CMS Upgrade

and its impact on Flavour Physics
Motivations

- LHC will undergo sizeable upgrades in the near and in longer terms
  - Luminosity increase
  - Pile-up and Background increase

- Purpose of CMS upgrades:
  - maintain / improve wrt present performances, despite the more difficult operating conditions
  - ensure radiation resistance, and easy replacements during short shutdown

- Major and minor interventions
  - mostly aimed at High-$p_T$ Physics
  - beneficent for B-Physics as well

Increased trigger rate and data-event size

FOCUS for this talk
2015: RUN with smaller beam pipe, useful for next upgrade
### Upgrade Plan

**2015:** RUN with smaller beam pipe, useful for next upgrade

**LS2:** replace pixels to cope with luminosity increase to $2 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}$
Upgrade Plan

2015: RUN with smaller beam pipe, useful for next upgrade

LS2: replace pixels to cope with luminosity increase to $2 \times 10^{34} \text{ cm}^{-2} \text{s}^{-1}$

LS2: replace tracker to cope with luminosity increase to $5 \times 10^{34} \text{ cm}^{-2} \text{s}^{-1}$ and ageing
PIXEL Upgrade

Main features

- four layers, inner closer to interaction region
- new readout, reduce data loss
- new cooling, lighter mechanical support, electronic & connections out of Tk volume
- overall easier access

Exploit smaller beam pipe
Increase precision and redundancy

Reduce material

Operation, replacement
Upgraded Pixel Performance

- Main benefit at low $p_T$
- Helpful for B-Physics

Impact Parameter Resolution, $xy$

Impact Parameter Resolution, $z$
Upgraded Tracking

- Radiation hardness
- Granularity
  - resolve 150-200 collisions per bunch, with few % occupancy
- Reduce material (nuclear interaction, $\gamma$ conversion)
- Repare modules at short stops
- Provide L1 trigger
Upgraded Tracking

- Radiation hardness
- Granularity
  - resolve 150-200 collisions per bunch, with few % occupancy
- Reduce material (nuclear interaction, $\gamma$ conversion)
- Repare modules at short stops
- Provide L1 trigger
- Measure (high) $p_T$ on board the modules:
  - two close modules red-out by one single chip

Inner : Pixel+Strip (PS)
Outer : Strip+Strip (2S)
Upgraded Tracker Layout & Performance

- Sizeable reduction of material
- Sizeable Improvement in $p_T$ resolution
Benchmark: $B \to \mu\mu$

Hypothesis:

- L1 track-Trigger allows same L1 thresholds as now ($p_T(\mu) > 3$ GeV)
- Efficiency:
  - pileup: $\varepsilon(\mu\mu) \downarrow 30\%$ (isolation)
  - $\mu$ reco & trigger: $\varepsilon(\mu\mu) \downarrow 2 \times 5\%$
- $\sigma$(syst):
  - $f_s/f_u$: $5\%$ (now) $\to 3\%$
  - Normalization ($B^+ \to \psi K^+$): $3\%^{(BR)} \oplus 5\% / \sqrt{L_{INT}} / 20 \text{ fb}^{-1}$ (Rate)
  - Peaking Backround: $10\%^{(BR)} \oplus 50\% / \sqrt{L_{INT}} / 20 \text{ fb}^{-1}$ (Control Sample)
  - Semileptonic Background: $20\%^{(BR)} \oplus 50\% / \sqrt{L_{INT}} / 20 \text{ fb}^{-1}$ (Control Sample)
- Resolution:
  - $\downarrow 1.6$ (Barrell) $\downarrow 1.2$ (Forward)
  - Ignore improvement due to 1st pixel layer
$B \rightarrow \mu\mu$ : expectations

- **3000 fb$^{-1}$**: statistic is not an issue
- **Use just barrel events**, resolution is enough to separate $B_d/B_s/B\rightarrow hh'$
- $Br\ (B_d) > 5 \sigma$

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<table>
<thead>
<tr>
<th>$L$ (fb$^{-1}$)</th>
<th>No. of $B^0_s$</th>
<th>No. of $B^0$</th>
<th>$\delta B/B(B^0 \rightarrow \mu^+\mu^-)$</th>
<th>$\delta B/B(B^0 \rightarrow \mu^+\mu^-)$</th>
<th>$B^0$ sign.</th>
<th>$\delta B(B^0 \rightarrow \mu^+\mu^-)$</th>
<th>$\delta B(B^0 \rightarrow \mu^+\mu^-)$</th>
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<td>20</td>
<td>16.5</td>
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<td>&gt;100%</td>
<td>0.0–1.5 \sigma</td>
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<tr>
<td>100</td>
<td>144</td>
<td>18</td>
<td>15%</td>
<td>66%</td>
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<td>300</td>
<td>433</td>
<td>54</td>
<td>12%</td>
<td>45%</td>
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<tr>
<td>3000</td>
<td>2096</td>
<td>256</td>
<td>12%</td>
<td>18%</td>
<td>5.4–7.6 \sigma</td>
<td>21%</td>
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Backup: current tracker layout
Backup: Hardware Track Trigger

- Subdivide tracker into trigger towers
- $8(r-\phi) \times 6(r-z)$ trigger sectors (some 10% overlapping)
  - Each sector $\sim 200$ stubs on average; tails up to $\sim 500$ stubs/event in 140 evts pileup+ttbar
  - About 600 Gb/s per one trigger tower

- Send data to Track-finding processors
- Full mesh ATCA shelves
  - "40G" full-mesh backplane on 14 slots = 7.2 Tb/s
  - time multiplexing data transfer from a set of receiving boards to pattern recognition and track finding engine
  - $O(10)$ time multiplexed at the shelf level