Silicon detectors R&D and physics drivers for future machines

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Starting point

- DOE Basic Research Needs Study on Instrumentation is in the process of releasing its conclusions on:
  - Survey the present state of the HEP technology landscape.
  - Identify key capabilities & performance requirements.
  - Identify technologies to provide or enhance such capabilities.
  - Articulate PRDs to push well beyond the current state of the art, potentially leading to transformative technological advances with broad-ranging applicability.
  - Flesh out required R&D efforts with deliverables with notional timelines & key technical milestones.
  - Elucidate the technical infrastructure required to support these efforts.
  - Formulate a small set of instrumentation Grand Challenges that could result in game-changing experimental capabilities.
- **Note this is a 10-years view: Snowmass has a much long-term target (20 years-vision)**

- **The report is not available yet BUT:**
  - Summary at the latest HEPAP meeting by B. Fleming and I. Shipsey
  - Lots of overlap between EF TG conveners and BRN contributors (Alessandro, Tulika, Michael, Jim, Meenakshi)
    - We have started collecting feedback from some members of the panel
      - thanks Jim & Meenakshi!

IF-EF liaison plan

- BRN study is our starting point

B. Fleming and I. Shipsey

What to do with this report and why now #1

During the course of this BRN study the Division of Particles and Fields of the American Physical Society announced the year-long U.S. Particle Physics Community Planning Exercise Snowmass 2021. This will be followed by a new meeting of the Particle Physics Project Prioritization Panel (P5).

We encourage the particle physics community to build on the research plans presented in this BRN study by developing and refining them further and introducing and developing new instrumentation ideas during Snowmass 2021.

- Snowmass is a time to for the community to innovate and set new directions without barriers and constraints set by our collaborations.

Let's collectively **DREAM BIG!**

Meenakshi

Welcome to Snowmass 2021

The Particle Physics Community Planning Exercise (a.k.a. "Snowmass")

EF drivers in the BRN

- The transformative physics goals include 4 inspiring & distinct directions:
  - Higgs properties @ sub-%
  - Higgs self-coupling @ 5%
  - Higgs connection to DM
  - New multi-TeV particles
- Technical requirements mostly from existing detector proposals.
  - muon collider is not on the map

Science	Measurement	Technical Requirement	PRD
Higgs properties with sub-percent precision Higgs self-coupling with 5% precision	TR 1.1: Tracking for e^+e^-	TR 1.1.1: p_T resolution: $\sigma_{p_T}/p_T = 0.2\%$ for tracks with $p_T < 100$ GeV, $\sigma_{p_T}/p_T^2 = 2 \times 10^{-5}$/GeV for tracks with $p_T > 100$ GeV TR 1.1.2: Impact parameter resolution: $\sigma_{r\phi} = 5 \bigoplus 15\ (p\ [\text{GeV}]\ \sin^{\frac{3}{2}}\theta)^{-1}\ \mu$m TR 1.1.3: Granularity : $25 \times 50\ \mu\text{m}^2$ pixels TR 1.1.4: 5 μm single hit resolution TR 1.1.5: Per track timing resolution of 10 ps	18, 19, 20, 23
Higgs connection to dark matter	TR 1.2: Tracking for 100 TeV pp	Generally same as e^+e- (TR 1.1) except TR 1.2.1: Radiation tolerant to 300 MGy and $8 \times 10^{17}\ \text{n}_{\text{eq}}/\text{cm}^2$ TR 1.2.2: $\sigma_{p_T}/p_T = 0.5\%$ for tracks with $p_T < 100$ GeV TR 1.2.3: Per track timing resolution of 5 ps rejection and particle identification	16, 17, 18, 19, 20, 23, 26
New particles and phenomena at multi-TeV scale	TR 1.3: Calorimetry for e^+e^-	TR 1.3.1: Jet resolution: 4% particle flow jet energy resolution TR 1.3.2: High granularity: EM cells of 0.5×0.5 cm^2, hadronic cells of 1×1 cm^2 TR 1.3.3: EM resolution : $\sigma_E/E = 10\%/\sqrt{E} \bigoplus 1\%$ TR 1.3.4: Per shower timing resolution of 10 ps	1, 3, 7, 10, 11, 23
	TR 1.4: Calorimetry for 100 TeV pp	Generally same as e^+e- (TR 1.3) except TR 1.4.1: Radiation tolerant to 4 (5000) MGy and 3×10^{16} (5×10^{18}) $\text{n}_{\text{eq}}/\text{cm}^2$ in endcap (forward) electromagnetic calorimeter TR 1.4.2: Per shower timing resolution of 5 ps	1, 2, 3, 7, 9, 10, 11, 16, 17, 23, 26
	TR 1.5: Trigger and readout	TR 1.5.1: Logic and transmitters with radiation tolerance to 300 MGy and $8 \times 10^{17}\ \text{n}_{\text{eq}}/\text{cm}^2$ TR 1.5.2: ...	16, 17, 21, 26

Ta... an...

Jim Hirschauer Gabriella Sciolla (leads)

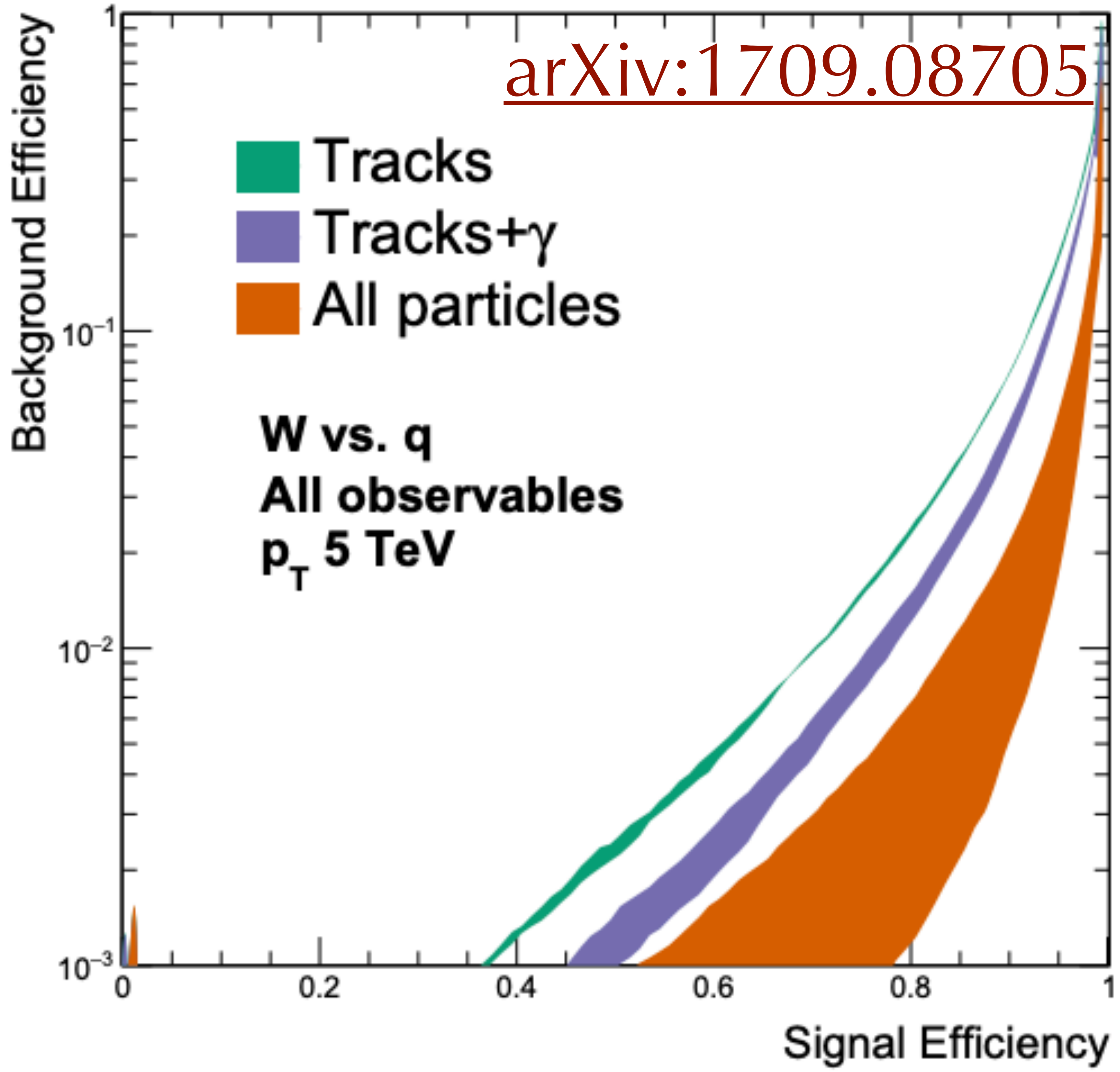
Michael Begel Meenakshi Narain B. Fleming and I. Shipsey

EF drivers : beyond BRN

In the BRN physics drivers are very Higgs-centered, beyond Higgs:

- **LLP searches** could be an important benchmark for timing/trigger (From Simone Pagan Griso):
  - Study of min radius for (few layers of) tracking detectors at future colliders
  - "Acceptance" for non-prompt charged particles at future detectors
- **Boosted/Substructure object reconstruction** is an important driver to guide detector design at future multi-TeV machines
  - pixel hit merging as one of the limiting factors
  - Also any improvement in tracking will directly impact jet reconstruction and calibration, pflow

Just one example:



EF drivers: b/c/strange tagging

- A class of BSM models predicts that the origin of the 1st and 2nd generation fermion masses is an additional source of EWSB, predicts large deviations from the SM values
  - Higgs to ss as well as cs at future colliders is the next milestone to probe the nature of Yukawa couplings
- Strange quarks mostly hadronize to prompt kaons which carry a large fraction of the jet momentum
  - The most powerful high momenta $K^{\pm}$ tags with dedicated particle identification detectors may be an exclusive territory of **e+ e- colliders**
  - The leading V0 s (K0 s and Lambda) have a distinctive 2-prong vertices topology
- The use of **precise timing information** would become very relevant for flavor tagging and providing an additional handle for separation between light quarks.
  - intermediate momentum $K^{\pm}$ ID from fast timing can become a significant contributor for b and c decays (s tag $K^{\pm}$ could be too high momentum for timing)
  - Detector design have a role too in capturing the high momenta V0 s that can decay deep into the tracker
    - Investigate optimal configurations for 4D tracking at future e+e- machines

We have submitted an LOI to study this further at Snowmass https://www.snowmass21.org/docs/files/summaries/EF/SNOWMASS21-EF1_EF2-IF3_IF0_Valentina_Maria_Martina_Cairo-047.pdf