GEFÖRDERT VOM
Bundesministerium
für Bildung
und Forschung

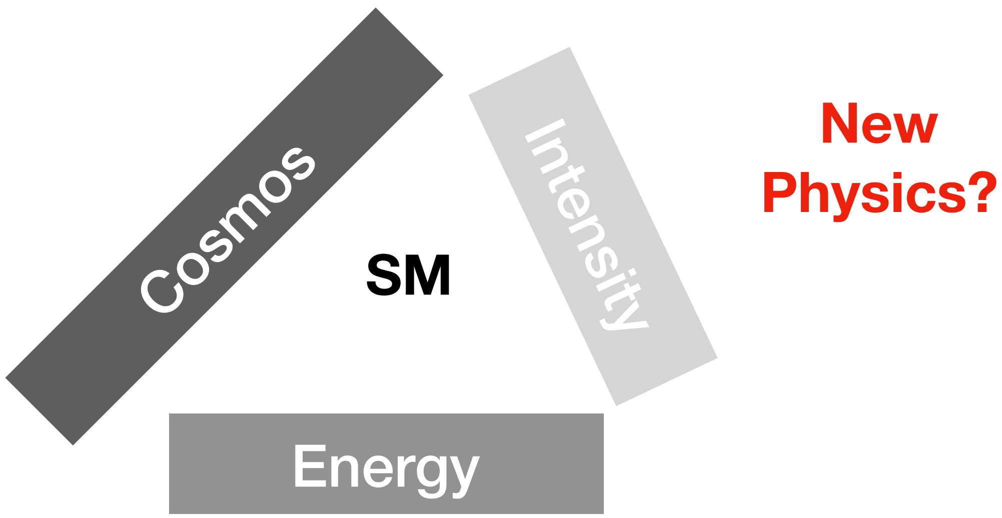
# Subject Area D

## Cost- and energy-efficient use of computing resources

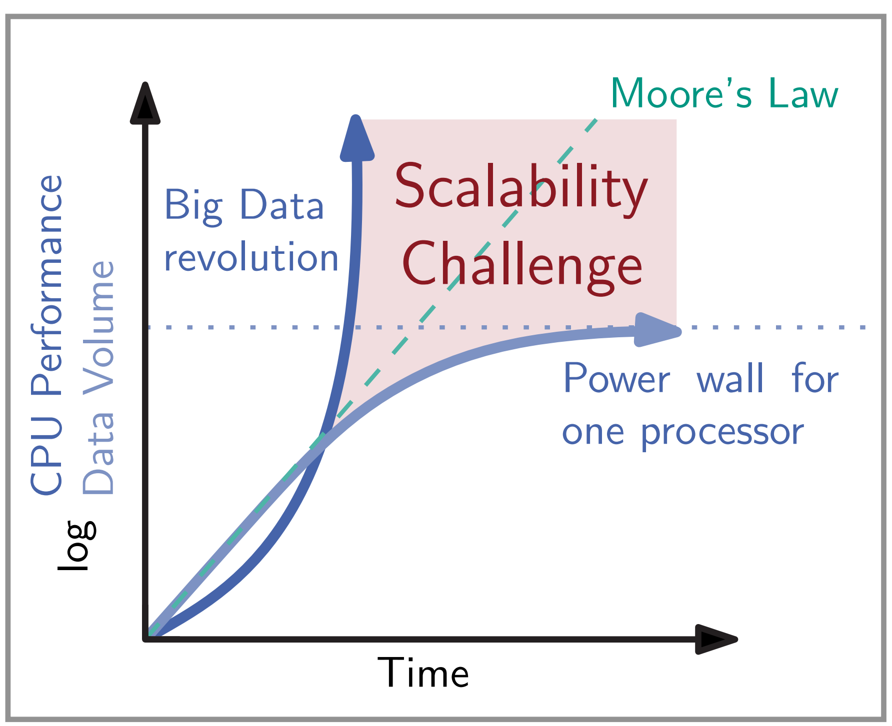
Florian Bernlochner

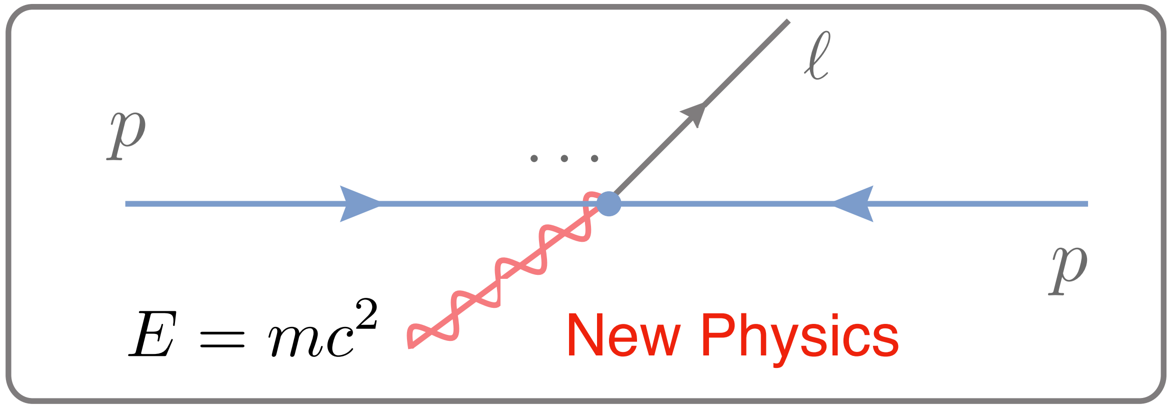
Kick-Off Meeting, Feb 2019

# Overview of Area D

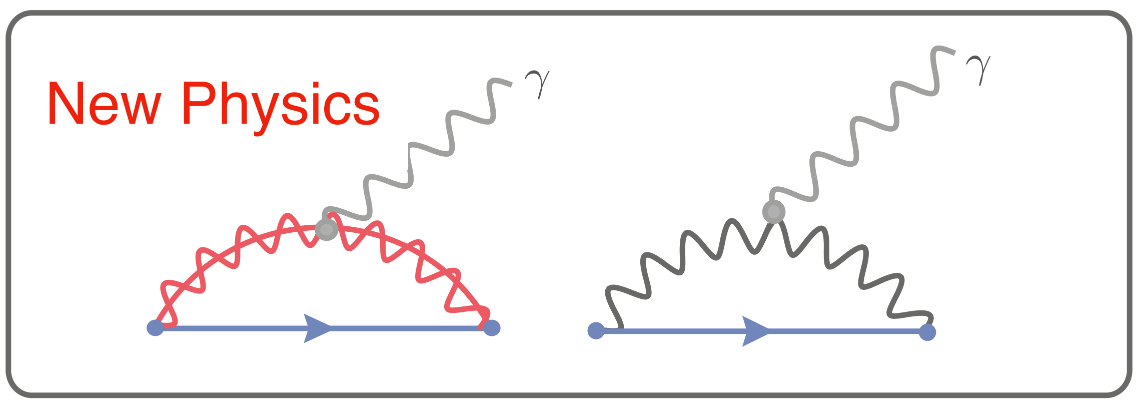



**Common Problem:**




Search for New Physics at the Energy Frontier




Search for New Physics at the Intensity Frontier

# Overview of Area D

Lösungsansätze können auf verschiedenen Ebenen gefunden werden. Im Rahmen dieses Teilprojekts stehen insbesondere die Entwicklung alternativer Algorithmen (z.B. *Cellular Automaton*-basierte Ansätze statt Kombinatorischer Kalman Filter), bessere Software Codes, die z.B. größere Datenlokalität und *single instruction, multiple data* (SIMD) Optimierungen möglich machen, und alternative Software-Architekturen (z.B. GPUs) zusammen mit einem grösseren Maß an Parallelisierung im Mittelpunkt. Um angesichts des erforderlichen Expertentums auch die Personalressourcen optimal zu nutzen, sollten die Entwicklungen möglichst in gemeinsam genutzten Bibliotheken gebündelt werden und Beispielanwendungen zum besseren Verständnis zur Verfügung stehen. Der größte Teil der Entwicklungen, die im Rahmen dieses Projekts angestrebt werden, wird daher mit Hilfe von ACTS (**A** **C**ommon **T**racking **S**oftware) angebunden.

**Three** work packages:

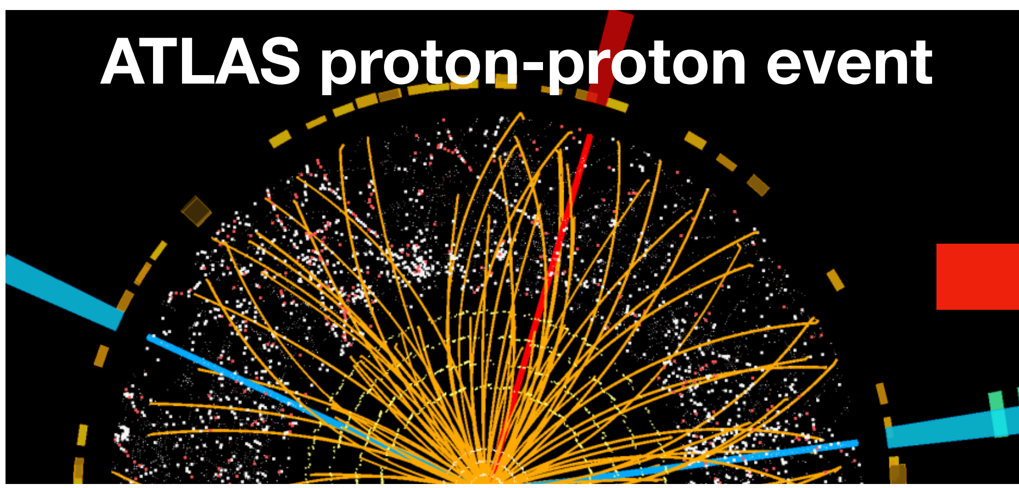
1. Novel Algorithms for track reconstruction
2. Common tools to determine optimal track parameters
3. Event reconstruction at neutrino experiments

# AP D1: Novel Track reconstruction algorithms

- Computing needs scale roughly as **CPU Power** $\simeq \mathscr{L}^3$

  inst. Luminosity

- HL-LHC will need need smarter algorithms to **identify charged particle trajectories**





  - **50%(!)** of event reconstruction time used for track reconstruction.

- Entwicklung effizienterer Algorithmen zur Spurfindung, die beispielsweise auf zellulären Automaten aufbauen. → **CA can be easily parallelised; first promising results using this at CMS (pixel-track seeding)**
- Anpassung der Algorithmen zur Nutzbarmachung moderner massiv paralleler Rechner-architekturen (GPUs).

# AP D2: Common tools for tracking

- Instead of each experiment writing their own tracking algorithms

  Often algorithms are not optimised for CPU usage and small runtimes

  → pool resources and expertise

http://acts.web.cern.ch

- ACTS ("A common tracking software") is an attempt to create such a common library, which implements many of the often used algorithms;

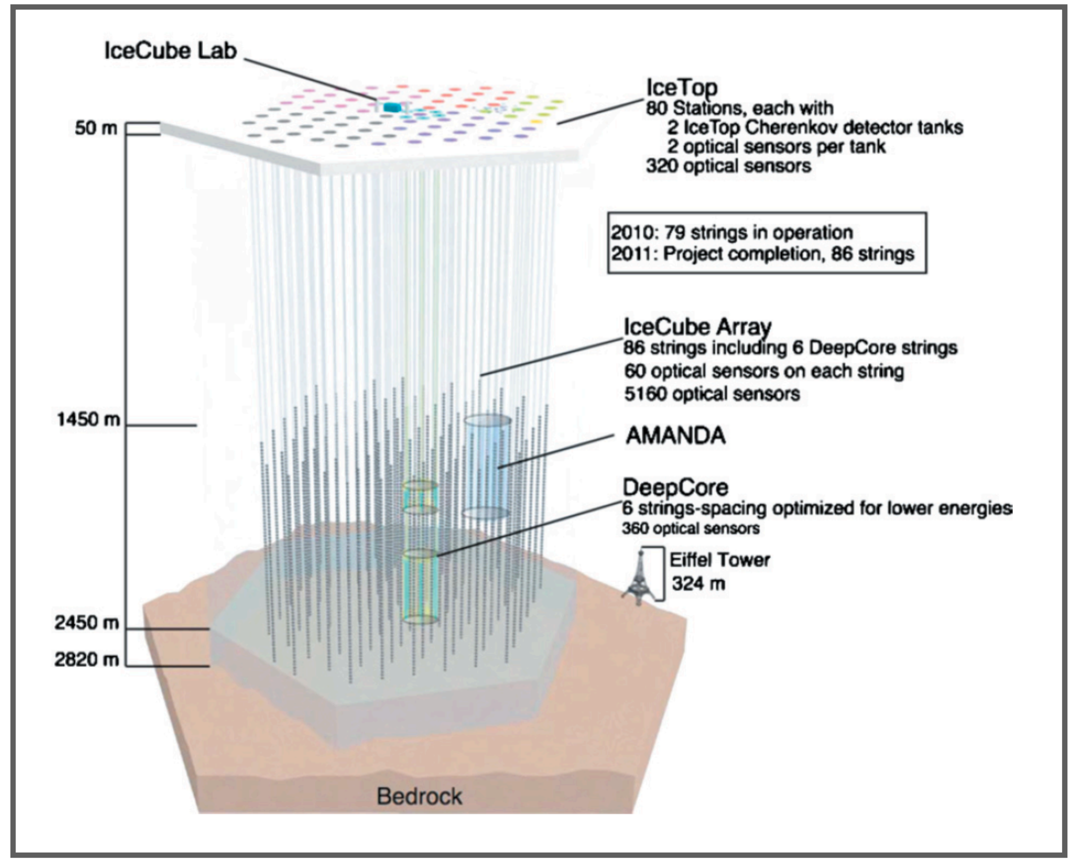
  many implemented algorithms much faster than what experiments currently are using

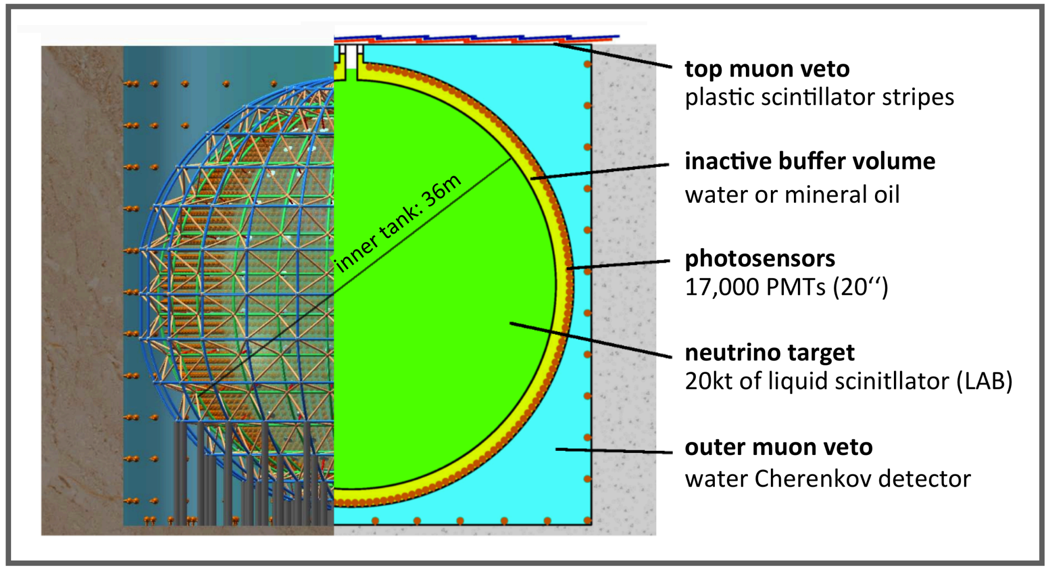
- **Goal:** Help to extend ACTS to become fully usable by energy and intensity frontier experiments

  Add missing features, evaluate how aspects of the library can be used to improve the current track finding and fitting.

# AP D3: Event reconstruction at neutrino experiments

- Neutrino experiments have unique challenges:
  - Huge detector volumes; sparse sensors that observe signals from a distance
  - Inclusion of time-information important to make sense of detector signals
  - Signatures typically have multiple components: e.g. Muon and hadronic recoil in CC-scattering of muon neutrinos
  - Immense amount of information that needs to be processed: e.g. JUNO uses O(17k) PMT signals to reconstruct a single muon track. A single fit to do this can take O(1h)



# Involved Groups

| Standort | PI | FTE | Experiment | AP D1 | AP D2 | AP D3 |
|---|---|---|---|---|---|---|
| Aachen | Schmidt | 0,5 | CMS | X | | |
| Aachen | Stahl | 0,5 | $\nu$-Exp. | | | X |
| Frankfurt | Kisel | 1 | CBM | X | | |
| KIT | Bernlochner | 1 | Belle II | | X | |
| Assoziiert | | | | | | |
| CERN(ATL/SFT) | Elsing/Hegner | - | ATLAS | X | X | |
| DESY | Gaede | - | ILC | | X | |
| FZJ | Prencipe | - | Panda | | X | |

# Activities Overview D (& C)

# AP D2: KIT

Belle II

Tracking workshop for HEP

14-18 January 2019
LBNL
US/Pacific timezone

**Organizing Committee:**

Florian Bernlochner (KIT)

Heather Gray (LBNL)

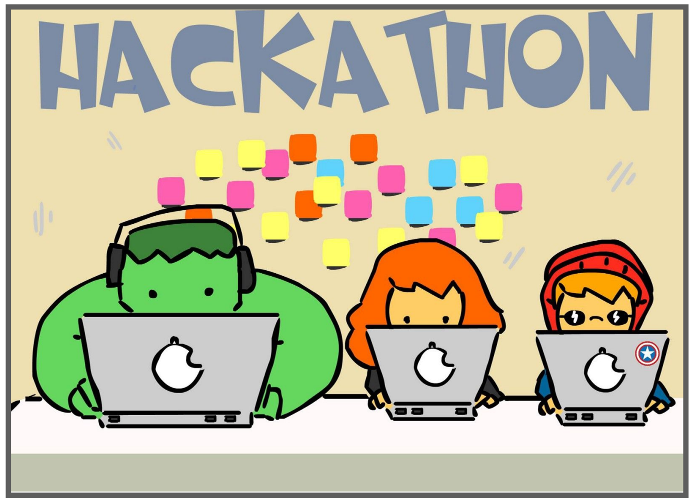
Simone Pagan Griso (LBNL)

Lauren Tompkins (Stanford)

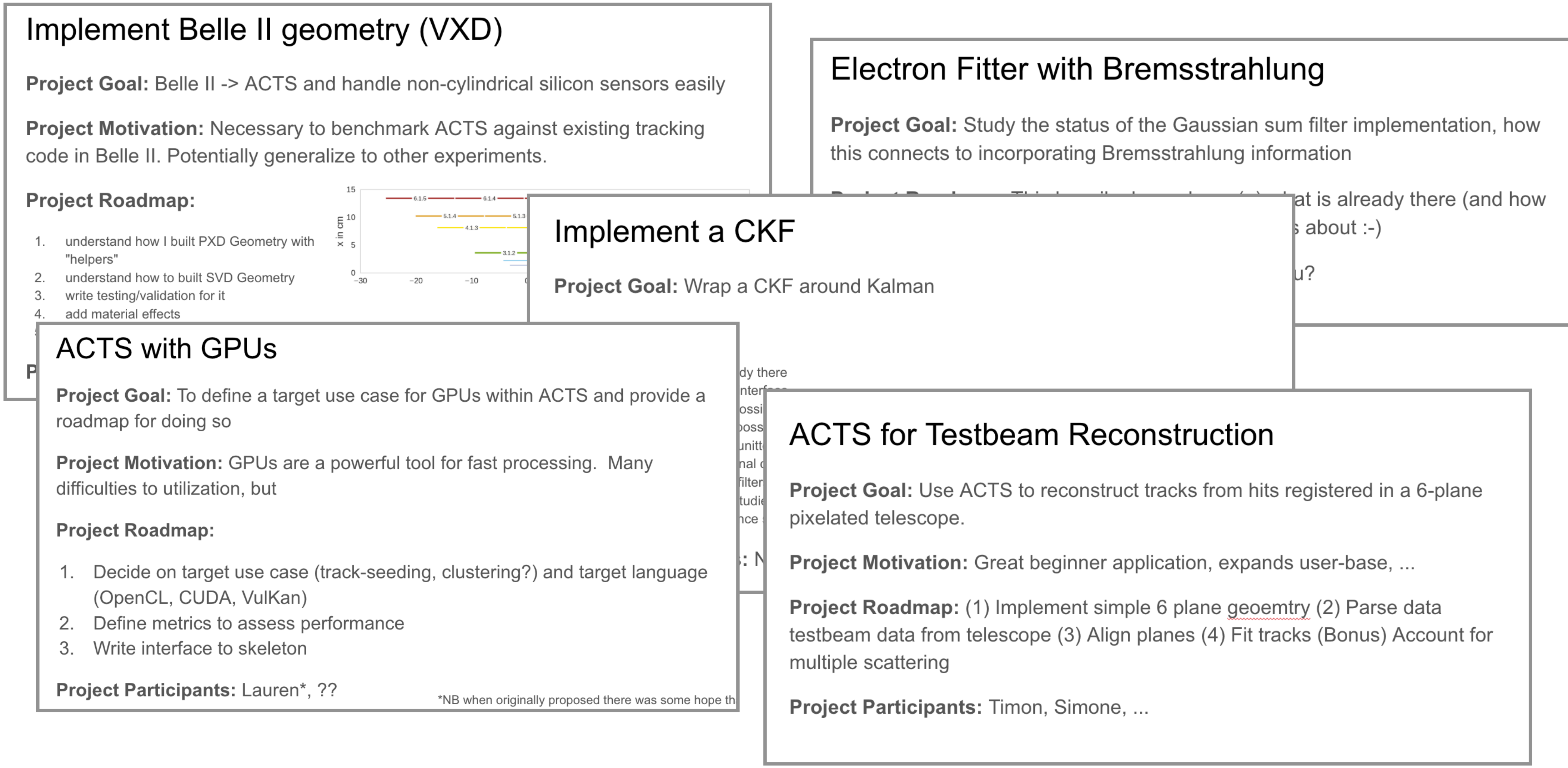
https://indico.physics.lbl.gov/indico/event/712/

# ACTS Workshop Overview

- 22 Participants from various experiments
  - **2 ACTS experts:** Dr. Moritz Kiehn und Paul Gessinger
  - Members from **ATLAS**, **Belle II**, and **Mu2e**
- Diverse 5 day program
  - Mix of **tutorials** from Moritz and Paul;
  - Talks from Belle II (Dr. Nils Braun), ATLAS (Dr. Nick Styles), Mu2e (Dr. Dave Brown) tracking challenges
  - A lot of **Hackathon** time to kick-start projects



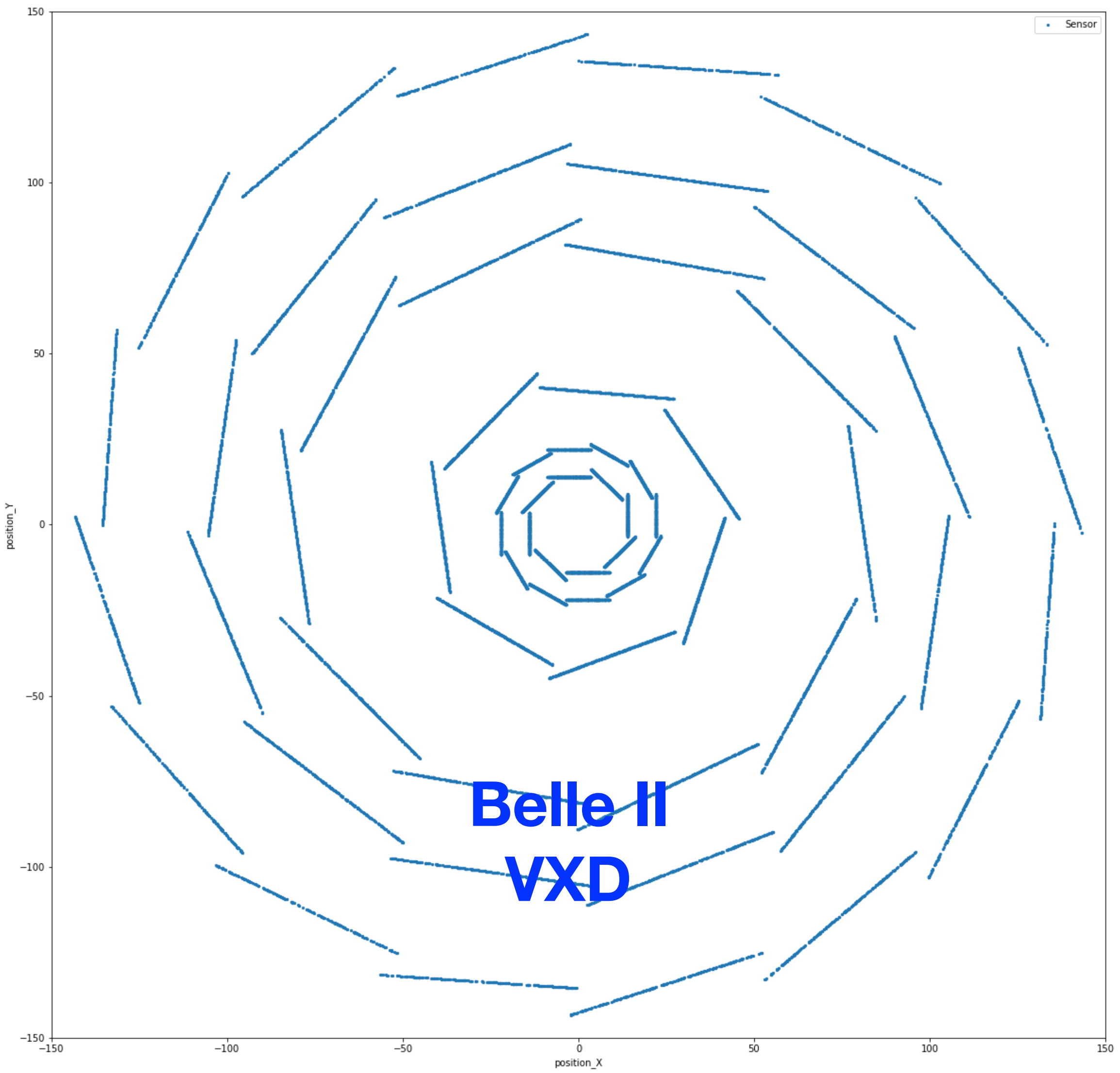
# Example Projects

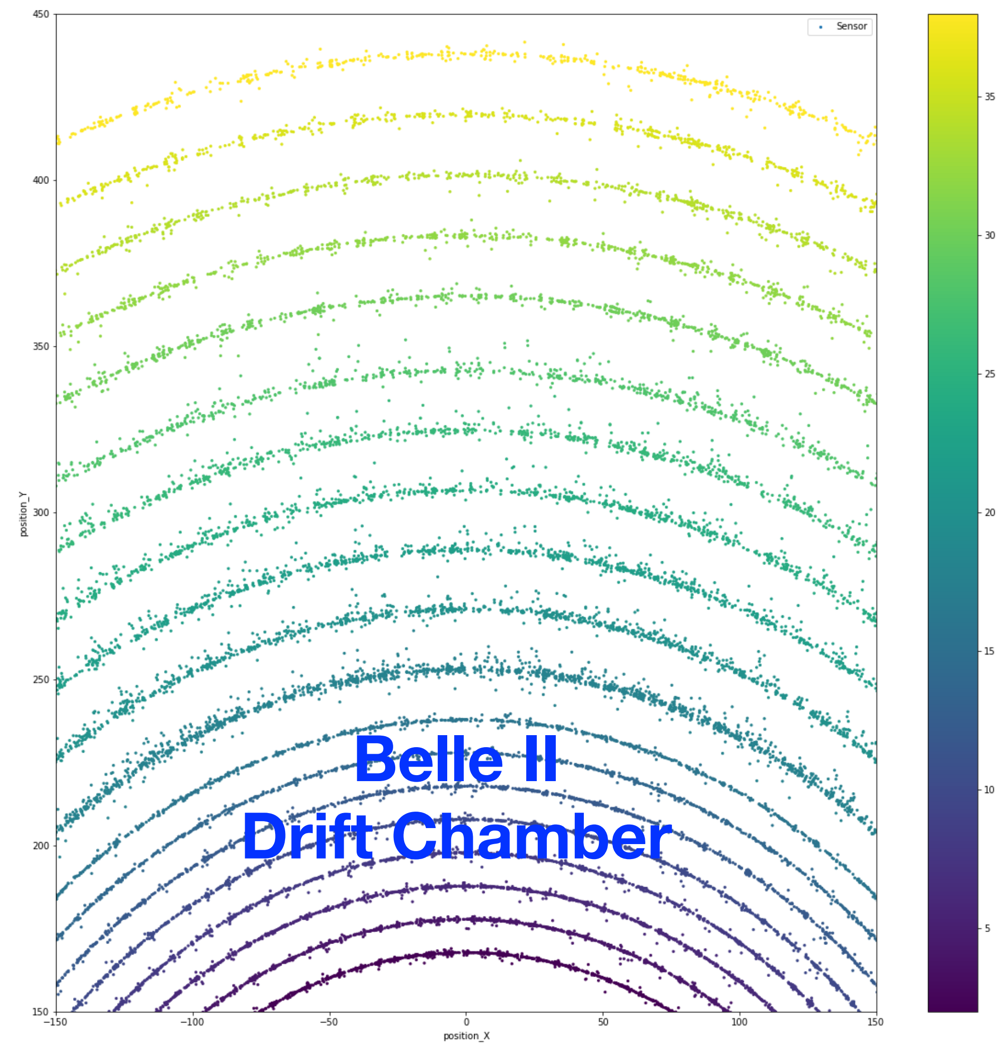



- Full list available here:

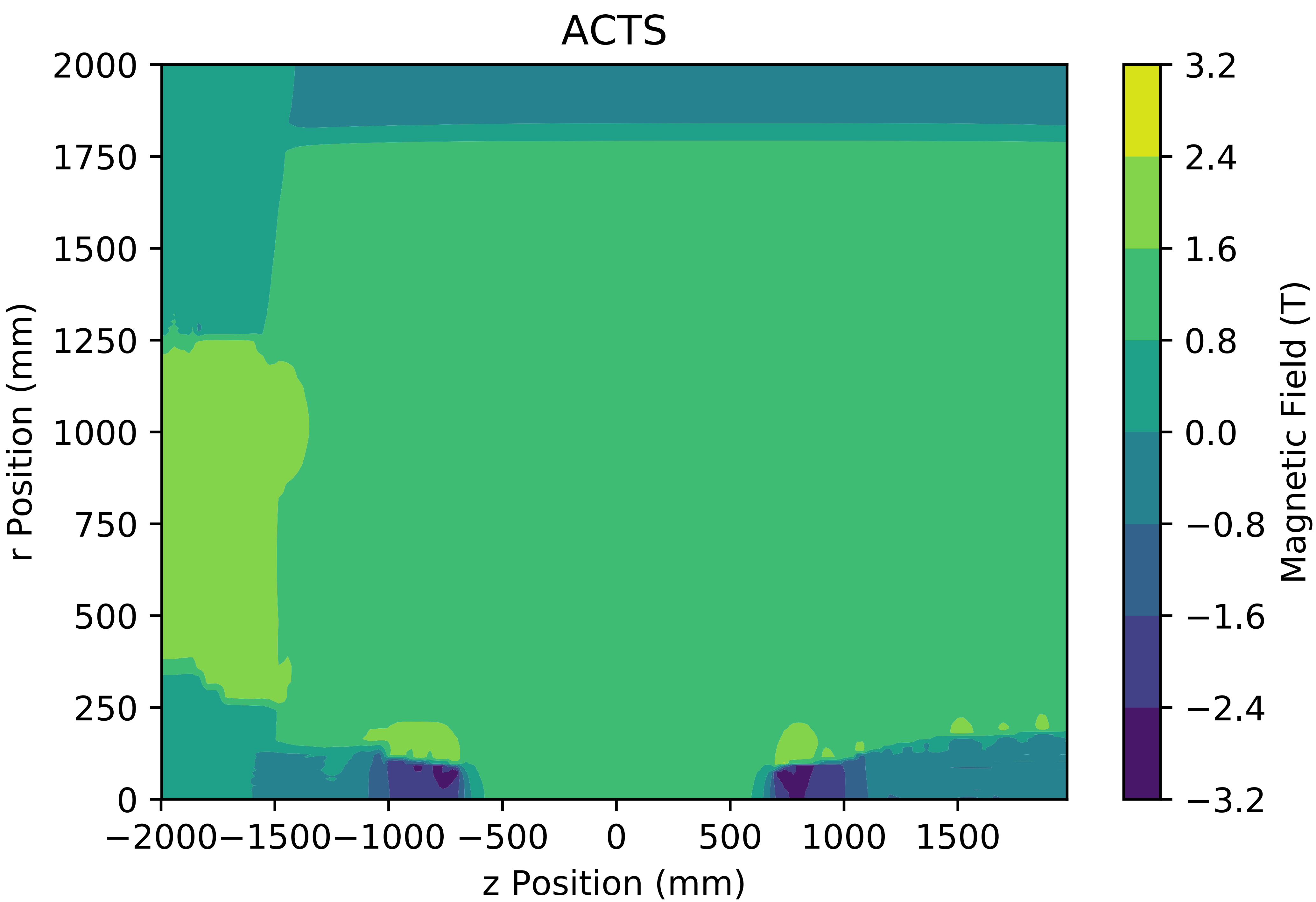
https://docs.google.com/presentation/d/1agWKZN0SilwxptRfx6kIwx9GimhbvHdNTwCk2Afef9Q/edit#slide=id.p

# First results: Belle II Geometry in ACTS

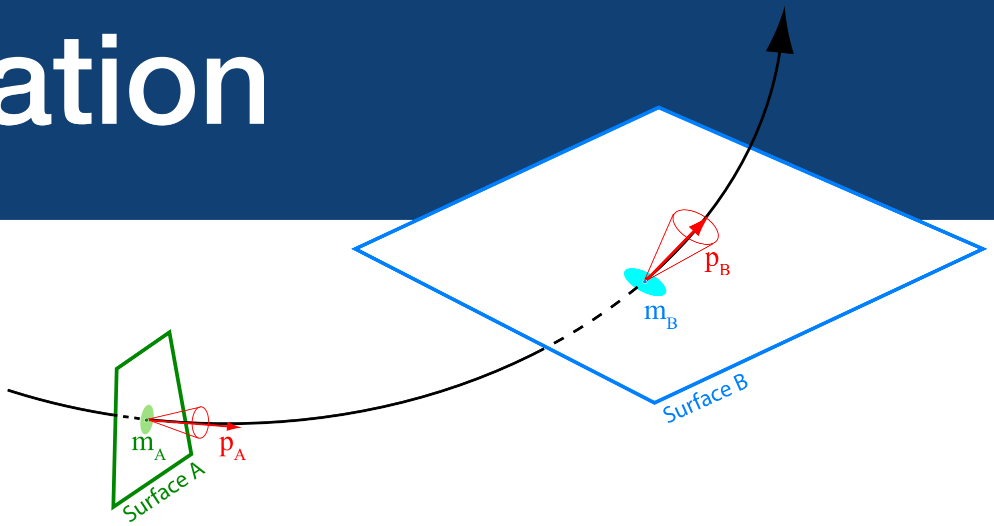


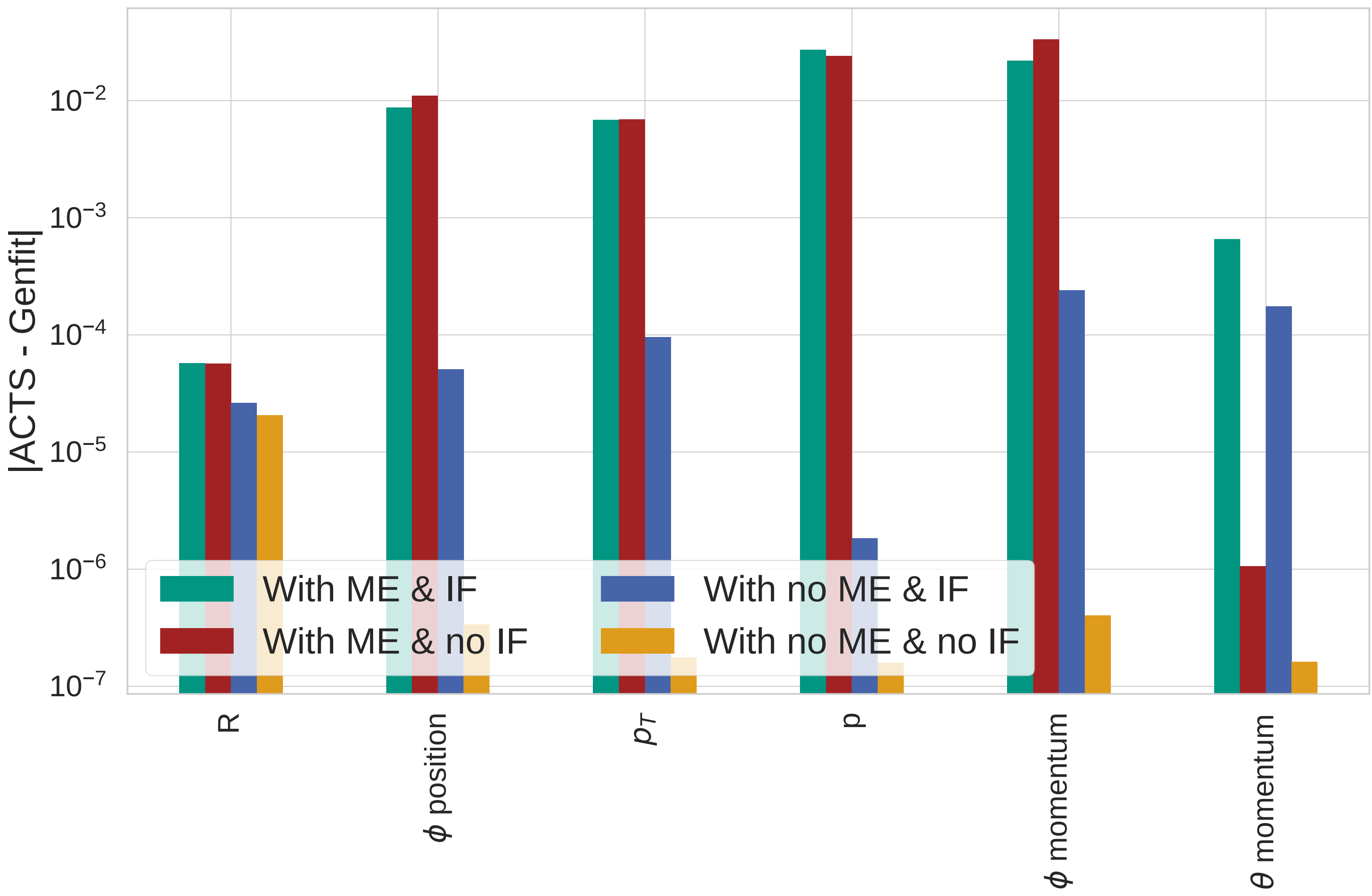
# First results: Belle II Magnetic field



# First results: Track extrapolation




Belle II algorithm versus ACTS




ME = Magnetic effects (turned on or off), IF = interpolated field of Belle II (instead of constant 1.5 T)

# Conclusion

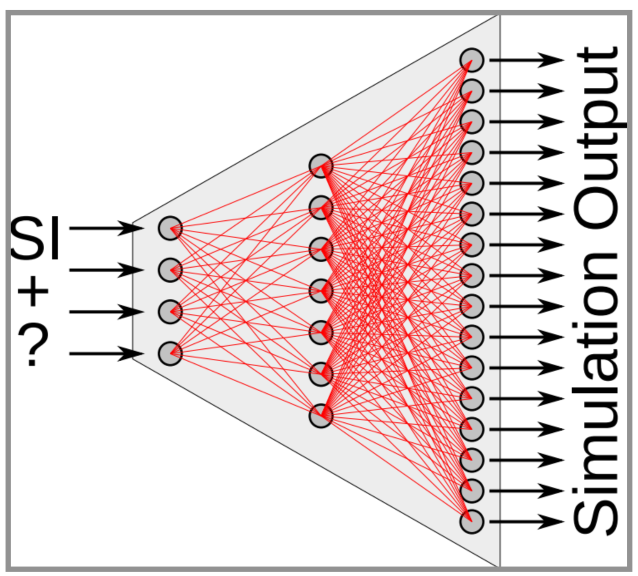
- There are not that many conceptual show-stoppers for just "plugging the ACTS extrapolation into Belle II instead of genfit":
  - No DAF (should be solvable easily)
  - No slanted parts (but not a conceptional problem with it)
  - Their Kalman is working a bit differently from ours, but should be no problem
  - Their CDC hit handling is different (maybe this will make a difference, maybe not)
- However, if we want to replace genfit with ACTS, there is a lot more to do:
  - The EDM is different
  - The measurement model is different
  - No CKF, no $T_0$
  - How about extrapolations in ECL, (B/E)KLM etc.?

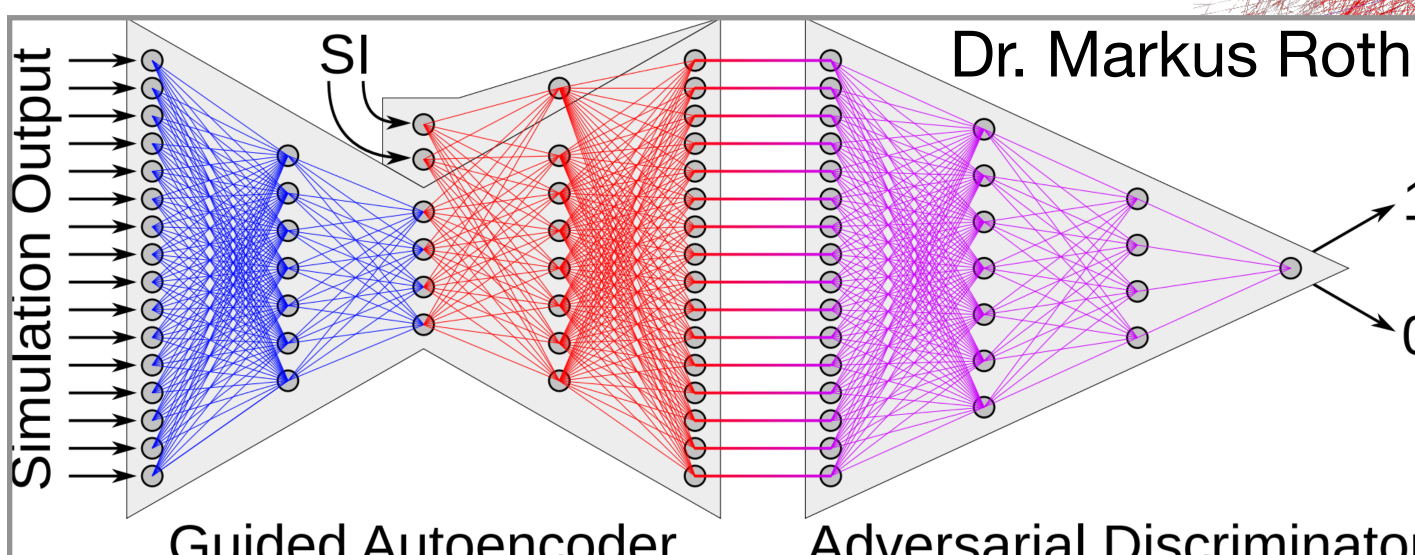
Dr. Nils Braun

- Could carry out first preliminary studies;
- KIT group could connect with the ACTS developers
  - Involved people at KIT: me, **Dr. Nils Braun**, Patrick Ecker, Lu Cao, Pablo Goldenzweig, **Michael Eliachevitch**
- Plan to organize **follow up workshop** in **August** or **September** in **Germany** with a similar style of agenda
  - Tutorials, some overview talks but ample time to work on dedicated projects with ACTS experts in the room to help.

# AP C3: KIT

- Simulation of extensive air showers or hadronic / electromagnetic showers from first principles are time intensive tasks
- Can we delegate the entire simulation (or parts of it) to a neural network?




**Key challenge**: sparse input features, e.g. particle type, energy, mass, etc. —> misses randomness of MC simulation