Cambridge Pandora For DUNE ND Plans

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Cambridge

- We plan to develop Pandora for use in all ND modules
  - Clear benefits to physics studies and reduced systematics in Near-Far SW complementarity.
  - Already has a wealth of tried and tested physics capability.
- Early integration with the ND groups is essential.
- Consultation period: speak with all the teams and gauge interest and determin needs.
- Long term minded design rather than organic growth.
- The current team:
  - Alex Moor – (PhD student) our Pandora ND Champion has started some early toy studies.
  - 2 new PhD students in Oct (1 experienced in ML for µBooNE Pandora).
  - We hope to have the resources for postdoc time coming soon.

Why Pandora?

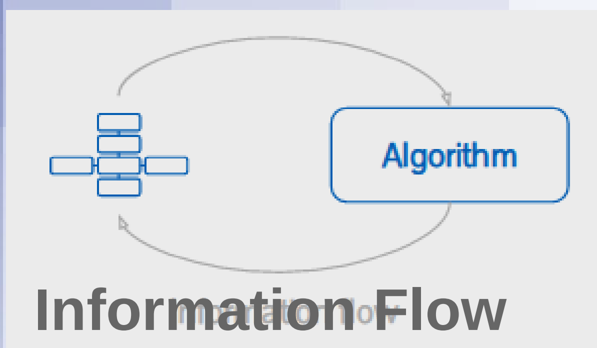
- Used for DUNE FD.
- Succesfully used by numerous experiments and detectors with varied use cases:
  - MicroBooNE, ProtoDUNE (SP/DP), DUNE FD, ICARUS, SBND, ILC, ARIADNE…
- Highly portable
  - Algorithms don’t modify data structures → request changes that are performed by the Pandora Framework.
  - New experimental designs –often have similar reconstruction needs.
  - Can adapt existing algorithms for new and unique detector technologies.

Pandora

- Pandora SDK created to identify energy deposits from individual particles in fine-granularity detectors – future e^+e^- colliders.
- Pandora algorithms designed to be generic, multi-experiment use.
- Input building blocks (e.g. hits) considered by many decoupled algorithms.
- Each algorithm targets a specific event topology and controls operations, eg: collecting hits into clusters, merging or splitting clusters, or collecting clusters into a representation of particles.
- Each algorithm aims only to perform pattern-recognition operations when it is deemed “safe”, deferring complex topologies to later algorithms.
- In this way, the algorithms can remain decoupled and there is little inter-algorithm tension.
- Complexity of algorithms varies.

The Pandora multi-algorithm Approach

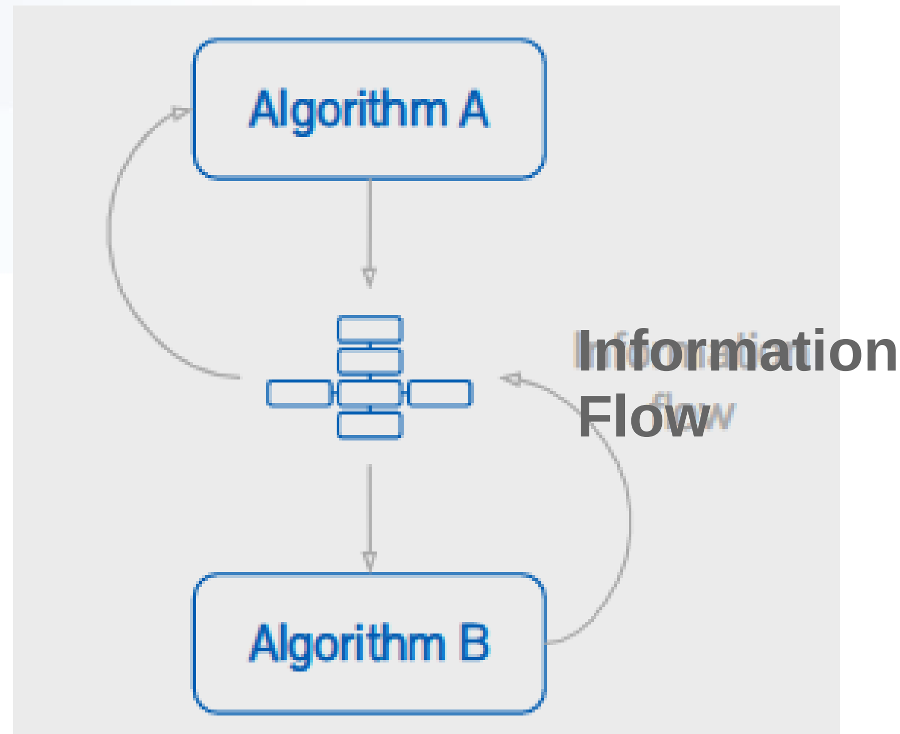
- Break the problem up into smaller well defined tasks and develop targeted algorithms for each task
  - E.g. Cluster together two hits if …



Algorithms update our current understanding of the event by modifying the event data

- Algorithm complexity varies from simple cuts up to more advanced machine learning techniques.
- The application runs many algorithms (for MicroBooNE ~100) to gradually build our understanding until a complete picture of the event develops.

- Iteration is used to allow 2-way information flow between algorithms



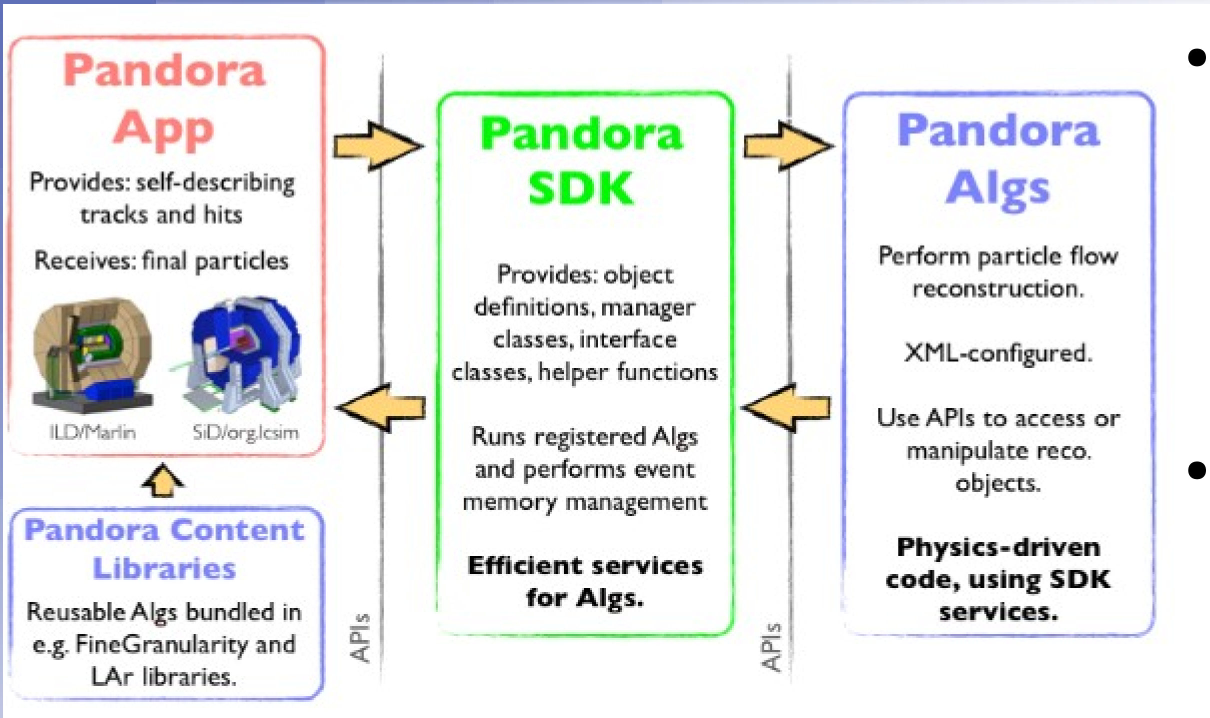
- Provides powerful feedback loops - a technique that Pandora frequently utilizes.

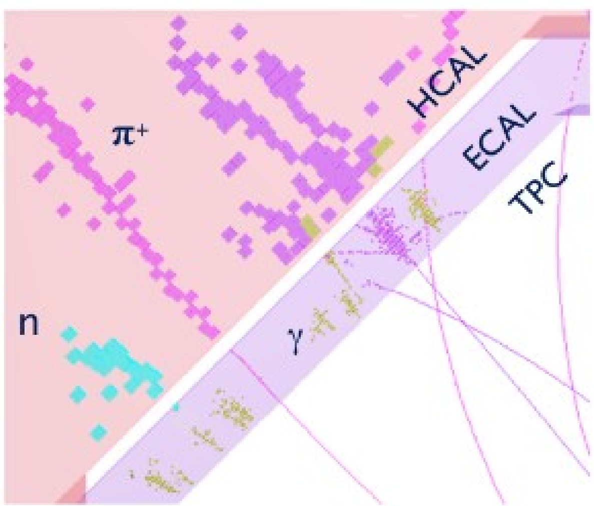
The Challenges

Harnessing Pandora for a new detector technology is not trivial, and requires a careful programme of work:

- Several varied near detector designs to be implemented.
- Tailoring the reconstruction to the experiment – yields significant performance improvements (cosmic rejection, neutrino tagging, optical info for recon and PID), but more work.
- Development of a Pandora event reconstruction able to work from fine granularity 3D image inputs.
- Currently a general assumption that *x* is the “drift time” co-ordinate and that all views have the same *x* value
  - A 3DST detector for example would provide three 2D images of neutrino interactions, and would require Pandora to handle three orthogonal projections of underlying 3D interactions.

Implementations





- **Pandora reconstruction software divided into client application, central framework and algorithms.**
- **The client application provides the input to the reconstruction and receives the final particles.**
- **The framework handles the memory management, whilst the algorithms implement the pattern recognition.**
- **~60 algorithms.**

µBooNE Implementations

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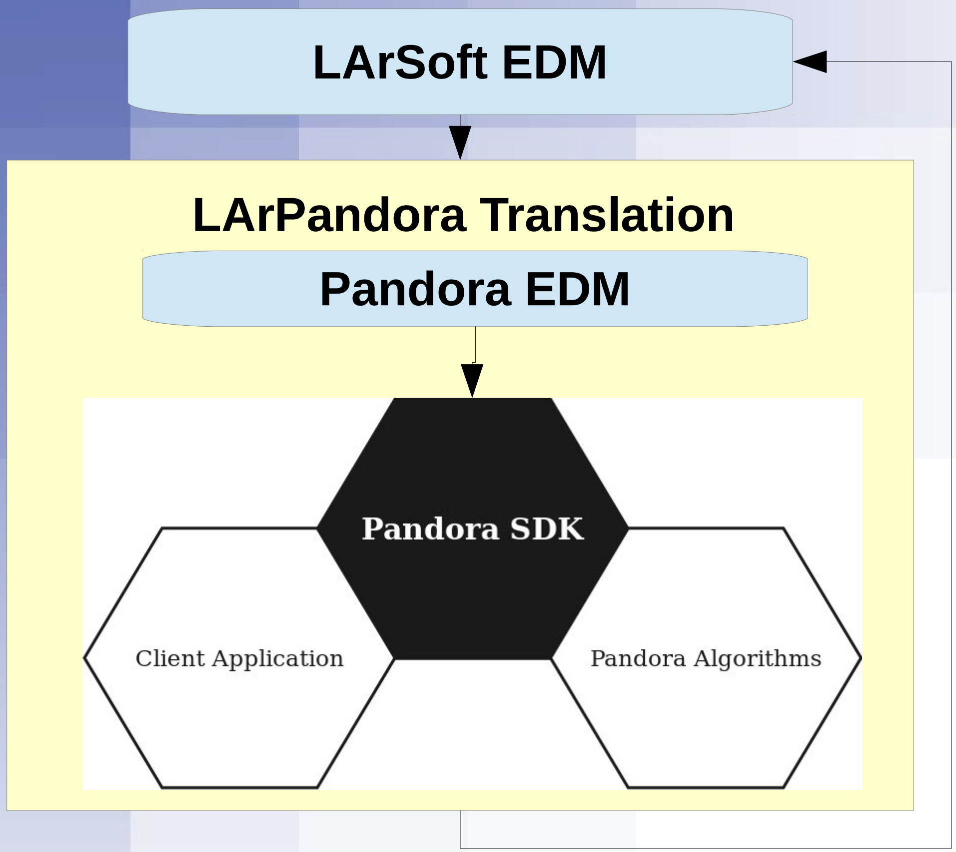
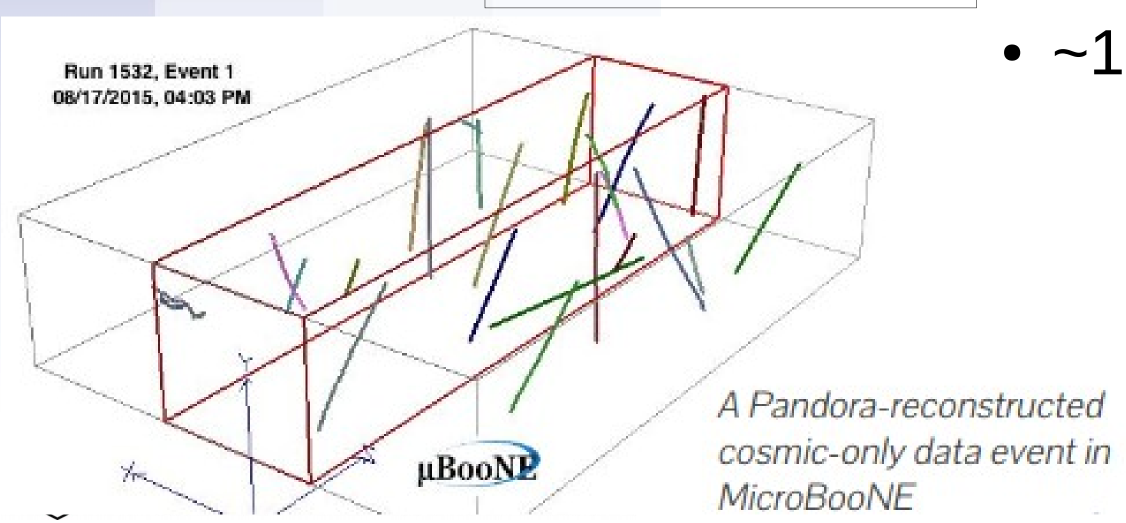


- **Integrated into LArSoft via LArPandora translation module.**
- Module translates the input patrec building blocks from the LArSoft Event Data Model (EDM) to the Pandora EDM, initiate and apply the Pandora algorithms, and then translates output Pandora patrec results back to the LArSoft EDM.
- Translation modules are ultimately responsible for controlling recon.
- ~100 algorithms.



A Pandora-reconstructed cosmic-only data event in MicroBooNE

protoDUNE

- Detector simulation and signal processing, including hit finding, performed using LAr-Soft.
- ~75 algorithms.

Planning

- Initial discussions to gauge response:
  - ✓LAr ND, ✓GAr ND, SAND, SW Integration team.

- Consultation (culminating in a set of requirements and design choices):
  - Long term design!
  - Pandora ND with 3 pluggins **OR** 3 versions of Pandora (my immediate preference is the former)
  - Use cases (e.g. I want to reconstruct ...)
  - Requirements (e.g. Pandora ND must support…)

↔

- Gather resources, expertise and experience:
  - Alex Moor working on toy studies at Cambridge.
  - Gather geometry models for each ND detector.
  - Additional PhD and post-doc effort at Cambs.
  - Current ND SW work.
  - Eldwan Brianne has started integration with the GAr software based on Pandora ILC.
  - Effort and time requirements – determined by outcome of consultation.

Thank you!

Discussion