Detector concepts for the RF frontier exploiting fast timing (few ps) & low mass tracking

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Case study I: the LHCb phase II upgrade

The key components of the physics:

- Flexible fully software based trigger ↔ general purpose detector in the forward direction:
  - New phenomena in rare b and c decays (anomalies…)
  - Precision tests of SM parameters (Yukawa couplings..)
  - Forward high $p_T$ physics (EW, Higgs-charm coupling, dark sector..)
- High quality tracking and vertexing
- Improved electron/photon detection (5d calorimetry)
The LHCb phase II upgrade

4-d high-granularity pixel VTX

Solid state tracker – timing helps forward tracking

RICH with timing, improved resolution

detectors in magnet, low-p tracking

large area pixel detector

time-of-flight, low-p PID

timing calorimeter, improved resolution

5D- calorimeter?
The role of timing – tracking

What time buys us:
- Disentangle multiple primary vertices
- Disentangle secondary vertices obscured by other primary vertices
- Reduce “ghost tracks” [very important to reduce track rate]
- Pattern recognition speed and efficiency

Real time analysis

No timing – fraction 20%

![Graph showing mis-association fraction vs time precision](image)
The role of timing - trigger

- First level of software trigger relies on impact parameter of B candidate with respect to associated primary vertex
- With high multiplicity, secondary vertex can be obfuscated/generate long decision time (combinatorics) - resolved by precision timing
Summary of fast-timing needs

- Precision timing for tracking detectors (10-30 ps/hit)
- Timing information added to the electromagnetic calorimeter (10-30 ps per track in the medium range, ongoing optimization studies)
- Timing in hadron ID devices (torch 10-30 ps/track) possible upgrade (1-3 ps/track)
- Infrastructure issues e.g. system level timing
- Related goals, fast moving of high data rate & tackle high radiation environment
Low mass tracking

- Minimization of inert material, especially in front of the first hit
- Data transmission challenge (what is going to be the next flex cable? A new way to transmit data?)
- Cooling challenge (how to minimize the material associated with the cooling system, additional power for high granularity, fast timing)
The LVF perspective – mu2eII

mu2eII’s goal: improve the sensitivity by x10 with respect to mu2e

Possible synergies in low-mass tracking with other communities

One of the goals of mu2eII – “transparent tracker”: Low mass [preliminary calculation indicates a requirement for the tracker total material budget \( \sim < 5 \times 10^{-3} X_0 \)], high granularity detector: baseline alternatives of low-mass straw tubes or a drift chamber with separated structural support [technologies studied thin silicon, \( \mu \)-R-well radial TPC.. [see LOI]
Issues for the tracker

Becky Chislett
https://indico.fnal.gov/event/45713/sessions/16420/

The increased muon intensity in the Mu2e-II experiment means the resolution of the tracker needs to be improved by about a factor 2

Reduction in the tracker mass
- Use thinner (8um) straws – currently testing a prototype and
- Remove the 200 angstrom layer of gold inside each straw

Different detector geometry
- Use an ultra light gas vessel to ease straw leakage requirements
- Consider an all wires construction and remove the straws
- Or wires separated by mylar walls
- Developing FastSim to assess this along with radiation levels

Different detector technology (e.g. Si sensors)
Summary on the low-mass needs of the applications discussed

- Optimize detector thickness and granularity for specific application
- Integrate electronics (perhaps 3d integration/with some local processing)
- New ways to push the data out (beyond the dataflex)
- Low mass cooling
- Minimize material before 1st hit measurement (beam pipe or velo RF foil)