IF03: Solid State Detectors and Tracking

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IF03: Solid State Detectors and Tracking

- This topical group aims to study detectors and technologies needed for charged particle tracking:
  - Technologies for colliders, fixed target, or precision measurement experiments
  - Ranging from silicon to diamond and other alternative materials.
  - Also non-solid-state trackers, e.g. for high-intensity experiments.
  - 3D integration, ultra-lightweight materials for mechanical support & cooling.
- Trackers should be discussed in the context of future experimental challenges
  - Identify opportunities and technological challenges with different future accelerators, and explore possible technology solutions or directions
  - Highlight the importance of generic “blue sky” R&D in creating opportunities and future transformative breakthroughs’

- **The goal is to collect input on areas and strategic directions that the US community is interested to pursue**
  - Collect and organize studies from the community and document its scientific vision

Organization of the work

- In collaboration with other working groups within the Instrumentation Frontier and in other Frontiers, we aim to identify:
  - Physics benchmark goals that drive the need for advances in tracking detectors
  - Translate the physics requirements into detector needs for future experiments, and study which advances bring transformational changes
  - Identify areas where R&D will significantly impact future capabilities

- Collect studies and organize ideas from the community on these set of topics
  - Capabilities, strengths and weaknesses of various approaches, and proposed future directions
  - Performance studies from new R&D directions, and promising directions
  - Identify the set of development tools, and the required expertise to maintain and strengthen the US intellectual contributions
  - Facilities required for effective work: fabrication, characterization, test beams, irradiation facilities, clean rooms, corresponding infrastructure, collaborative efforts

Existing Collaborative Frameworks

- A lot of work has been done already for BRN, CPAD, EPSG
  - CPAD Workshops
    - Annual workshops since 2015
    - Report from CPAD 2019: https://wp.physics.wisc.edu/cpad2019/
    - Report from CPAD 2018: https://arxiv.org/abs/1908.00194
  - DOE BRN Study Workshop on HEP Detector R&D, Dec. 2019
    - Report expected to be available soon
  - European Strategy for Particle Physics Preparatory Group
    - "Physics Briefing Book": https://arxiv.org/abs/1910.11775
    - Final report expected to be available soon
  - Intend to collect common challenges and common development needs,
- Collaborative frameworks within CERN RD groups, and university-lab collaborative efforts

Future machines and requirements

- Trackers for future colliders
  - Different requirements depending on e^+e^- or hh
    - e^+e^-: very high spatial resolution, and low material budget
    - hh: very high radiation tolerance (10^{17} n/cm^2), high resolution in position and/or time
    - $\mu^+\mu^-$: very high spatial resolution, and low material budget PLUS timing, high radiation tolerance
  - Need to collect similar technical requirements for fixed target and intensity frontier experiments, electron-ion collider
  - Upgrades in HL-LHC, extensions of the existing trackers

- **Given the timescales of these machines, we need to ensure that "*blue-sky*" R&D is pursued, and new opportunities and developments are fully taken advantage**

Sample topics to be covered

- Traditional silicon sensors development:
  - Low mass, finely-segmented radiation hard detectors needed for future experiments, with different degrees of focus on rad-hardness or position resolution
- New silicon technologies: MAPS, SoI
  - Avoid bump-bonding, many developments in industry, many opportunities and challenges to adapt to HEP needs
  - Reduction in material budget and material cost
- Advanced simulation tools to help in understanding the performance of new prototypes and to optimize the design of new detectors
  - Essential to minimize development costs and R&D cycles, often a rare set of expertise within collaborations.
  - Development and improvements of rad-damage simulation and comparisons with experiments

Sample topics to be covered

- 4D trackers for the future machines: position + time
  - Reduce backgrounds, track reconstruction, triggering, will need precision timing information, in addition to the precision position
  - Particle ID and LLP searches are new areas where we start utilizing the timing and position information

- Time resolution:
  - Pico-second level time resolution critical for high occupancy environments in future hadron colliders.
  - Requirements in the range from ~5 to ~30 ps resolutions, need to clearly identify the needs and simultaneous requirements on position resolution

Sample topics to be covered

- Electrical and thermal services: work in coordination with IF07
  - Efficiently deliver thousands of amps for powering the ASICs
  - Efficiently remove the heat: increasingly complex readout schemes, ASICs generate 100s of kWs
  - Approaches to improve the efficiency: DC-to-DC conversion and serial current delivery for HV; improve conversion efficiency and rad hardness.

Sample topics to be covered

- Precision support structures and cooling
  - **Cooling and support as an integrated problem**
  - Issues related to development of support structures needed for increasingly complex tracking detectors
  - Typically interested in very stable and precise structures to support tracking sensors, with minimal mass and low radiation lengths
  - Studies of novel materials, advanced compounds, foams etc

- Interconnections and readout:
  - Issues related to modules designs, assembly and large-scale productions
  - Packaging technologies: bump-bonding, wire-bonding, glues and adhesives, flex circuits, TSV, etc.

Sample topics to be covered

- Developing and preserving knowledge and expertise
  - The EPSG “Physics Briefing Book” raised this point well, and presented a compelling case
  - We aim to study this question in the US context, and identify areas where funding agencies and the community can help to ensure that young talent is attracted and is maintained within the field
  - It is of critical importance to the future of the field to ensure career opportunities exist and are expanded

- Explore and encourage multi-institutional developments and shared use of resources at labs and universities
  - Encourage the support of workshops, conferences, seminars on tracking detectors and encourage participation
  - Collaborative environments for sensor developments: e.g. multi project foundry submissions

Synergies with other groups

- Some areas expected to be cross-cutting:
  - MAPS detectors or 3D integration: *IF03 and IF07*
  - Tracking reconstruction: development of new algorithms both online and offline, development of the detector designs, and will need to leverage on the computing developments: *IF03 and CompF1*
  - Effective use of precision timing in track reconstruction, and trigger formation: *IF03 and IF04+CompF1*
  - TPC and large area muon chambers: *IF03 with IF05*

- We should identify how most effectively organize work in these cross-cutting areas

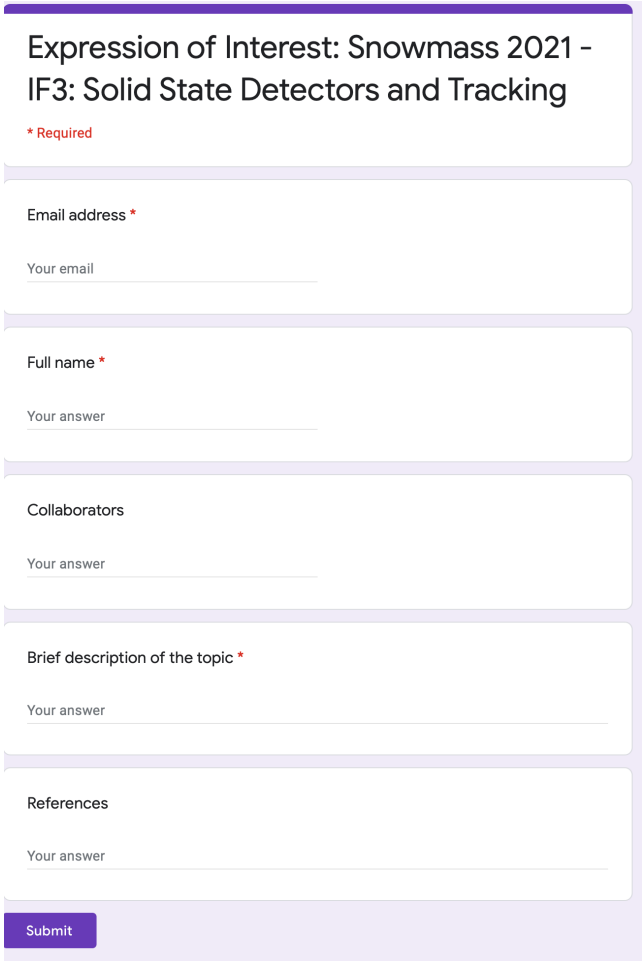
How to contribute

- Several mechanisms to indicate your interest and contribute with studies to the group
  - Google form to collect basic info: contact info, brief description of interests
  - Letters of Interest: short documents
  - Contributed papers: more extensive studies which will be part of Snowmass report

- Follow-up meeting in ~1 month, based on inputs collected from GForm and LoI
  - Short talks aiming to identify interested contributions and possible collaborations.

- Regular “general” IF03 group meetings
  - Topical meetings in closely related areas

https://forms.gle/aknT8FsFU1Pk47hn7



Conclusion

- Many ideas and directions to explore and study
  - We look forward to your input, contributions, and working together towards the final report

- The aim is to gather input and express the vision of the US community in the future R&D, so it's vital to receive the submissions and technical documents

- Reminder: fill out the GForm: https://forms.gle/aknT8FsFU1Pk47hn7
- Subscribe to the mailing lists and slack channels:
  - https://snowmass21.org/instrumentation/start