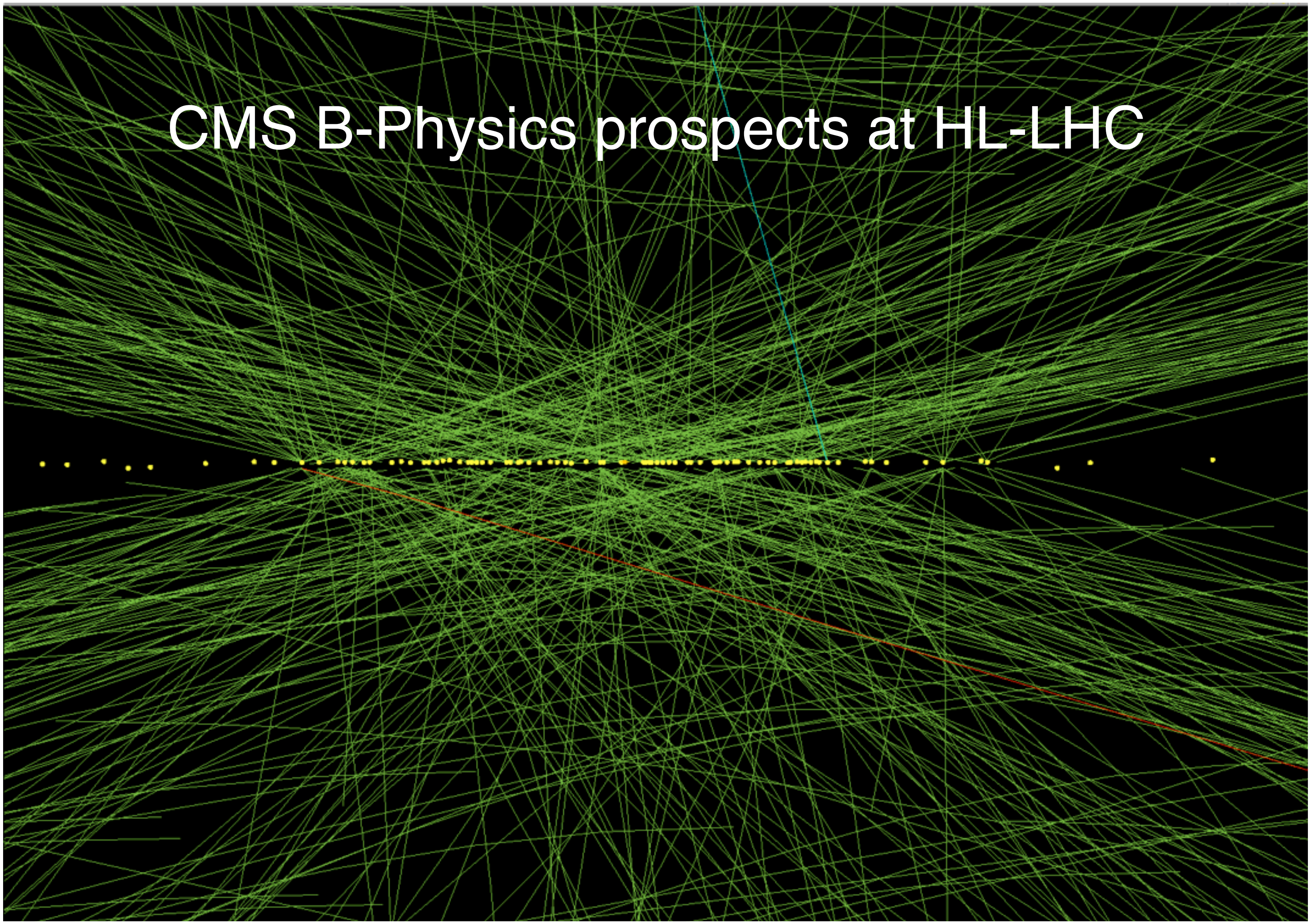
CMS B-Physics prospects at HL-LHC



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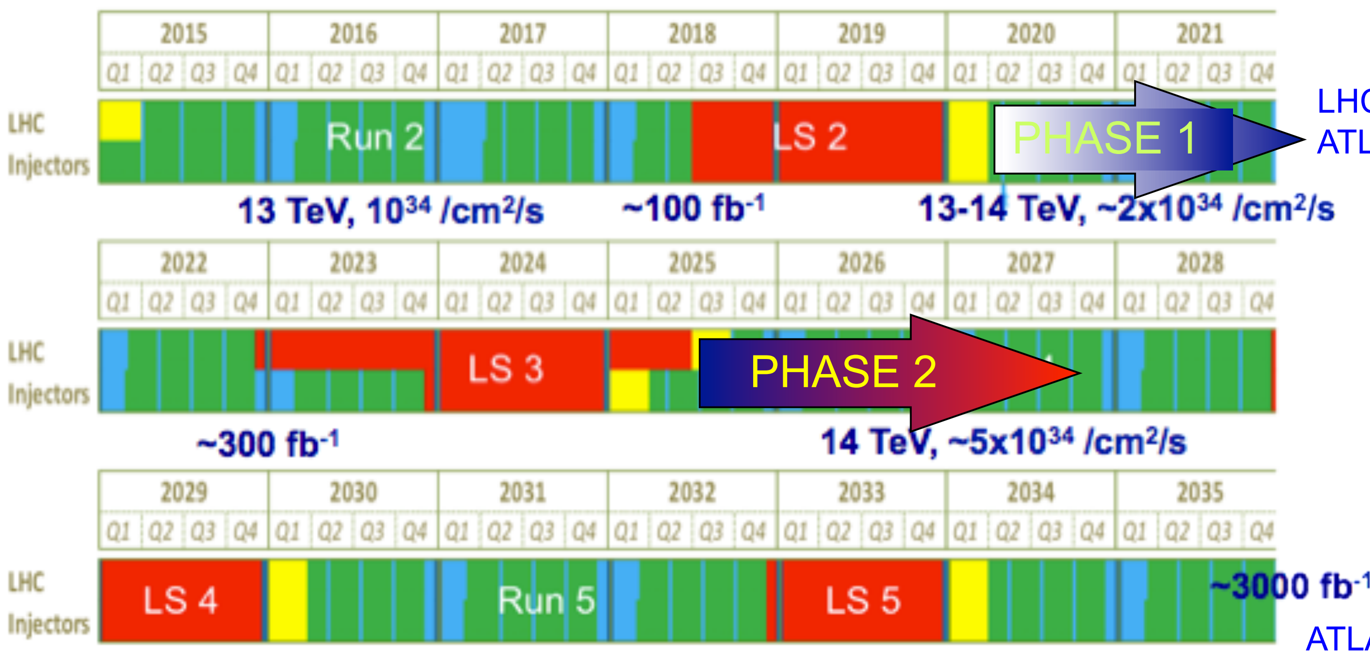
University of Padova and INFN Padova

The HL-LHC scenario



LHCb Upgrade
ATLAS/CMS Upgrades phase 1

HL-LHC
14 TeV
>250 fb-1/year

ATLAS/CMS
Upgrades phase 2

At HL-LHC ~140 events/bx spread over ±15 cm (3 σ)
~3000 fb^{-1} expected in 10 years running

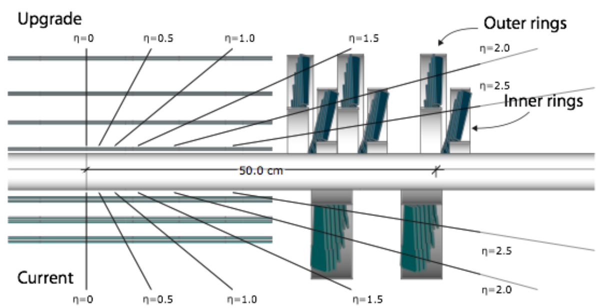
Excellent opportunity to search for (rare) and new phenomena

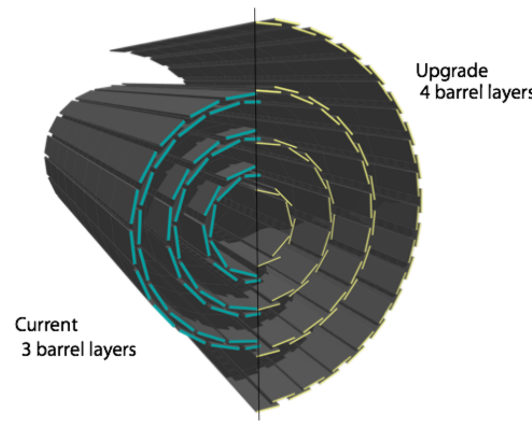
Tracker needs to be rebuilt

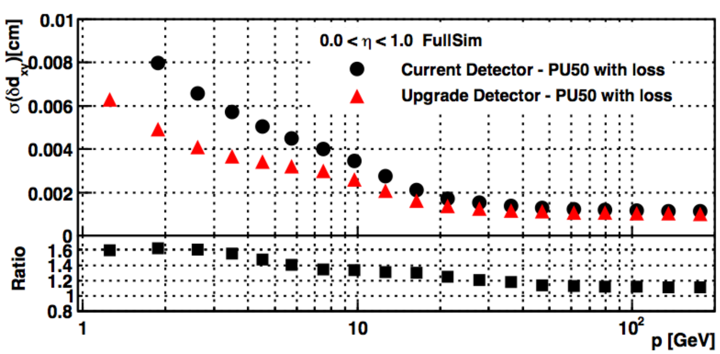
Phase 1 Upgrade

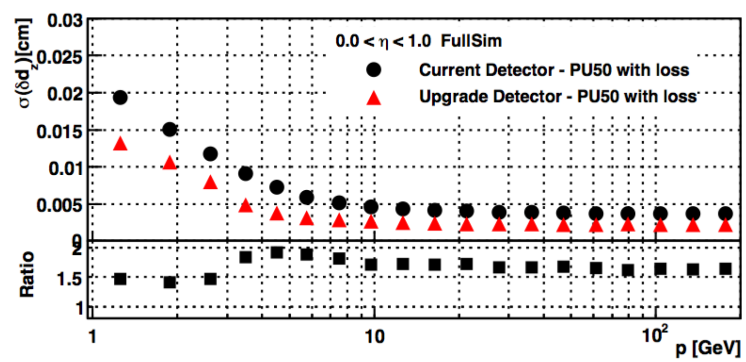
- In Phase 1 the pixel detector will be replaced
  - One more layer, closer to the beam pipe -> more precise
  - Lower material budget -> smaller multiple scattering
- Overall better performance for low pT tracks, used for B-physics

CERN-LHCC-2012-016
http://cds.cern.ch/record/1481838?ln=en

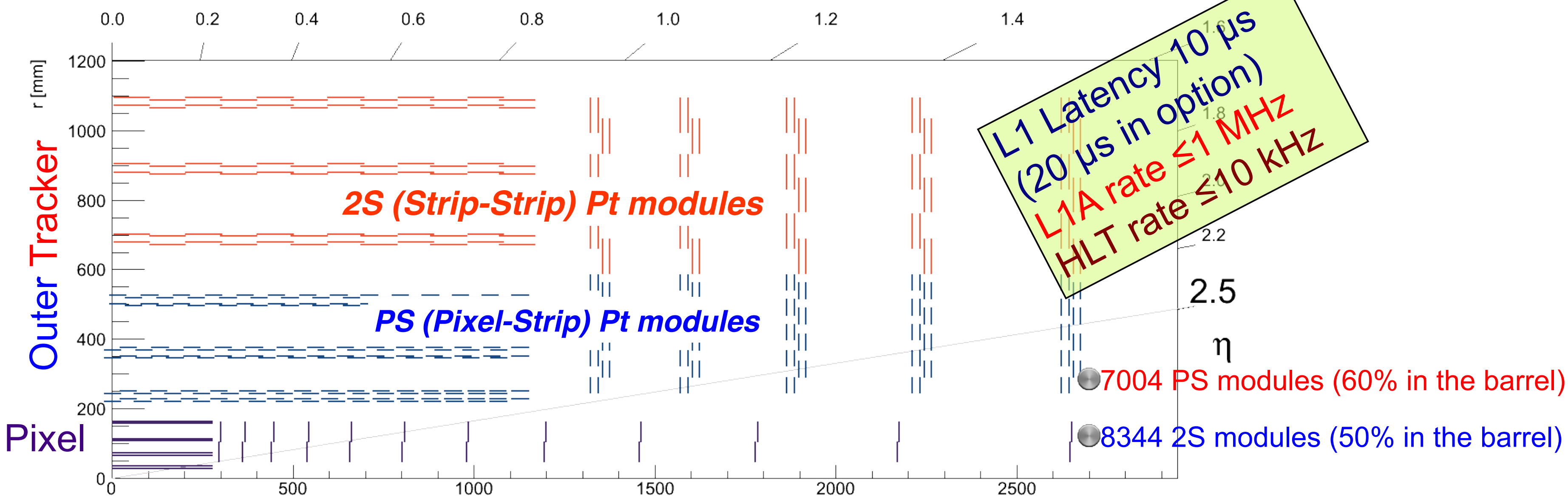






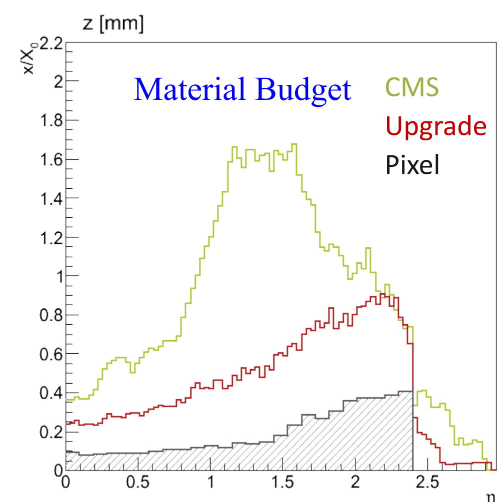


Phase 2 Upgraded Tracker

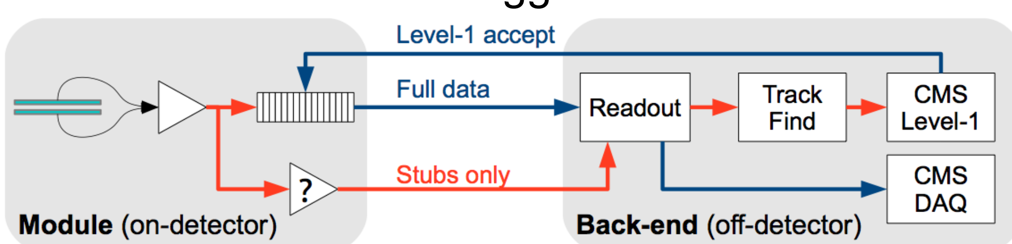


Better p_T resolution and lighter than current tracker

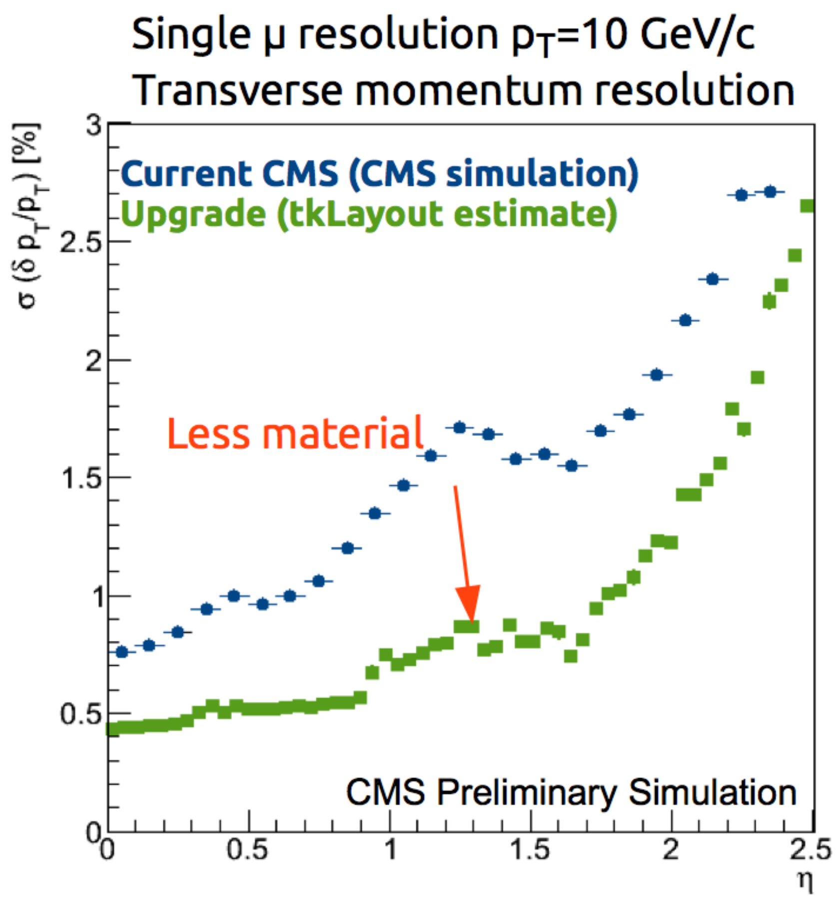
L1 Trigger functionality down to ~ 2 GeV p_T tracks



Readout and Trigger schematics



Offline tracking resolution



Clear improvement expected in the whole η range

- 2S(trip) sensors modules

100 µm x 5 cm long strips on both sensors

P(ixel)S(strip) module

strips = 100 µm x 2.4 cm

pixels = 100 µm x 1.5 mm

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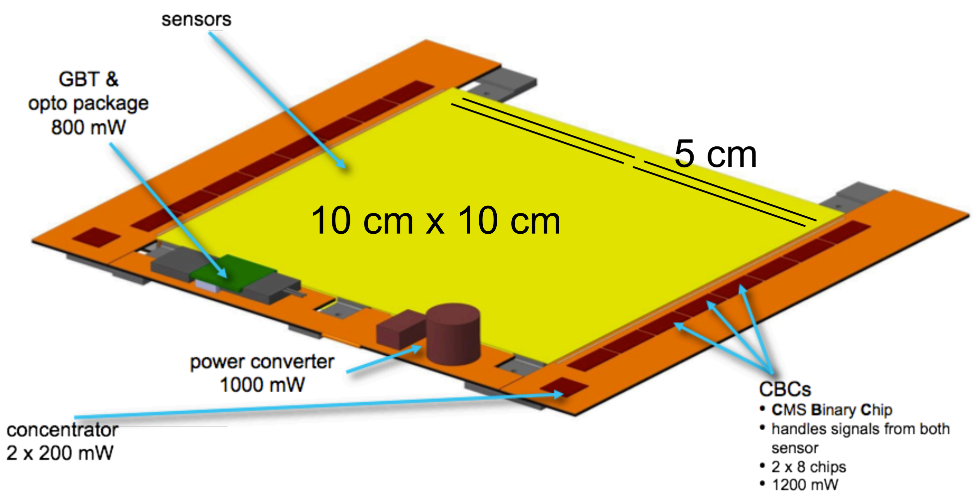
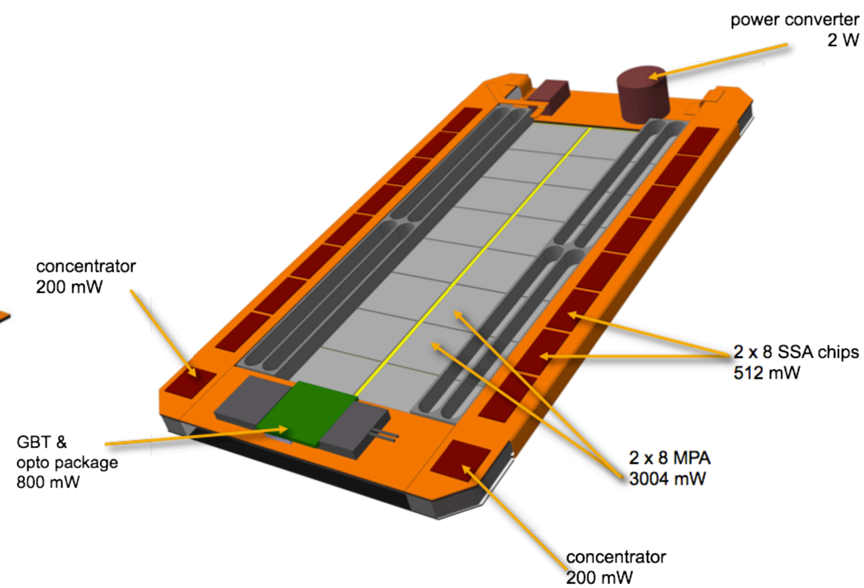
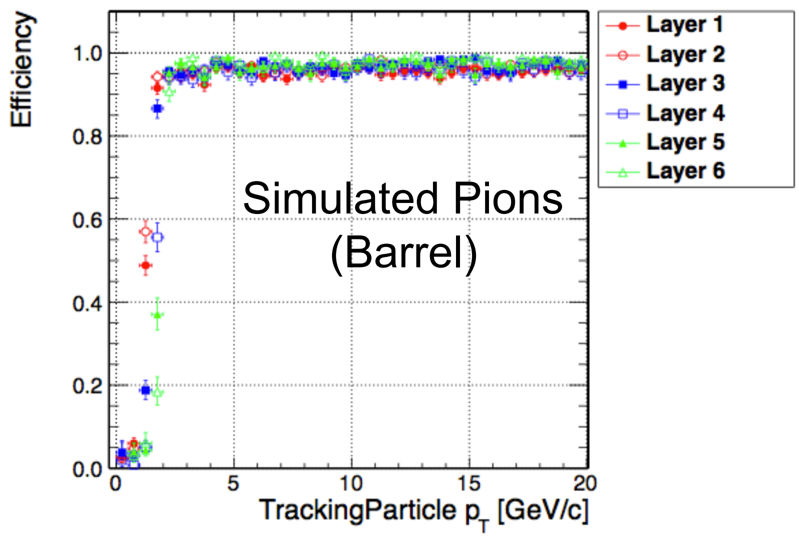
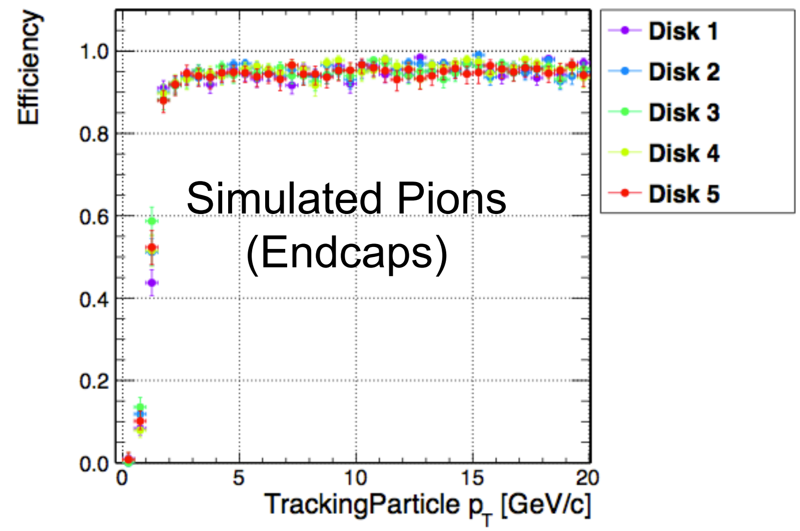
Pixels are logically OR-ed for finding coincidence in the r-ϕ plane, and the precise z-coordinate is retained in the pixel storage and provided to the trigger processors



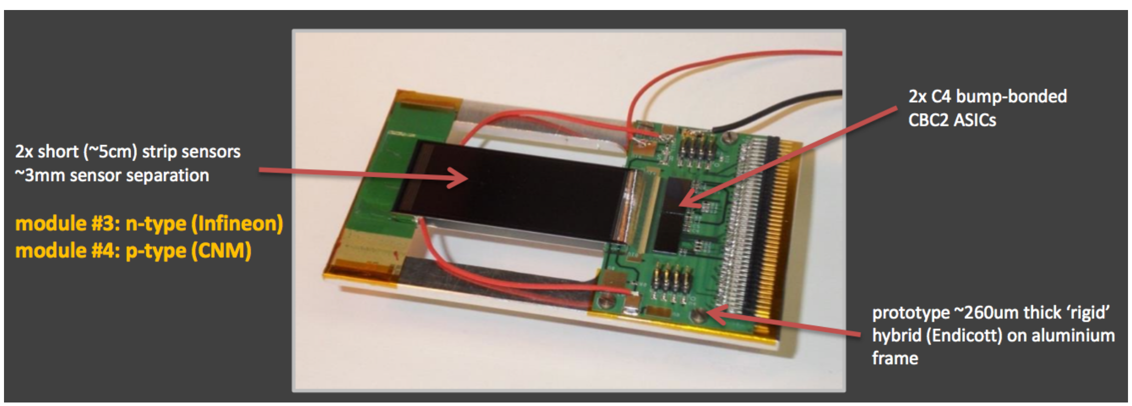


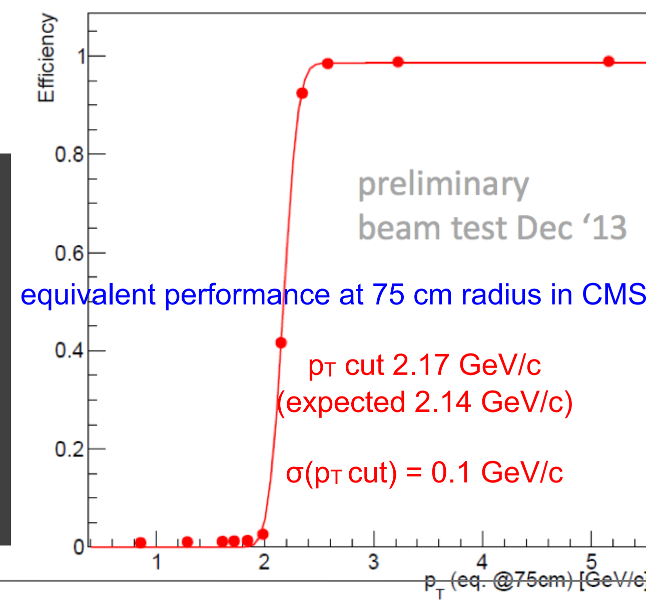
p_T modules performances



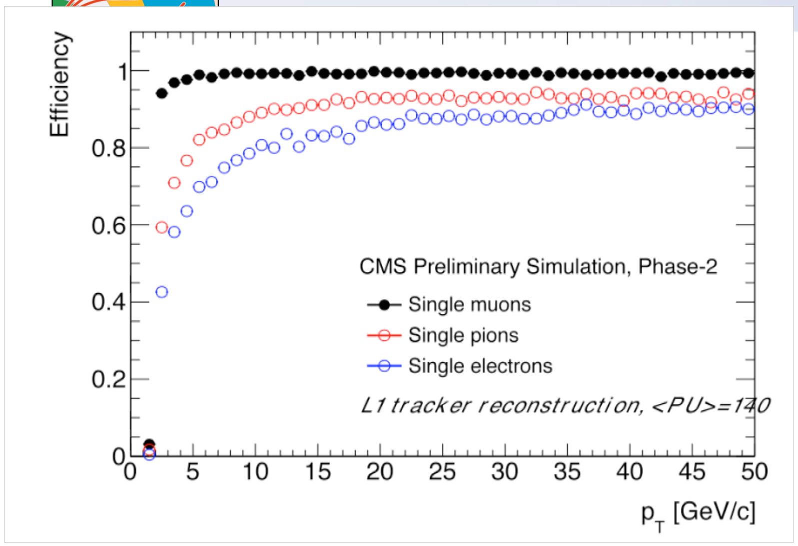


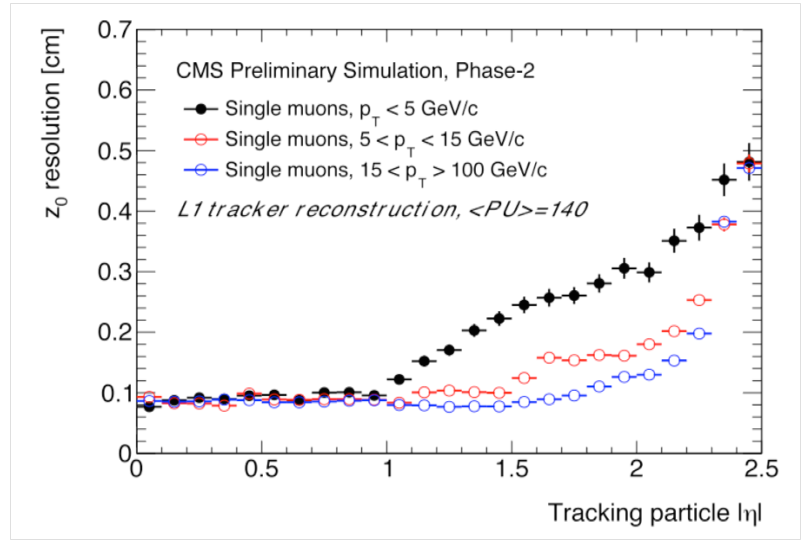
Prototype module test beam at DESY (2-4 GeV e^+)

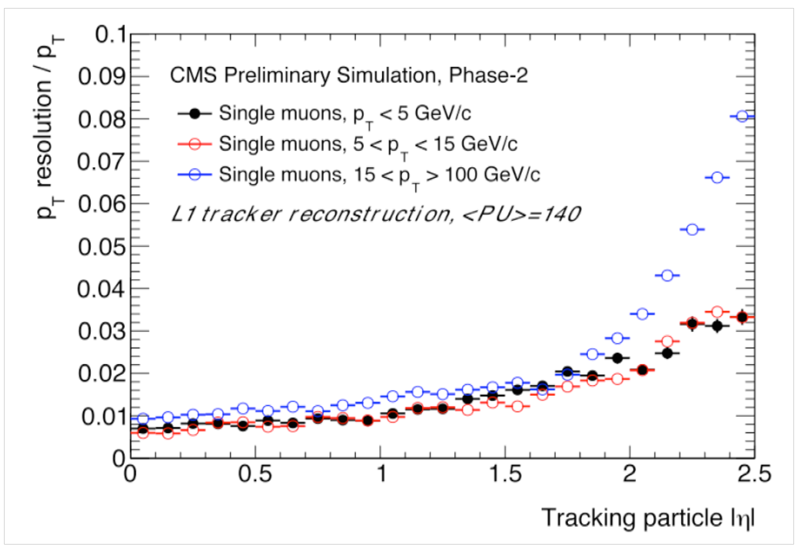


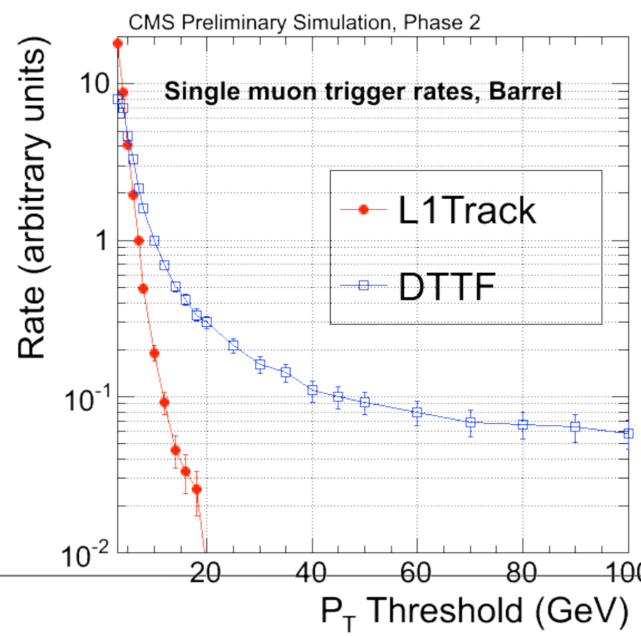


L1 Trigger expected performances









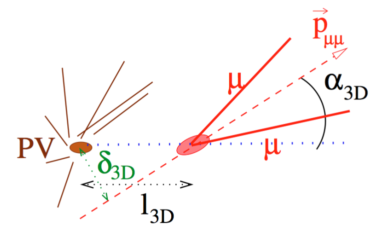
Matching Drift Tube trigger primitives with L1Tracks: large rate reduction

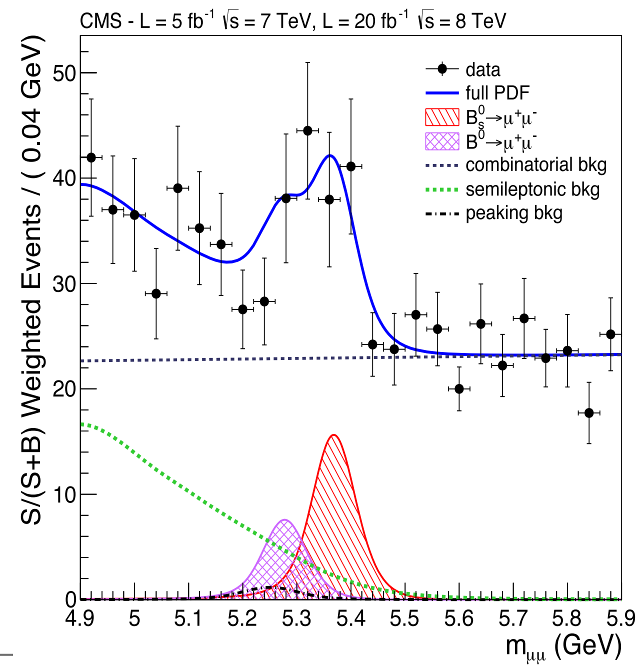
Normalized to present trigger at 10 GeV.

Effects on $B_{s/d} \rightarrow \mu\mu$

- Chosen benchmark channel to illustrate benefits
  - Toy MC studies based on the published analysis (Phys. Rev. Lett. 111 (2013) 101804)
    - Average pileup in 2012 was 21.
  - Basic analysis relies on
    - Low μ trigger p_T thresholds (3 GeV at L1)
    - Muon and di-muon vertex isolation
    - Displaced vertex
    - Di-muon vertex aligned with flight path
    - Low muon fake rate $\varepsilon(\mu|\pi) < 0.15\%$

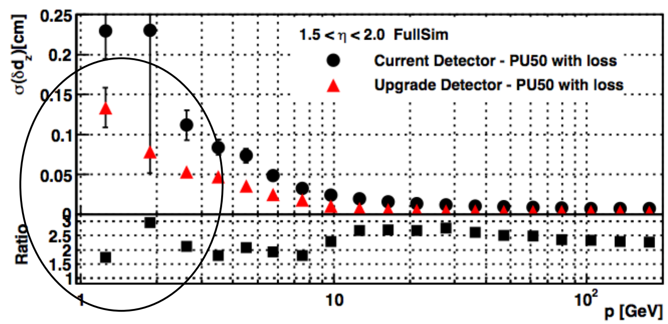
    - All the above points will be possible with Improved tracking detectors





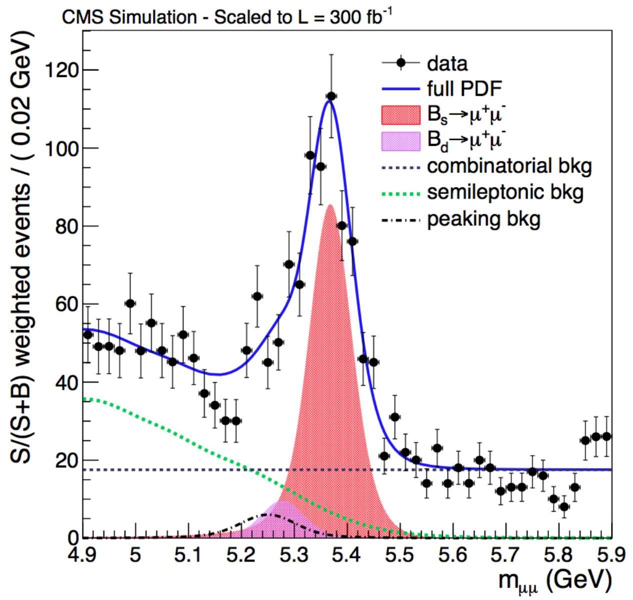
Working scenario

- Assumptions
  - Same trigger thresholds as the current one, in particular the $p_T(\mu)>3$ GeV at L1
    - Feasible with the L1-Track Trigger
  - Reduced efficiencies due to 140 pileup events expected
    - Assume 30% loss in the isolation efficiency
    - 2.5% loss per μ reconstruction efficiency
    - The resolution in the endcap (0.5 to 1 mm) is comparable to the average vertex separation

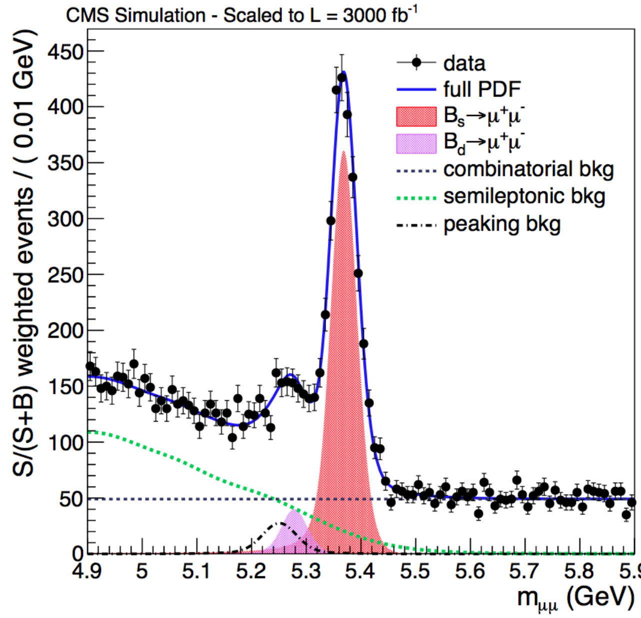


      - Reduced impact of this region in the analysis in discerning Bd from Bs peak.
  - Systematics
    - fs/fu = 5% [now is 9%]
    - Normalization (still assume $B^{\pm}\rightarrow J/\psi K^{\pm}$) = 3% ⊕ 5%/√ (L/20 fb^{-1}) [now 5% from yields and 3% from BR]
    - Peaking background uncertainty = 10% ⊕ 50%/√(L/20 fb^{-1})
    - Semileptonic background uncertainty = 20% ⊕ 50%/√(L/20 fb^{-1})
- Detector resolutions
  - Tracker phase 2 detector has better p_T resolution
    - a factor of ~1.6 in the barrel and ~1.2 in the endcap
  - Do not take into account the better resolution in the impact parameter due to 1st layer closer to the beam-pipe and (possibly) smaller pitch

Effects on $B_{s/d} \to \mu\mu$



CMS PAS
FTR-13-022



Improved Tracker

L (fb^{-1})	No. of B_s^0	No. of B^0	$\delta\mathcal{B}/\mathcal{B}(B_s{}^0 \to \mu^+\mu^-)$	$\delta\mathcal{B}/\mathcal{B}(B^0 \to \mu^+\mu^-)$	B^0 sign.	$\delta \frac{\mathcal{B}(B^0\to\mu^+\mu^-)}{\mathcal{B}(B_s^0\to\mu^+\mu^-)}$
20	16.5	2.0	35%	>100%	0.0–1.5 σ	>100%
100	144	18	15%	66%	0.5–2.4 σ	71%
300	433	54	12%	45%	1.3–3.3 σ	47%
3000	2096	256	12%	18%	5.4–7.6 σ	21%

Conclusions

- In the coming years, the LHC accelerator and the CMS detector will undergo a series of upgrades in two major steps.
  - The first will result in a data sample corresponding to 300 fb^{-1} of integrated luminosity and the second to 3000 fb^{-1}.
  - New Tracker detectors will be deployed in the two steps
  - For Phase 2 the Tracker will provide L1 trigger tracks down to 2 GeV p_T

- With the increased data sample sizes it will be possible to reduce both systematic and statistical errors leading to high precision measurements of $B(B_s \to \mu\mu)$ and $B(B_d \to \mu\mu)$, which would allow stringent tests of the Standard Model
  - Other decay modes are expected to benefit
  - A new era for Heavy Flavour physics at CMS will be opened