

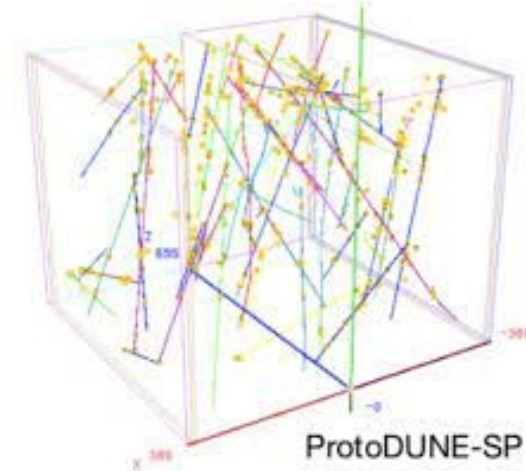
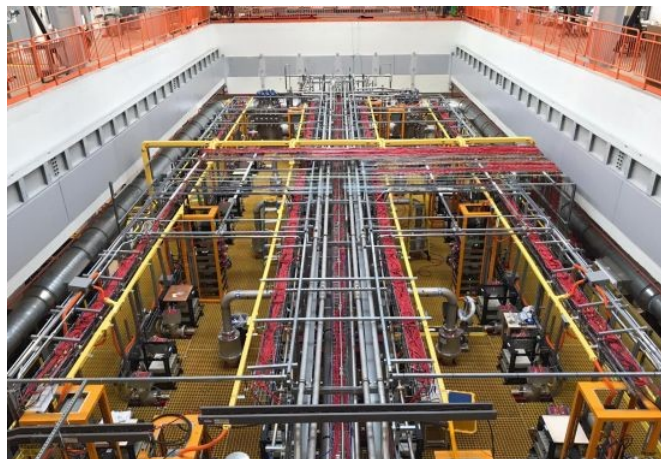
Pandora_ND Overview

Melissa Uchida
05/07/22

Pandora_ND Intro



- Successfully used for:
 - MicroBooNE, ICARUS, ADRIAN & ILC etc.
- Main Reconstruction choice for DUNE:
 - ProtoDUNE SP / DP / VD
 - DUNE FD
- Over 100 algorithms exist for the various flavours.



Pandora_ND Why



- Clear physics benefits to using similar reconstruction frameworks for Near and Far detector analyses:
 - to minimise model dependencies and
 - systematic errors.
 - DUNE's systematic uncertainties modelled by:

$$\frac{N^{FD}(E_{rec}) = \Phi^{FD}(E_\nu) \times \sigma^{FD}(E_\nu) \times \epsilon^{FD}(E_\nu) \times \mathbf{D}^{FD}(E_\nu \rightarrow E_{rec})}{N^{ND}(E_{rec}) = \Phi^{ND}(E_\nu) \times \sigma^{ND}(E_\nu) \times \epsilon^{ND}(E_\nu) \times \mathbf{D}^{ND}(E_\nu \rightarrow E_{rec})}$$

- Easier well matched global reconstruction.



Pandora_ND History



- Idea began Jan 2019.
- One of 2 selected proposals (alongside DAQ_ND) by DUNE UK for unspent VAT recovery...
- Funding from AIDA++ → 2 PDRA's:
 - John Back (Warwick) who leads neutrino event reconstruction for NDLAr and
 - Steve Dennis (Cambridge) Project Deputy Lead.
- **Ode to Alex Moor who has been the primary developer:**
 - ND content libraries, ND detector geometries and performing early Pandora algorithm developments.
- Today we have 7 international groups signed on: 2 USA, 2 in UK, 2 in Italy and BERN (who have just signed up to provide several collaborators) +++



- Workplan developed with all ND Sub-detector groups following a consultation process for top down use-case driven SW design.
- **NDLAr:**
 - Development well underway see following talks.
- **SAND:**
 - Working with Italian teams led by Luca Stanco (inc GRAIN)
- **NDGAr:**
 - Based on Pandora for ILC – Eldwan Brianne.
- **TMS:**
 - Under development TBD.



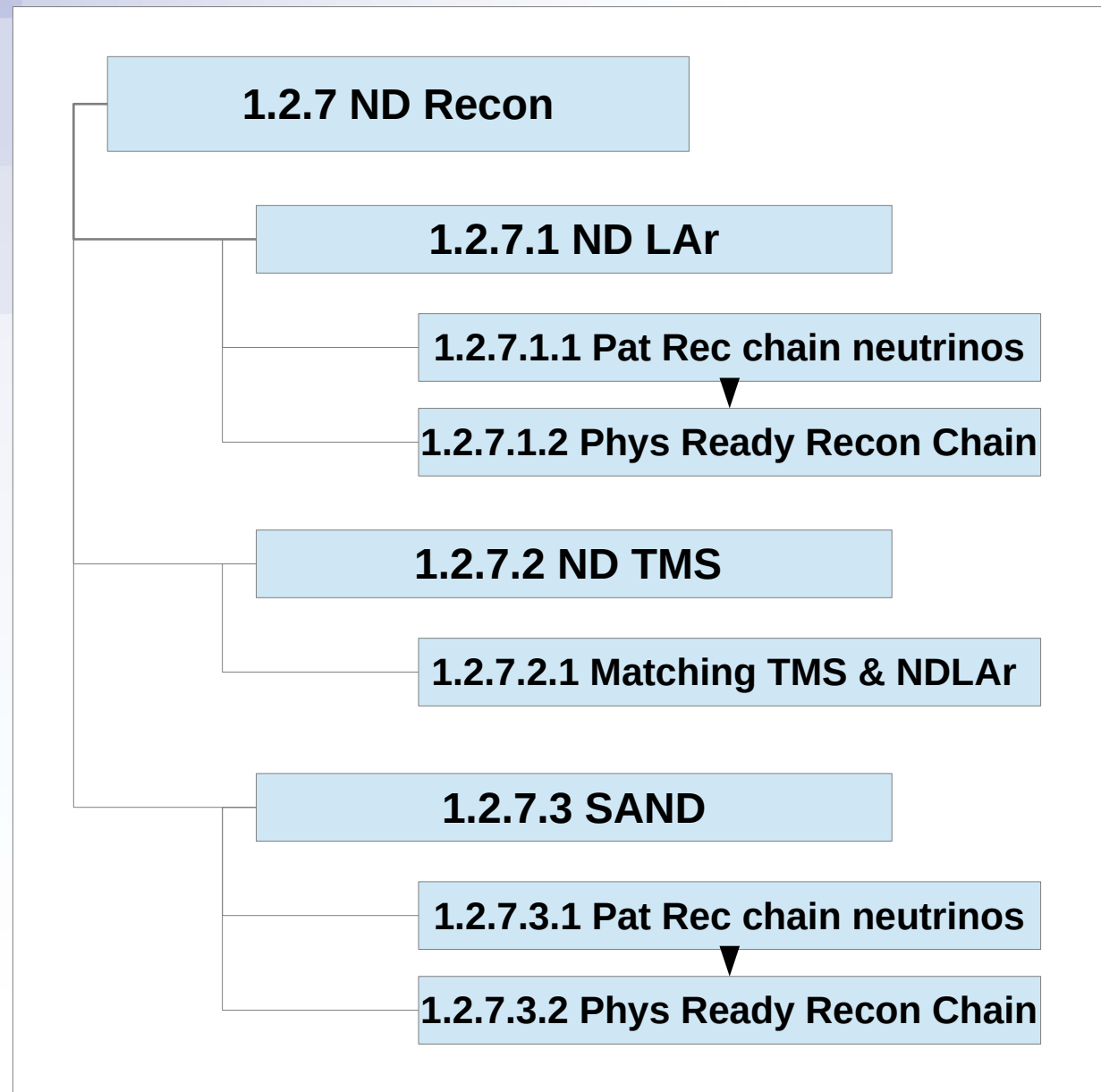
Pandora_ND 5 year plan



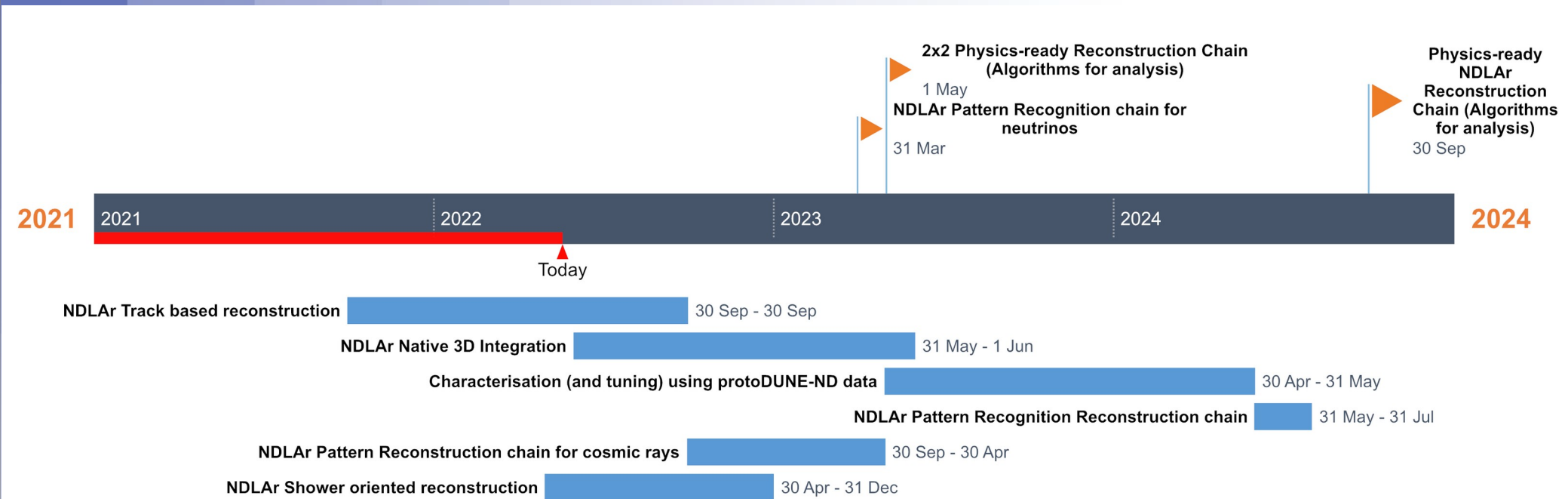
WP	Deliverable	Start Date	End Date	Responsible	Accountable	Consulted
	NDLAr					
M1	Track based reconstruction	Sep 2021	Sep 2022	PDRA, PhD1	Marshall	Blake, Marshall, Uchida, ND Integration, ND LAr Consortium, DUNE-UK Reconstruction Manager.
M2	Shower oriented reconstruction	Apr 2022	Dec 2022	PDRA, PhD2	Blake	
D1	Pattern Recognition chain for neutrinos	Dec 2022	Mar 2023	PDRA, PhD1, PhD2	Marshall	
M3	Native 3D Integration	May 2022	Aug 2023	PDRA, PhD1	Uchida	
M4	Pattern Reconstruction chain for cosmic rays	Sep 2022	Apr 2023	PDRA, PhD3	Blake	
D2	2x2 Physics-ready Reconstruction Chain (Algorithms for analysis)	Apr 2023	May 2023	PDRA, PhD5	Uchida	
M5	Characterisation (and tuning) using protoDUNE-ND data	Apr 2023	May 2024	PDRA, PhD1	Blake	
M6	NDLAr Pattern Recognition Reconstruction chain	May 2024	Jul 2024	PDRA	Uchida	
D3	Physics-ready NDLAr Reconstruction Chain (Algorithms for analysis)	Jul 2024	Sep 2024	PDRA, PhD5	Uchida	
ND TMS						
M1	Pattern Recognition chain for muons	Dec 2022	Aug 2023	PDRA, PhD4	Blake	Blake, Marshall, Uchida, ND Integration ND TMS Management
D1	Matching TMS and NDLAr	Aug 2023	Dec 2023	PDRA, PhD4	Blake	
M2	Dedicated reconstruction chain for cosmic rays	Aug 2024	Aug 2025	PDRA, PhD4	Uchida	
M3	Full Pattern Recognition Reconstruction chain	Aug 2025	Jul 2026	PDRA,	Marshall	
ND GAR						
M1	ECal Pattern recognition	Dec 2024	Apr 2026	PDRA, PhD5	Marshall	Blake, Marshall, Uchida, ND GAR Management, ND Integration
M2	TPC to ECal matching	Mar 2025	Jul 2026	PDRA, PhD6	Uchida	
D1	Pattern Recognition Reconstruction chain	Jul 2026	Aug 2026	PDRA, PhD5, PhD6	Marshall	
ND SAND						
M1	Track based reconstruction	Sep 2022	Nov 2023	PDRA, PhD3	Marshall	Blake, Marshall, Uchida, ND Integration, ND SAND Management and DUNE-UK Reconstruction Manager.
M2	Shower oriented reconstruction	Sep 2023	Dec 2024	PDRA, PhD5	Uchida	
D1	Neutrino Reconstruction Chain	Jan 2025	Apr 2025			
M3	Dedicated reconstruction chain for cosmic rays	Feb 2025	Dec 2025	PDRA, PhD3	Uchida	
M4	Sub-detector matching	Dec 2024	Dec 2025	PDRA	Blake	
D2	Coordination and Design of Physics-ready Reconstruction Chain	Jan 2026	Aug 2026	PDRA	Blake	
Pre-Grant Deliverables						
D1	Skeleton ND Pandora framework		Aug 2021	PhDA, PDRA_A, Marsha	Blake, Marshall, Uchida	Blake, Marshall, Uchida, ND LAr, GAR, TMS and SAND Management ND Integration
D2	ND Content library designed		Sept 2021	PhDA, PDRA_A, Marshall		
D3	Create new ND Pandora content libraries.		Nov 2021	PDRA_A, PDRA		
D4	Implement ND-specific visualisation and MC event validation algorithms.		Sept 2021	PhDA, PDRA_A, PDRA		
D5	Review of DUNE-FD and Pandora reconstruction algorithms		Nov 2021	PhDA, PDRA_A, PDRA		
D6	Review of general Pandora reconstruction algorithms		Nov 2021	PhDA, PDRA_A, PDRA		
D7	Start of Pattern Recognition chain for neutrinos for NDLAr		Dec 2021	PDRA_A, PDRA		



Pandora_ND WP Breakdown



Pandora NDLaR



WP	Deliverable	Start Date	End Date
	<u>NDLaR</u>		
M1	Track based reconstruction	Sep 2021	Sep 2022
M2	Shower oriented reconstruction	Apr 2022	Dec 2022
D1	Pattern Recognition chain for neutrinos	Dec 2022	Mar 2023
M3	Native 3D Integration	May 2022	Aug 2023
M4	Pattern Reconstruction chain for cosmic rays	Sep 2022	Apr 2023
D2	2x2 Physics-ready Reconstruction Chain (Algorithms for analysis)	Apr 2023	May 2023
M5	<u>Characterisation (and tuning) using protoDUNE-ND data</u>	Apr 2023	May 2024
M6	<u>NDLaR Pattern Recognition Reconstruction chain</u>	May 2024	Jul 2024
D3	Physics-ready NDLaR Reconstruction Chain (Algorithms for analysis)	Jul 2024	Sep 2024

Pandora_ND Future



2021

2021

2022

2023

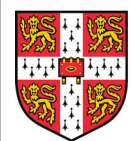
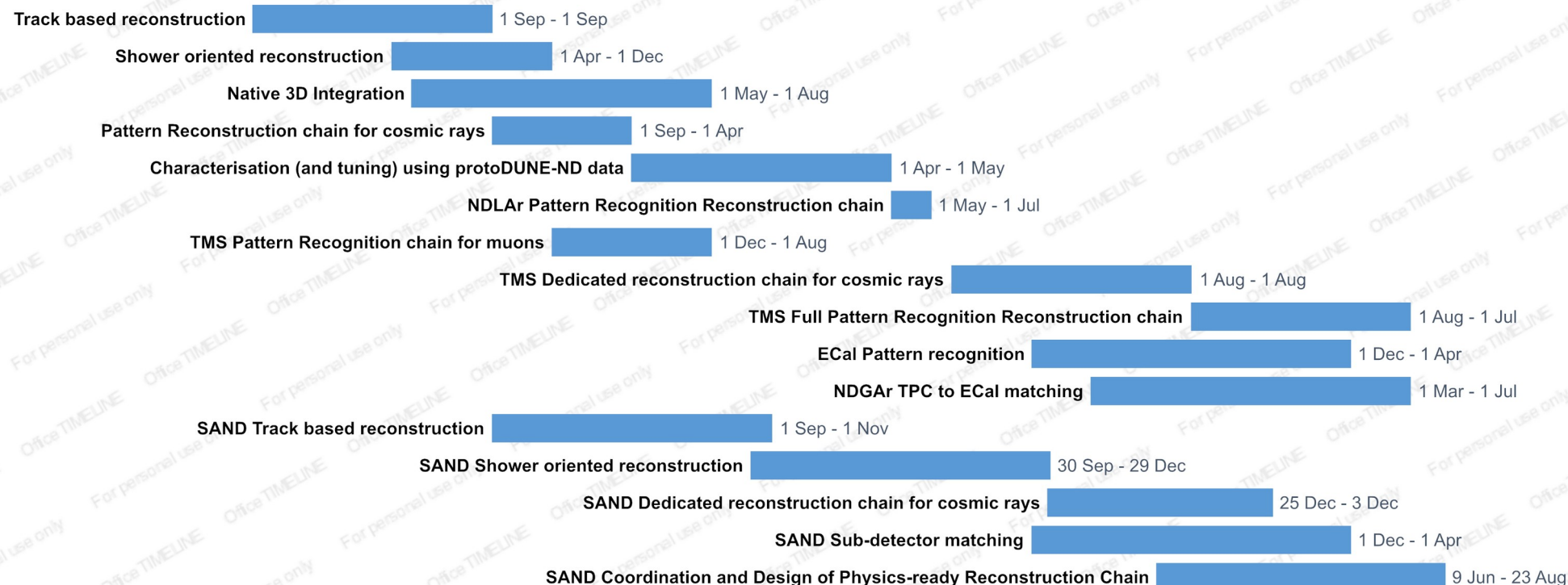
2024

2025

2026

2026

Today



UNIVERSITY OF
CAMBRIDGE

Melissa Uchida

DUNE UK Meeting – July 2022

Summary Pandora_ND



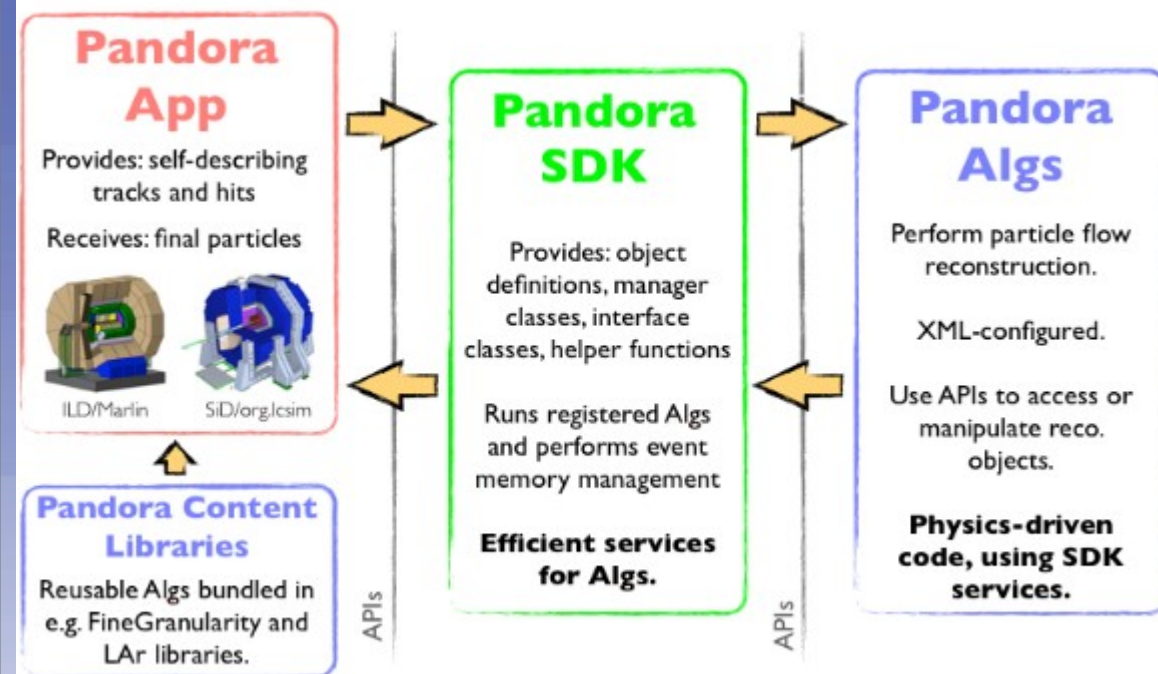
- The physics choice.
- Work well underway.
- International collaborators on board.
- Your Pandora_ND needs you.
- Details in the following talks...



Thank you!

Discussion





- 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.**

DUNE UK Meeting – July 2022

LArSoft EDM

LArPandora Translation

Pandora EDM

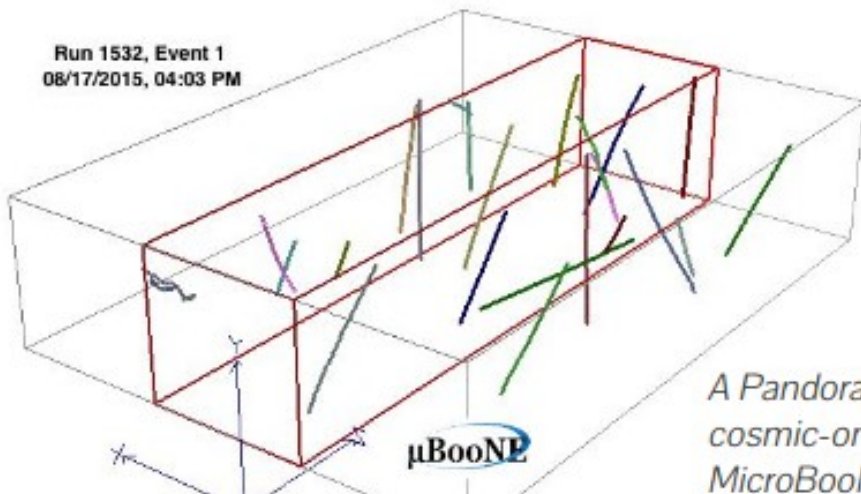
Pandora SDK

Client Application

Pandora Algorithms

- 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.

Run 1532, Event 1
08/17/2015, 04:03 PM



A Pandora-reconstructed
cosmic-only data event in
MicroBooNE

protoDUNE

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