Frameworks Workshop:

EMPHAT!C

Jonathan Paley

On Behalf of the EMPHATIC Collaboration

June 7, 2023

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EMPHATIC

- **E**xperiment to **M**easure the **P**roduction of **H**adrons **A**t a **T**est beam **I**n **C**hicagoland

  - Uses the FNAL Test Beam Facility (FTBF) (eg, MTest)

  - Table-top size experiment, focused on hadron production measurements with p_{beam} < 15 GeV/c, but will also make measurements with beam from 20-120 GeV/c.
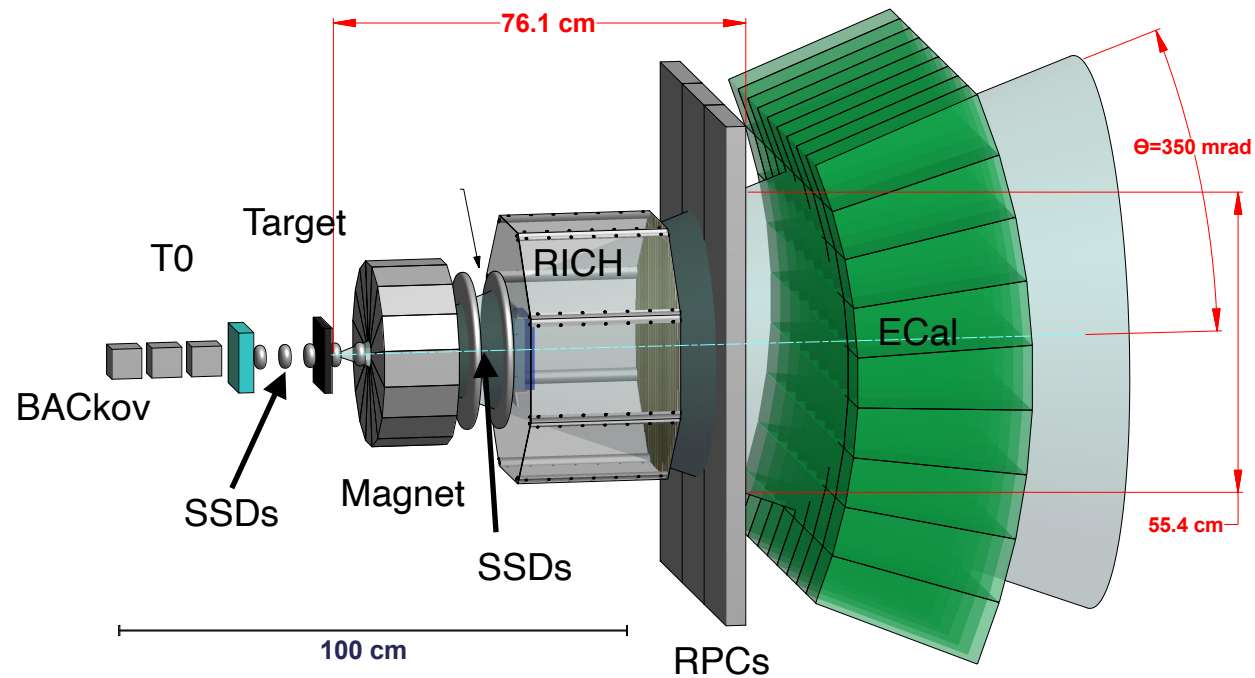
- Ultimate design:

  - 350 mrad acceptance, compact size reduces overall cost

  - high-rate DAQ, precision tracking and timing

Goals:

- Fill in the gaps of missing hadron-scattering and hadron-production cross sections measurements needed to improve neutrino flux uncertainties

- First-ever measurement of the hadron spectrum downstream of a target and horn.
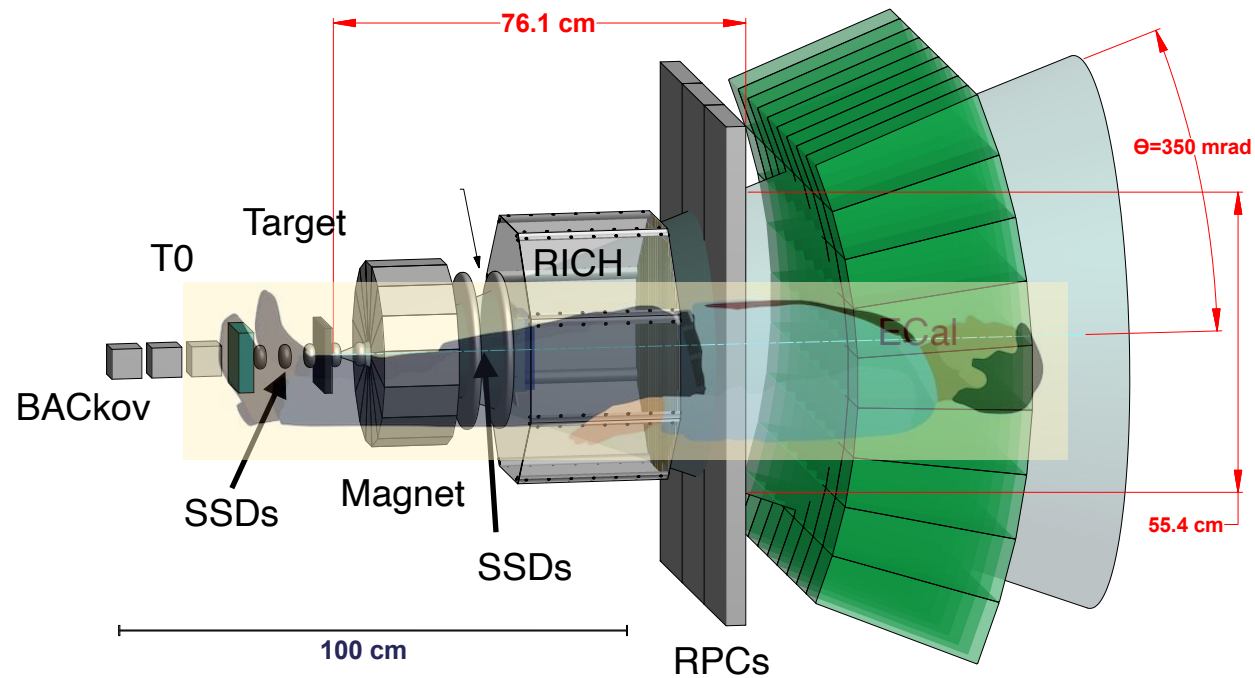
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- International collaboration, with involvement of experts from NOvA/DUNE/SBN and **SK/T2K/HK**.

Institutions from US, Japan, Canada and India

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EMPHATIC: Run Plan

Phase	Date	Subsystems	Momenta (GeV/c)	Targets	Goals	Status
0	2018	Beam Gas Ckov + FTBF SiStrip Detectors + Emulsion Bricks	20, 31, 60, 120	C, Al, Fe	Proof-of-concept Forward-scattering measurement w/ 20 mrad acceptance	Complete - Paper accepted by PRD
1	2022-23	Beam Gas Ckov + Beam ACkov + FTBF SiStrip Detectors + Small-acceptance magnet + Prototype ARICH + ToF + Small-acceptance Calorimeter	4, 8, 12, 20, 31, 60, 120	C, CH2, Al, Fe, Be, Ti, Ca, H20	Improved elastic and quasi-elastic scattering measurements, 100 mrad-acceptance hadron production measurements	In-progress
2	2024-25	Phase 1 on Motion Table	4, 8, 12, 20, 31, 60, 120	Spare NuMI Target and [unpowered horn] + various thin-targets	Charged-particle spectrum downstream of horn + thin-target measurements at larger angle	Funded and Planning
3	2025	Upgrade spectrometer to 350 mrad acceptance + Hybrid RICH	4, 8, 12, 20, 31, 60, 120	Same as Phase 2	Full-acceptance hadron production with PID up to 15 GeV/c	Concept
4	2025-26	Upgraded spectrometer + Hybrid RICH + Powered Horn	120	Spare NuMI Horn and Target	Charged-particle spectrum downstream of horns	Concept

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Forward-scattering measurement: Phys. Rev. D 106, 112008 (arxiv:2106.15723).

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Data already collected, analysis is underway.

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Funded, and planning is underway to construct the motion table, move the experiment and install the NuMI target and horn in MCenter at Fermilab.

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EMPHATIC Status

- We have collected ~400M triggers over ~5 weeks of uptime, and are working on understanding our data.

- We are upgrading some detectors, purchasing a new magnet, constructing a motion table and preparing the spare NuMI target and horn so that we can move into MC7 and collect an additional ~2B triggers.

- Software:

  - Art 3.12

  - We have an art G4 simulation, based on NOvA and other examples I found.

  - We have an art-based online-monitoring system, based on NOvA's.

  - We have a rudimentary art-based event-display, based on the toyExperiment example. Very much a work-in-progress.

  - No significant art reconstruction modules exist, although we expect this to change very quickly (we are having a working workshop in ~2 weeks to move forward on this).

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EMPHATIC: Things to Keep in Mind

- EMPHATIC is a very small collaboration. Aside for some graduate students, this is a part-time gig for most collaborators. We have about 15 people working at an average of 0.2 FTE on the experiment.

- We have about 4 Ph.D.-level scientists who have real experience coding with art (from NOvA and ICARUS).

- ~½ of the collaboration will never work with art outside of EMPHATIC.

- Part of our DAQ uses artdaq (many thanks to Eric F for his support!)

- We expect to collect data until the long-shutdown.

- We have not identified anything critical that we cannot do within art. Our requests are more about improving our workflow.

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EMPHATIC: Requests

- DOCUMENTATION in the [prioritized] form of:
  - Examples, like "how do I…"
    - Avoid using art jargon or class names in the questions themselves, because most of the time the user has no idea what they are.
    - Searchable
    - Should include examples and jargon-free explanations of cmake files or commands; users spend an enormous amount of time trying to figure this out.
    - Also shed light on cetbuildtools/cetmodules magic.
  - Update the ToyExperiment code and Workbook
  - Table of art classes, methods, etc. that has use-case examples. Eg: "art::Assn : use this when you want to …"

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EMPHATIC: Requests

- The ability to dynamically reload a fhicl job configuration (which would reload all configs) and reprocess an art event.

  - The use-case I have in mind is for an event display where you can run and modify the parameters of a reconstruction algorithm to see the behavior.

  - We had this ability in MIPP's framework from over 20 years ago, and it was one of the most useful and powerful aspects of the framework.

- Add some base [virtual?] classes that experiments can use to quickly put together an event display.

  - I argue that data visualization, in particular visualization of objects stored in art::Events, should be a critical component of any framework.

  - Would be extremely beneficial to smaller experiments that do not have the resources to "roll their own".

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Thank you!

- Thank you to especially to Kyle and Chris for their help over the past couple of years in getting us up and running with art!

- Thank you for listening and considering these requests!