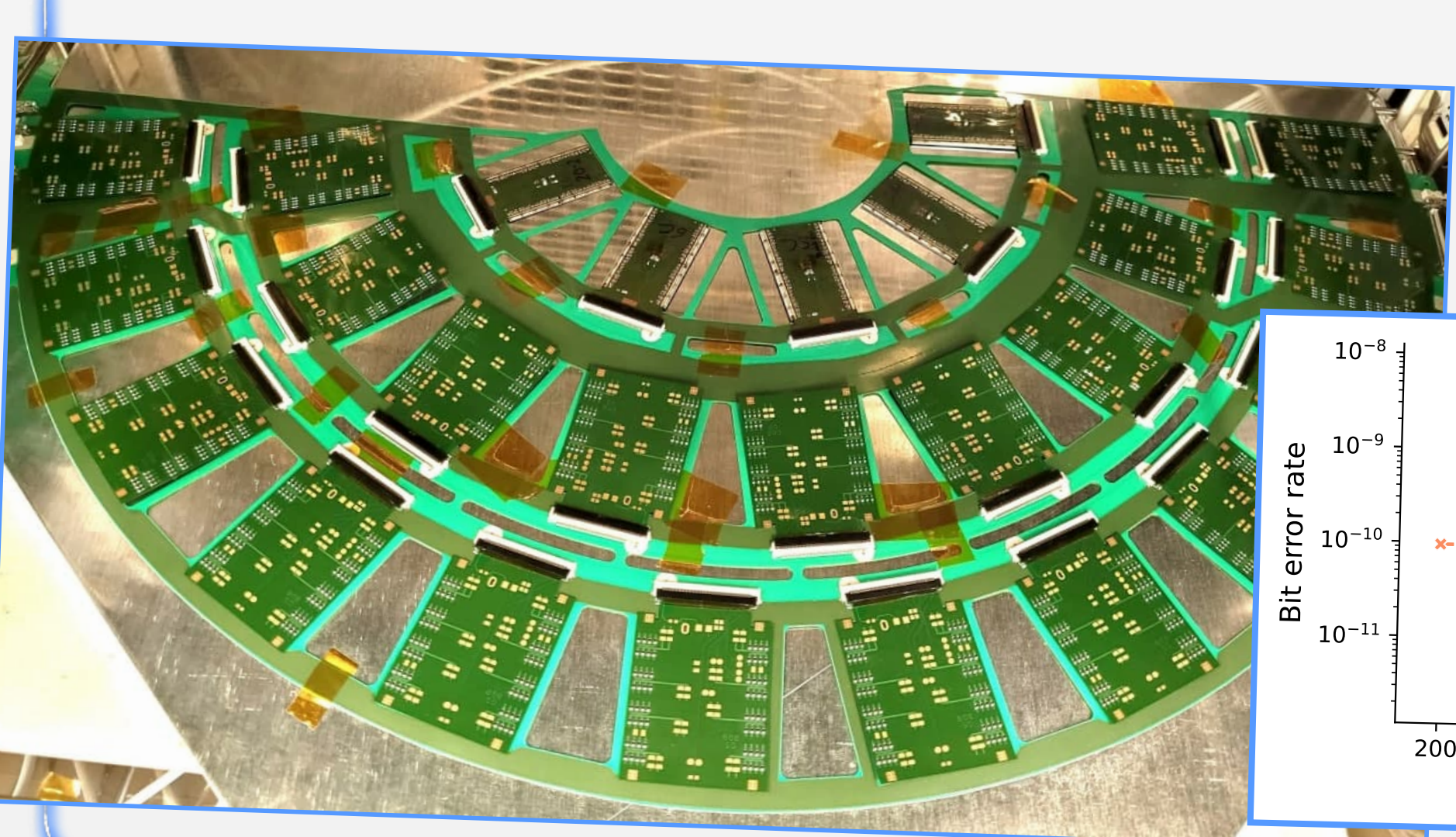
- Major upgrade of CMS detector
- Starting operations in 2027
- Pixel size = 50x50 μm<sup>2</sup>
- ≈ 2 Gigapixels
- Hit rate = 3 GHz/cm<sup>2</sup> compare to your smartphone



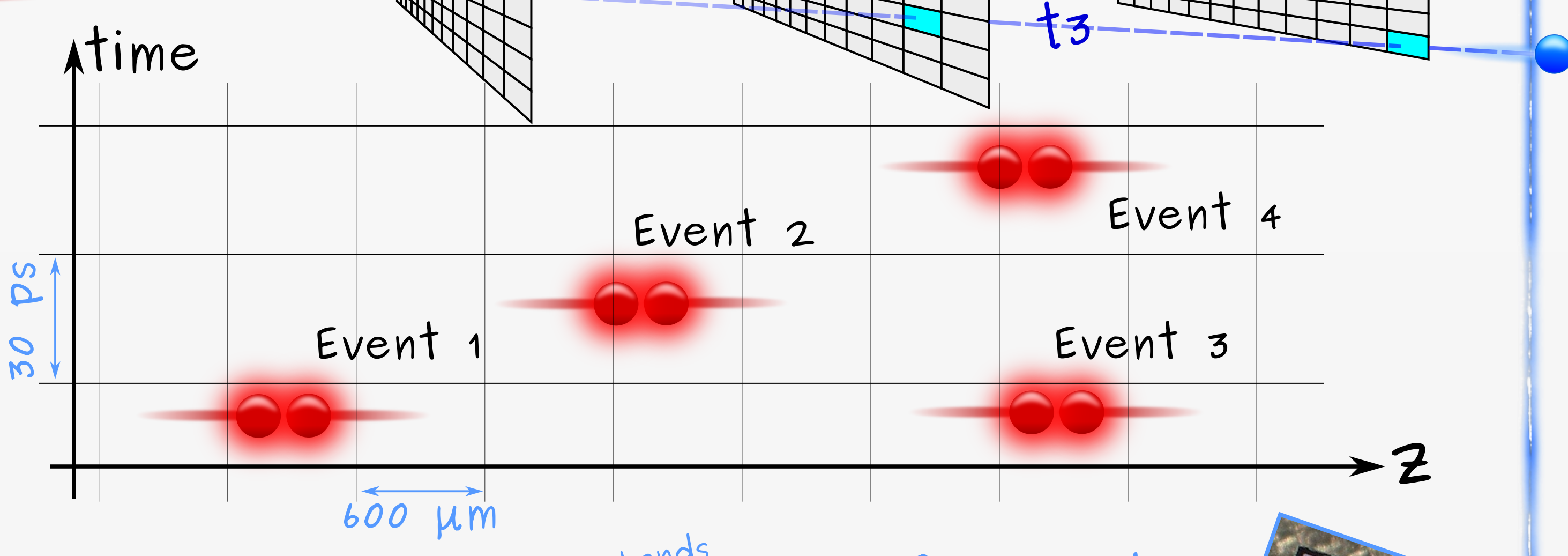
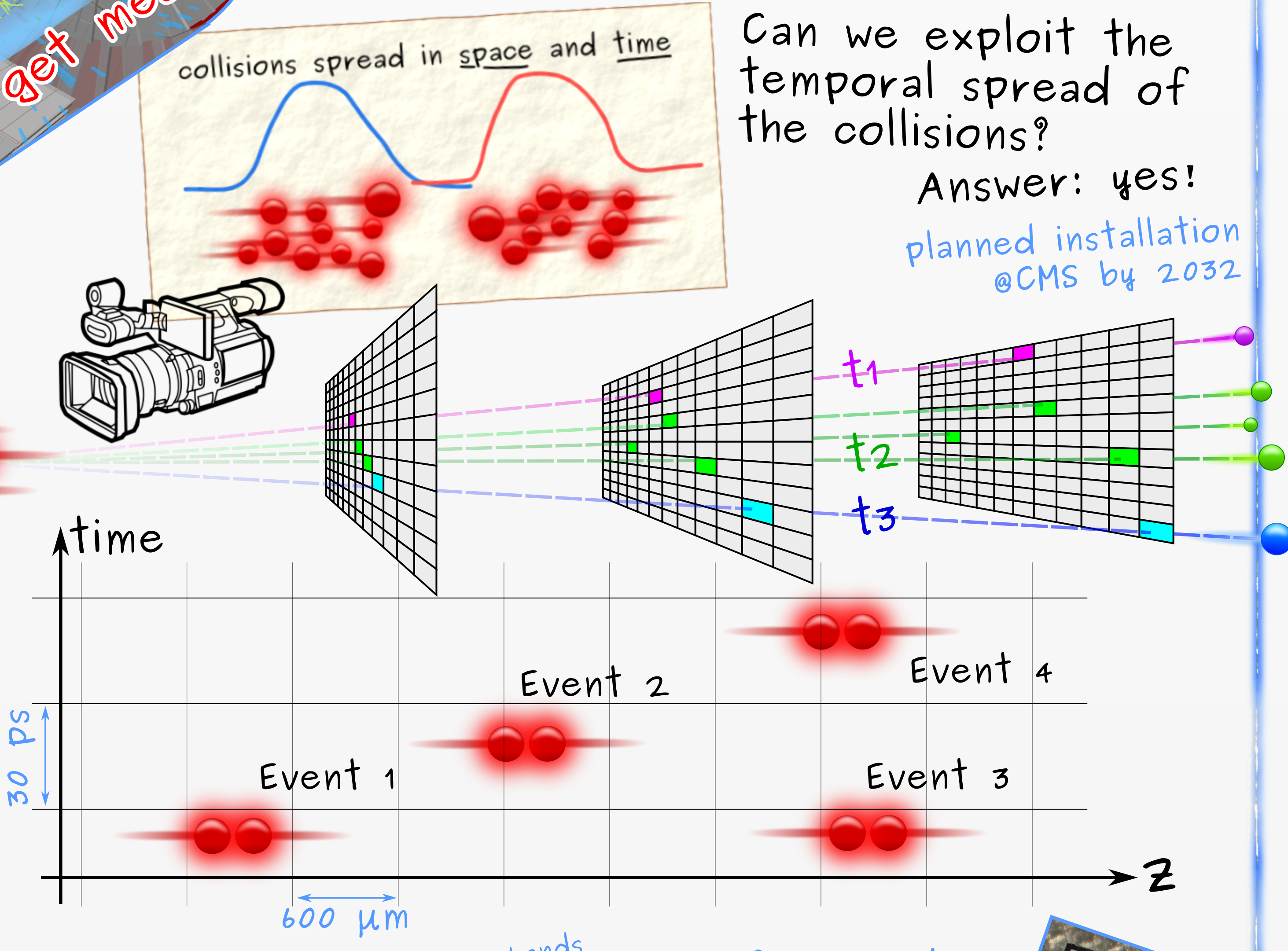
Things get messy!



- In our lab:
- Test pixel modules
  - Study TEPX prototype @ UZH
  - Work on CMS code
  - Help build our super-camera



## 4 4D-TRACKING



Can we exploit the temporal spread of the collisions?  
Answer: yes!  
planned installation @CMS by 2032

- In our lab: your hands get dirty!
- Novel LGAD technology
  - 4D sensors:
    - position measurements
    - timing measurements
  - ASIC design

