The BEAST II project: Status & Goals

[New logo, courtesy Peter Lewis]

Contents

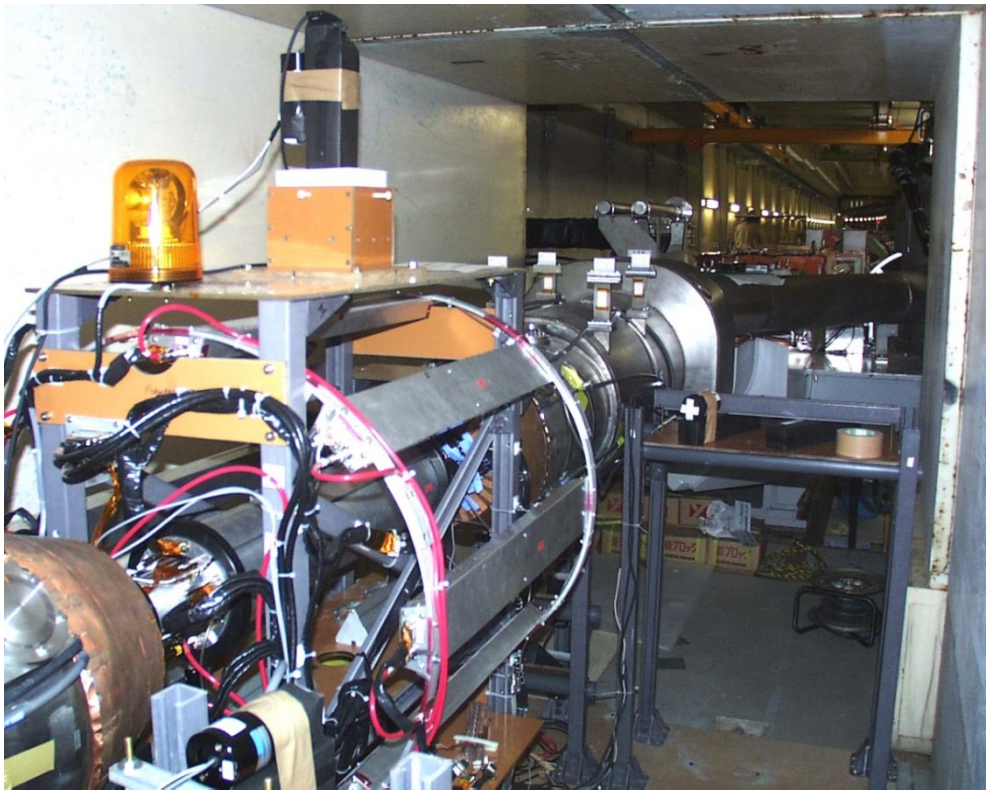
- What is BEAST ?
- BEAST II @ SuperKEKB
  - Phases 1 & 2, MiniBEAST
  - Main goals
  - Systems to be installed
  - Status of each
  - Challenges ahead

BEAST = **B**eam **E**xorcisms for **A** **St**able Belle Experiment

a.k.a. Commissioning Detector

Goals:

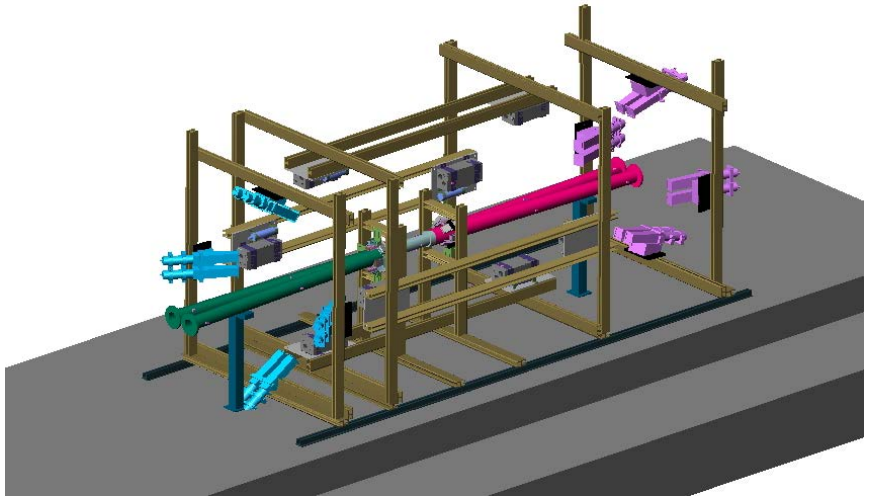
1. Protect Belle II: Ensure radiation levels safe before Belle roll-in
2. Measure individual beam background components
3. System tests (beam abort, VXD occupancy, cooling, mask control system)
4. Provide real-time feedback to SuperKEKB

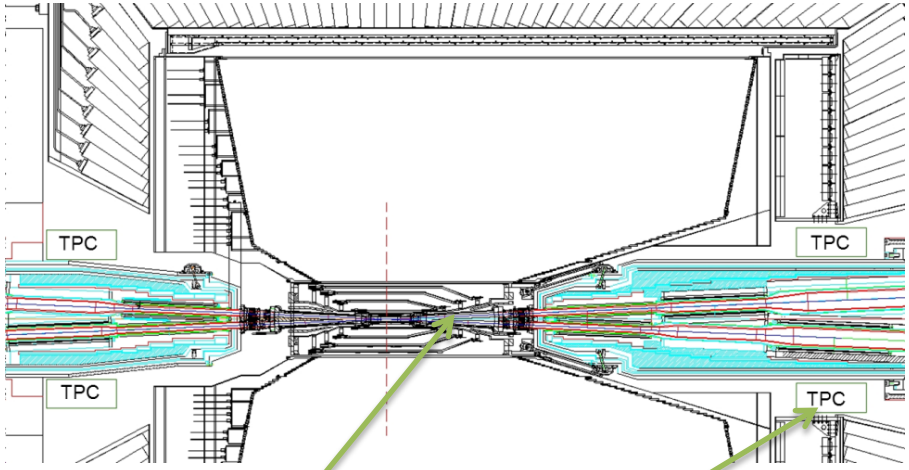


BEAST I in the Cave, ca. 1998

There already was a BEAST. The current effort is really BEAST II.

SuperKEKB: Two Commissioning Phases





BEAST Phase 1: assuming ~ Jan 2016

- Vacuum scrubbing of beam pipe.
- No collisions. Belle will not roll-in.
- Variety of subsystems on fiberglass support structure

BEAST Phase 2: assuming ~ Feb 2017

- Belle rolled in.
- VXD BEAST (see Marinas, Tanaka talks)
- He-3 & TPC neutron detectors in VXD dock space

BEAST systems resulted from what could be done, in time, at low cost, by institutes involved. Not the ideal system one would build if starting design from scratch.

Systems to be installed

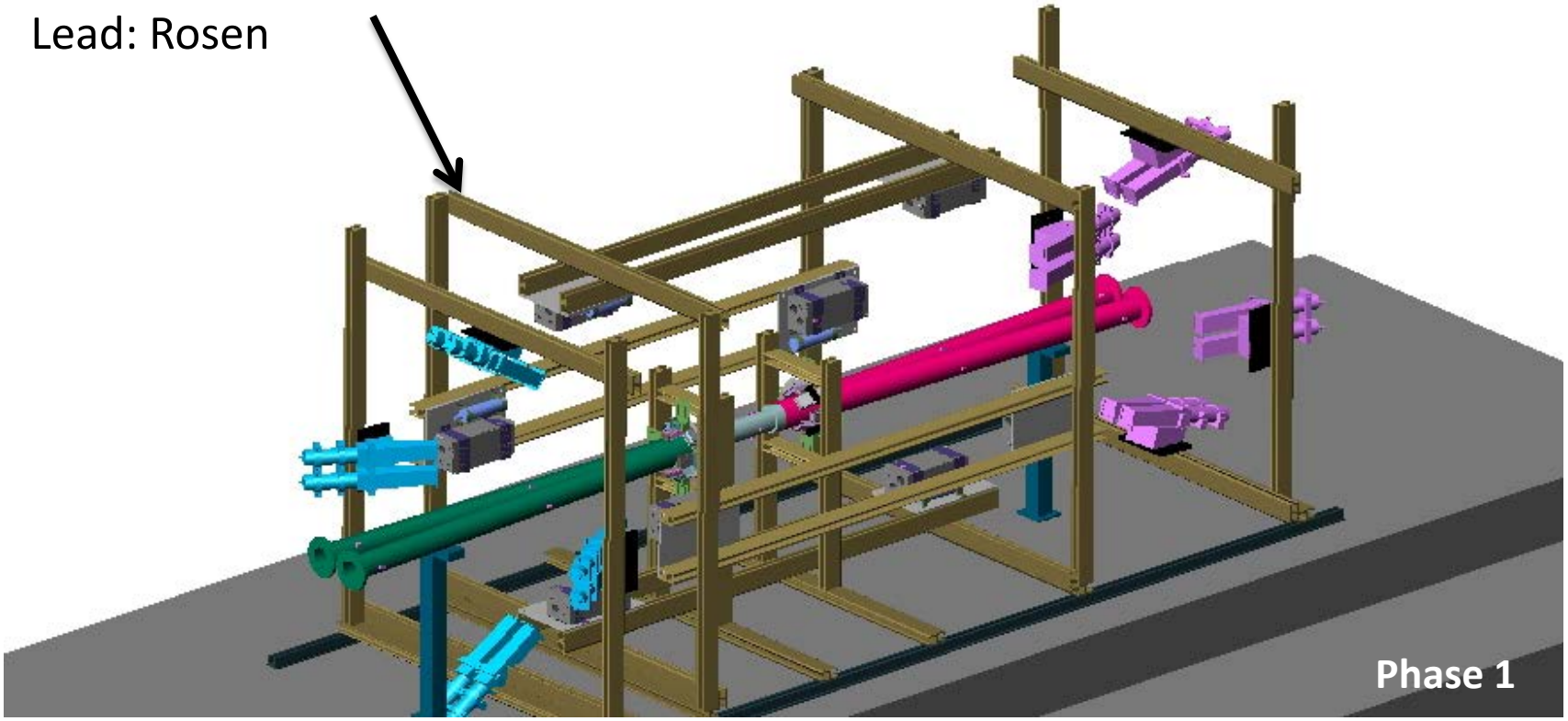
Core BEAST: Part of BEAST stand-alone DAQ

	no QCS no solenoid no Belle Phase 1	QCS, solenoid, Belle No PXD No SVD Phase 2	Full Belle Phase 3
PIN Diodes	64	64	?
Micro-TPCs fast neutron detectors	2-4	8 in SVX dock	2 - If space allows
He-3 thermal neutron detectors	2	4 in SVX dock	2- If space allows
BGO	8	8 – if space allows	-
CsI Crystals	8	-	-
Beam abort: diamonds	final prototype , 4 sensors	final system	final system
Synchrotron x-ray measurement	-	SDDs & ATLAS FE-I4 pixels	-
SVD, PXD ladders & monitors	-	2 PXD half ladders (L1+L2) 4 SVD single modules (L3-L6)	Full VXD
Loss monitors for collimator auto adjustment	-	PIN diodes Scintillator + MPPC	PIN diodes Scintillator + MPPC
PLUME CMOS pixels	-	?	-

Will focus on “core BEAST”, overall goals, and non-VXD topics - complementary to other talks

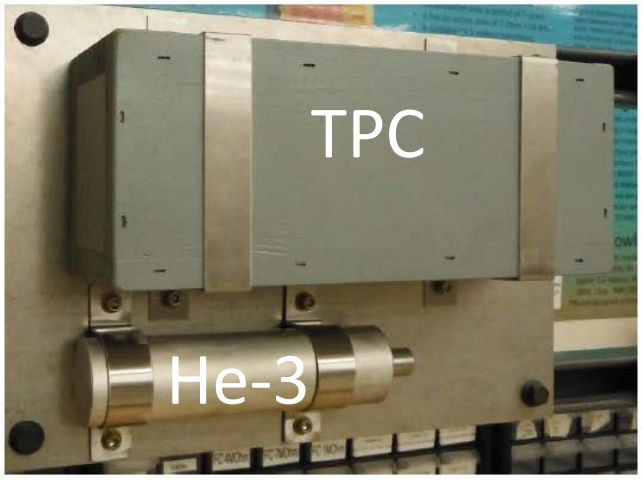
Phase 1 Design

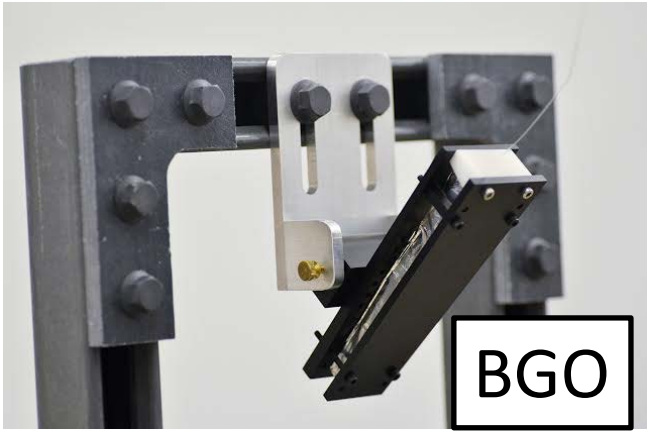
- Hawaii delivering phase 1 mechanical mounting structure
- Lead: Rosen



- Variety of detector systems on fiberglass support structure
- Some detectors (TPCs, He-3 tubes, PIN diodes) can be easily moved manually
- Full 3D CAD exists (Rosen). Also has been incorporated in the Belle II simulation (Jaegle).
- All parts procured, most assembly, to be used for “MiniBEAST” system test January 2015.
- Disassemble and ship to KEK August 2015.

Mechanical Mockups





Small-scale mockups have been built to validate mechanical interfaces.

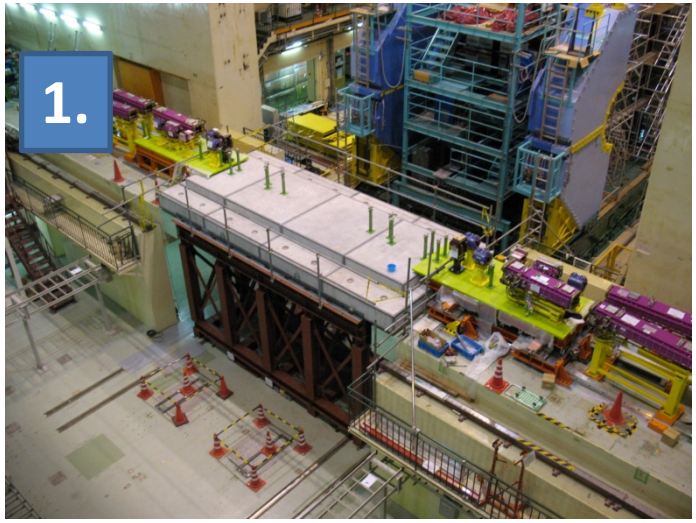
MiniBEAST

To ensure timely readiness, robustness, mechanical & software compatibility, MiniBEAST integration test starting this month:

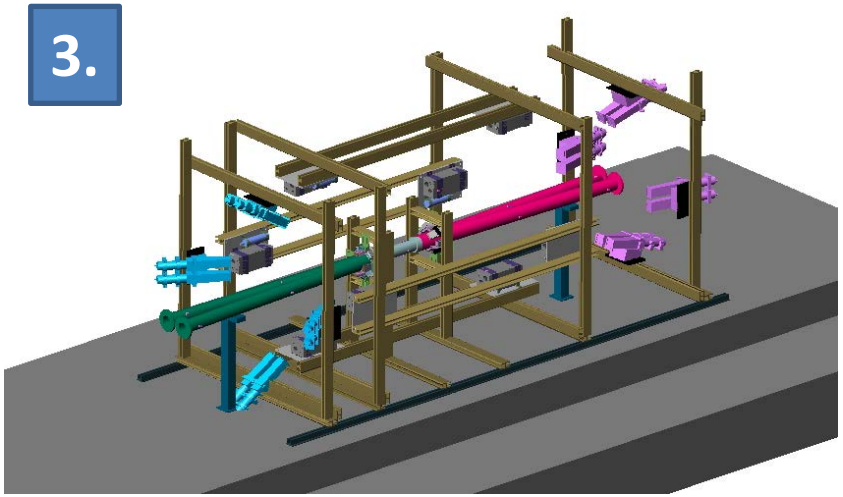
- BEAST (Standalone) DAQ
- 2 BGO, 8+ PIN, 2TPCs, 1 He-3, 1 CsI(pure) and 1 CsI (Tl)
- Final 37m cables (HV, LV, DAQ) and EPICs code – each institute must supply

MiniBEAST at the University of Hawaii.

Installation Plan, Phase 1



Install IP bridge: Completed



Install BEAST Phase 1 at IP: Sep & Oct 2015

Repair & Install IP chamber: ~April & May 2015

Add IP shield wall w/ crane Oct-Nov 2015 [tbd]

Phase 1 Activities

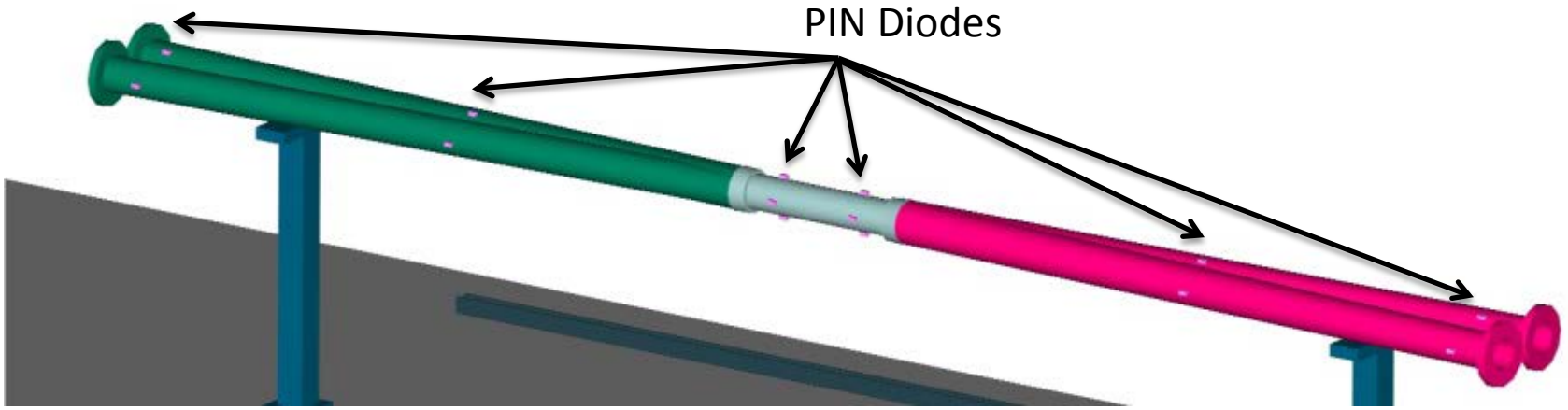
from BEAST, as apposed to SuperKEKB, point of view:

- Phase 1 ends when it is “safe” to roll-in Belle, i.e.
  - SVX beam abort is functional and tested (protects BEAST SVX setup & rest of Belle)
  - Radiation level are acceptable, as measured by PIN diode system. Need to define quantitative goal.
- Critical activities
  - Measure x-ray and total particle dose at 64 positions with PIN diode system. More by moving PINs.
  - Test Diamond sensor VXD beam abort system, cross-check abort threshold against PIN diodes
- Desired activities
  - Measure CsI background using 4 pure CsI & 4 CsI(Tl) crystals in ECL location w/ BEAST DAQ
  - First measurements of total dose, x-rays dose, fast neutron flux, thermal neutron flux, versus phi & z
    - Allows first comparison against beam background MC
    - w/ 64 PINs, 2-4 TPCs, 2 He-3 tubes.
    - Requires moving TPCs and He-3 tubes manually
    - Due to large x-ray dose in phase I, TPCs may require lead shields

    [Would be nice to repeat for multiple beam /vacuum conditions to disentangle contributions from Touschek/Beam Gas/LER/HER → First crosscheck of beam-gas and Touschek MC]

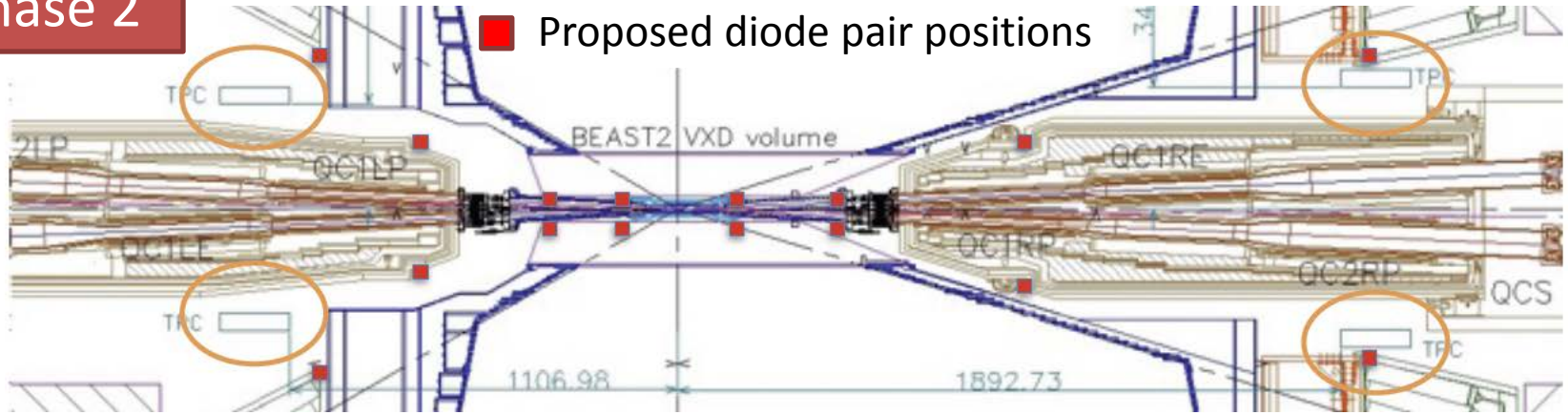
PIN Diode System

Phase 1

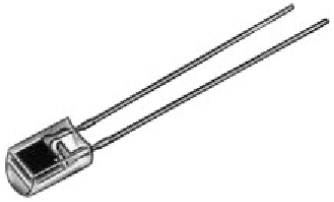


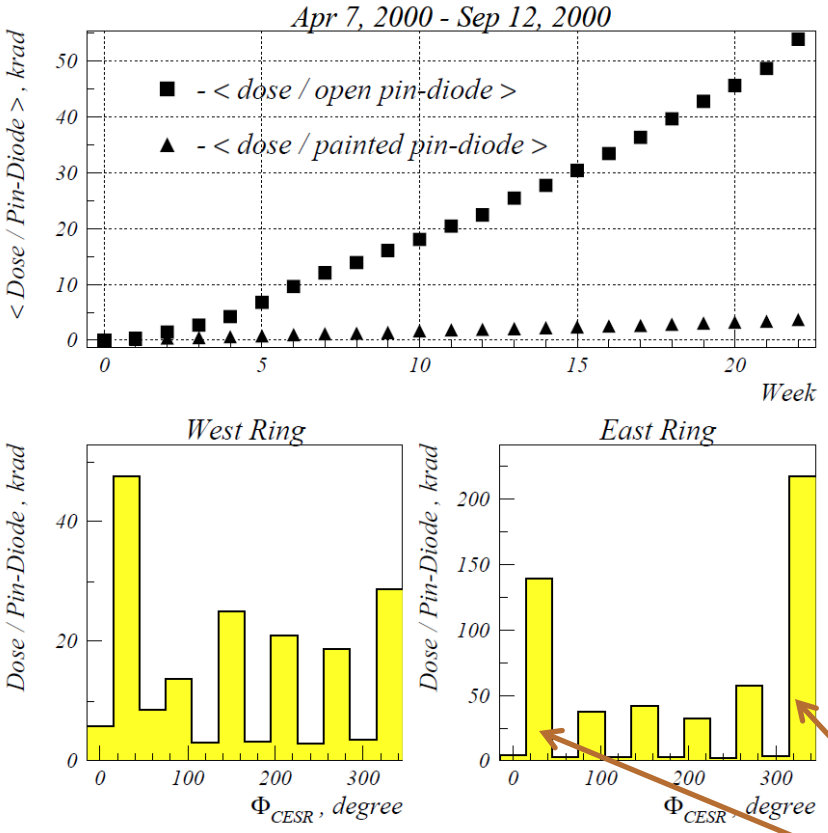
64 channels: 8 z-positions X 4 phi positions X 2 diodes (shielded+unshielded)

Phase 2



PIN Diodes System II





CLEO Measurements

Figure 5: Week-by-week integrated dose and their angular distribution.

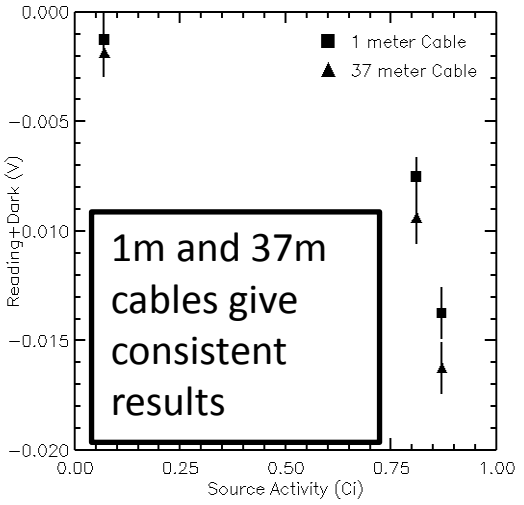
- Lead: David Cinabro (Wayne State)
- Use PIN diodes, Siemens SFH 206K PIN to measure ionizing radiation dose
- Inexpensive & robust
- Successfully used in CLEO for ~10 years and integrated a dose of < 3 Megarads
- Every 2nd diode (in phi) coated with gold-paint
- Allows separating dose from charged particles and x-rays

Synchrotron fan

PIN Diode Status

- 8 channel prototype delivered, good good performance with final cables
- 64 channels in rack-mount enclosure being assembled at Wayne State
  - parts procured
  - assembly behind original schedule due to lack of manpower, but compatible with new KEK schedule
- Temperature monitoring essential - order placed for commercial system
- New Wayne State postdoc, now resident in Hawaii, to integrate & test
- Ship to send to Hawaii by February 2015, to KEK August 2015

8 channel prototype



CsI Crystals

- Plan to measure CsI BGs using 4 pure CsI & 4 CsI(Tl) crystals in ECL location
- BEAST DAQ
- Beam-gas & Touschek only, unfocused beams
  - Checks whether simulation can predict these two background reliably
  - Provides data on pure CsI advantage, needed for Canadian calorimeter funding proposals

Holder for pair of crystal, preliminary mechanical design by U. of Victoria.

Phase II Activities

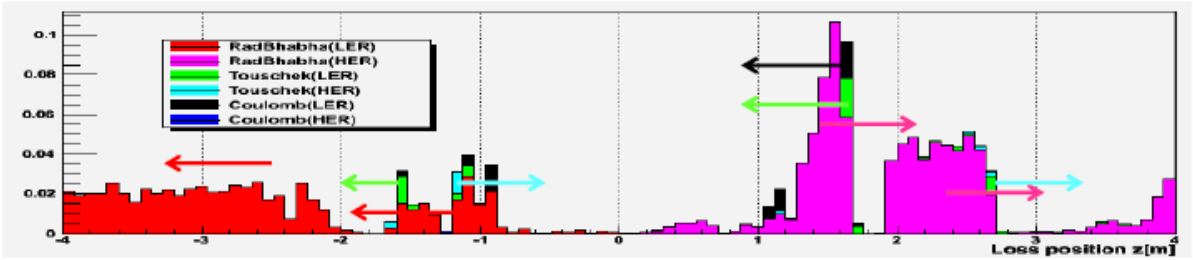
- Ensure VXD services operational & detector can be safely installed
  - Final test of beam abort
  - Measurement of x-ray synchrotron flux, total dose, occupancy in VXD location
    - → validate BP gold layer thickness, modify if needed
    - Use VXD specific sensors (SDDs, FE-I4s) & PIN diodes (see talks by C. Marinas & S. Tanaka)
- Provide BG levels near IP to accelerator via EPICs
- Establish system for mask control
  - Needs more detailed discussion / planning
- Measure individual beam BG components (Touchek, RBB, Beam Gas)
  - Needed to validate BG simulation, confirm dependence on beam parameters, *and to reliably extrapolate backgrounds to full luminosity*

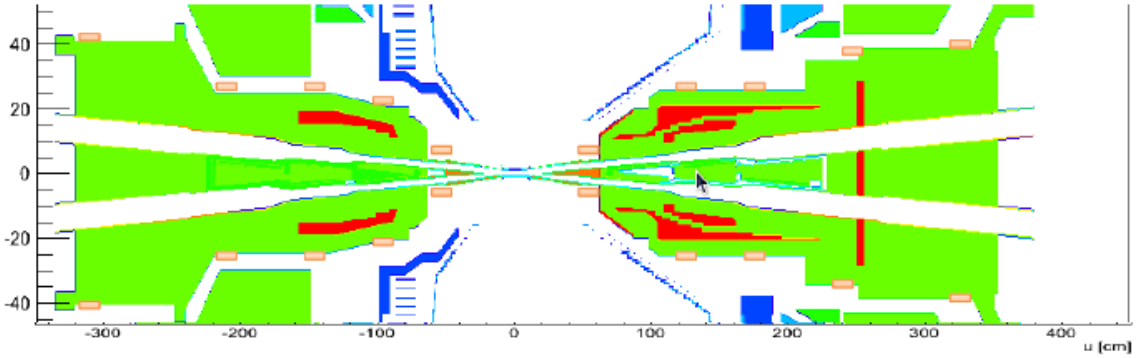
  → Vary accelerator beam parameters and vacuum pressure (see talk by H. Nakayama)

  → Measure x-rays/charged/neutrons vs Z and phi
    - PIN diodes / loss monitors: x-rays + neutrals vs z and phi
    - TPCs: fast neutrons versus z and phi
    - He-3 tubes: thermal neutrons versus z and phi
- Time-dependence of backgrounds
  - FE-I4 study of VXD injection backgrounds.
  - Can PLUME help?

Motivation for Neutron Measurements

- Neutron backgrounds highly penetrating; difficult to predict & measure accurately, caused problems already at Belle and Babar
- Will be critical for Belle-II operation and lifetime
  - KLM deadtime, ECL electronics lifetime, TOP PMT lifetime
- Idea: neutrons produced at specific loss-positions along the beam-line. Fast neutrons preserve directional information and can be directionally reconstructed. Use them to “image” loss spots.

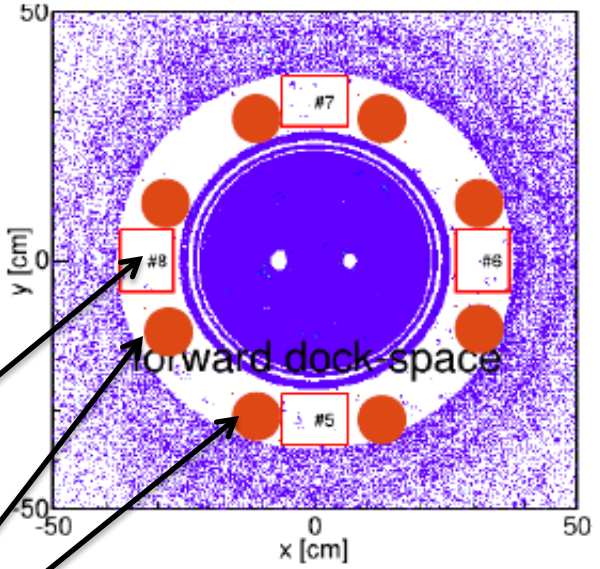


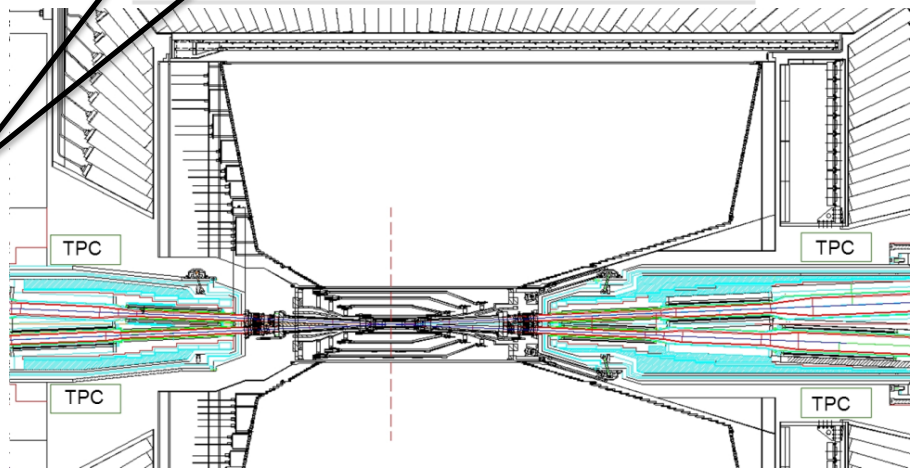


Phase 2

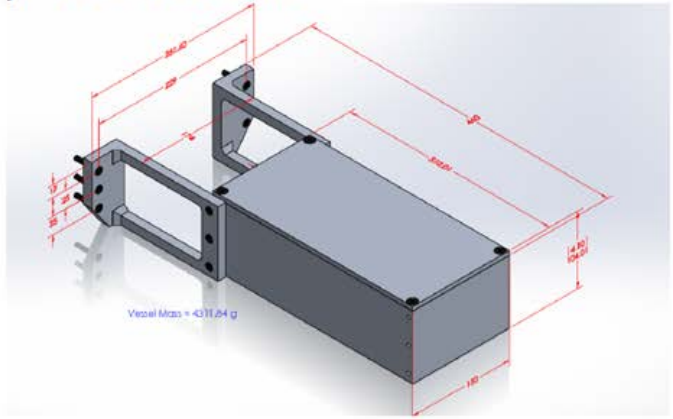
Neutron Detectors

- He-3 tubes and micro-TPCs in dock space
- Complimentary detectors
  - TPCs image direction of incoming fast neutrons, but detected rate is low
  - He-3 tubes measure rate of thermal neutrons, which is high

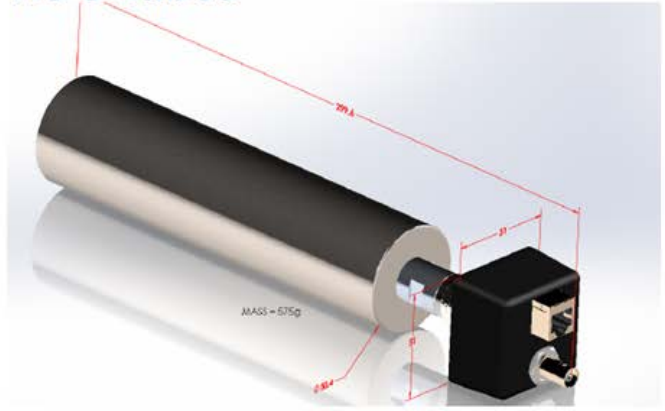




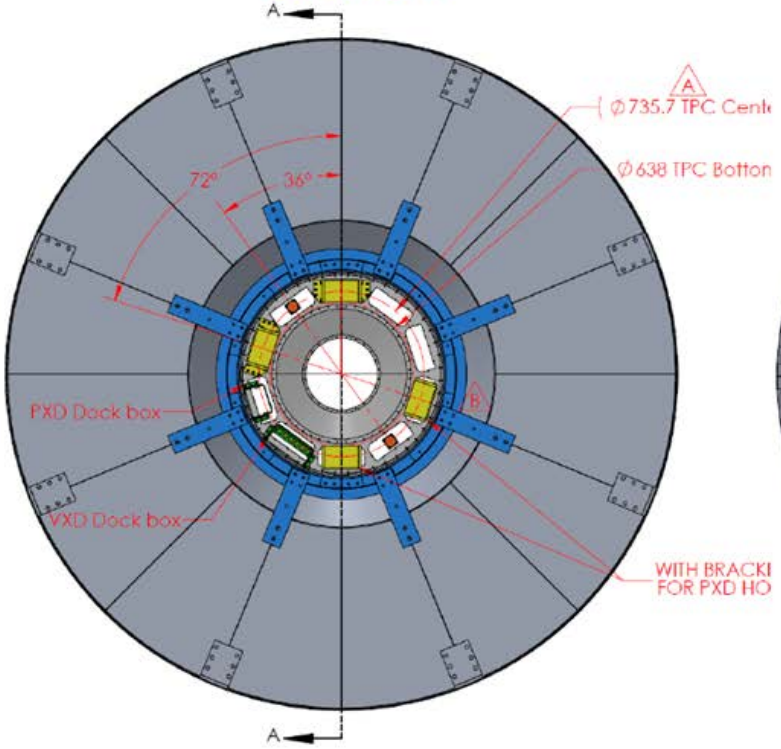
- μ-TPC vessels



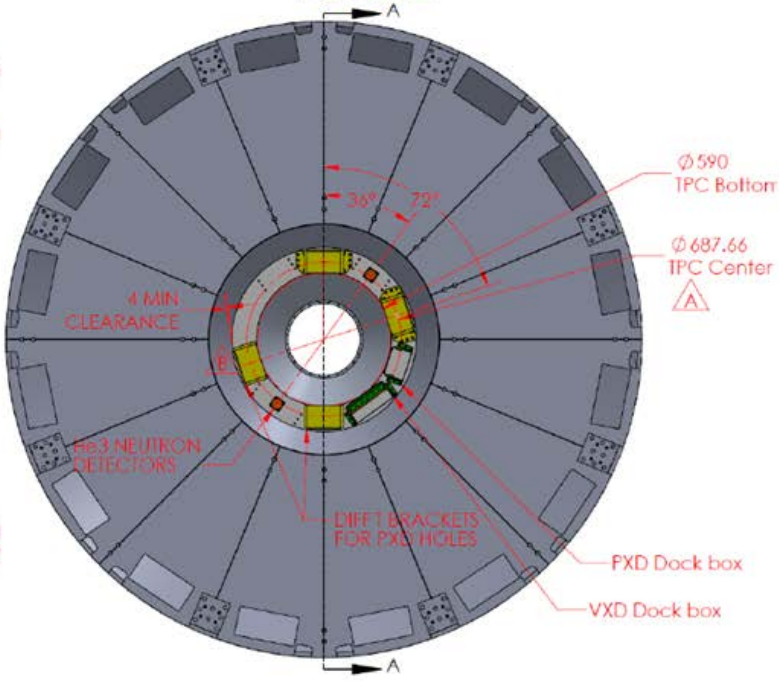
- He-3 tubes



Backward



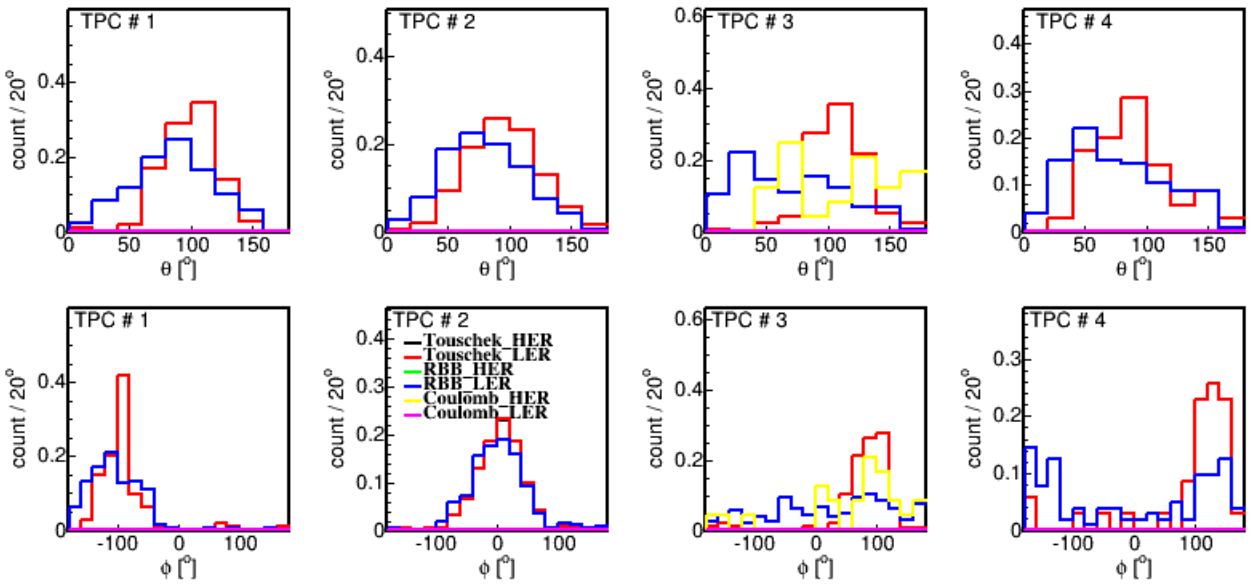
Forward



Jan 15th: Heroic CAD effort by Alexandre Beaulieu (Victoria) confirmed detectors fit into VXD docks.

Measuring Individual Neutron BGs w/ TPCs

I. Jaegle (Hawaii)



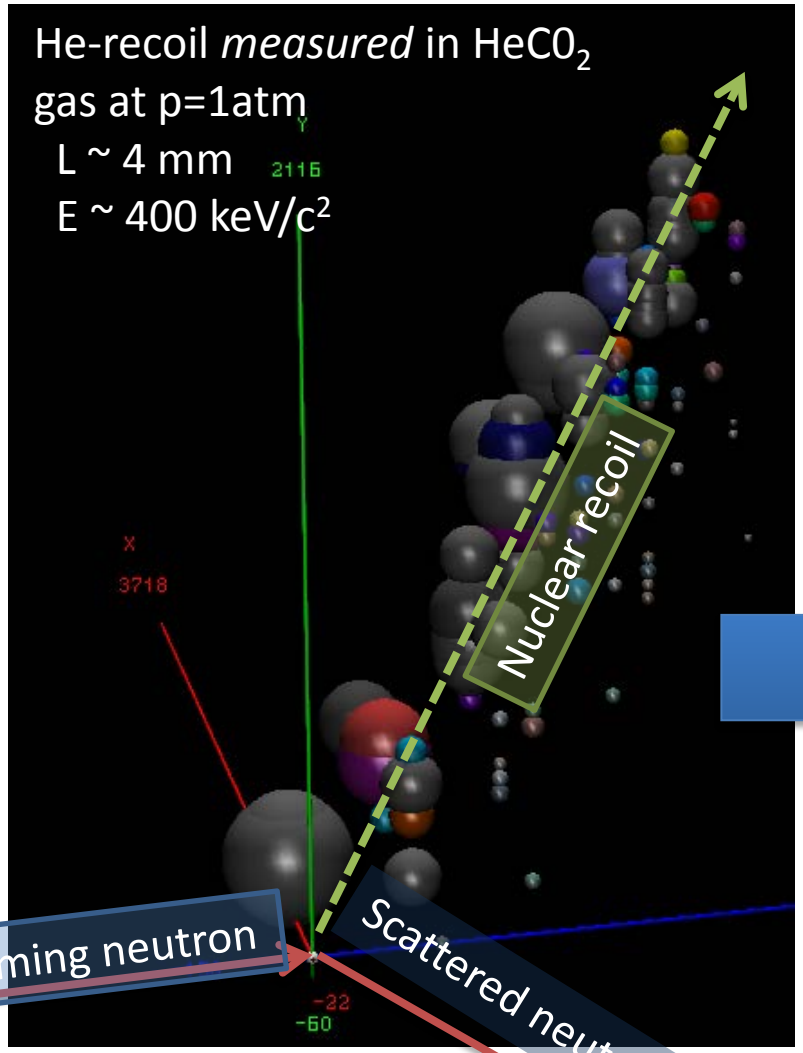
(note: Distributions normalized to same area)

Directional detection motivation

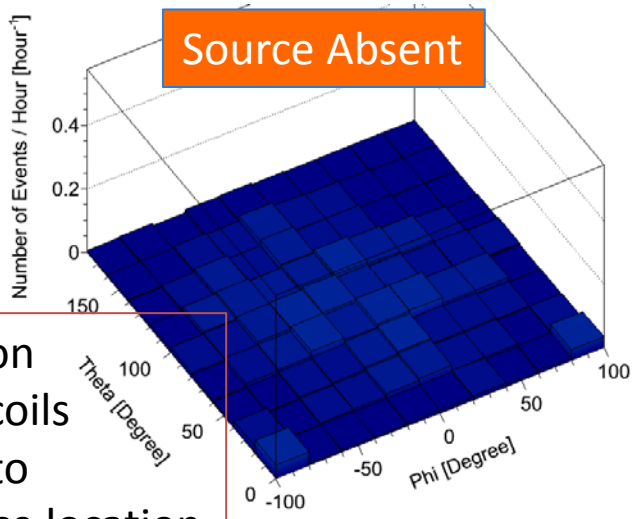
1. Isolate neutrons coming directly from beam lines (rather than re-scattered)
2. Measure neutron flux versus polar angle (beam line position) → validate/tune simulation

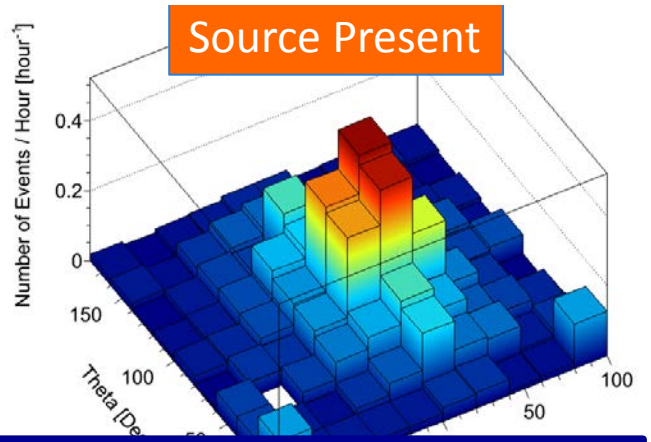
- nominal beams: RBB HER dominates → measure
- Run single beams
  - no RBB
  - measure Touchek
  - vacuum bump → measure Coulomb

micro-TPC Detector Prototyping



Mean direction of nuclear recoils corresponds to neutron source location





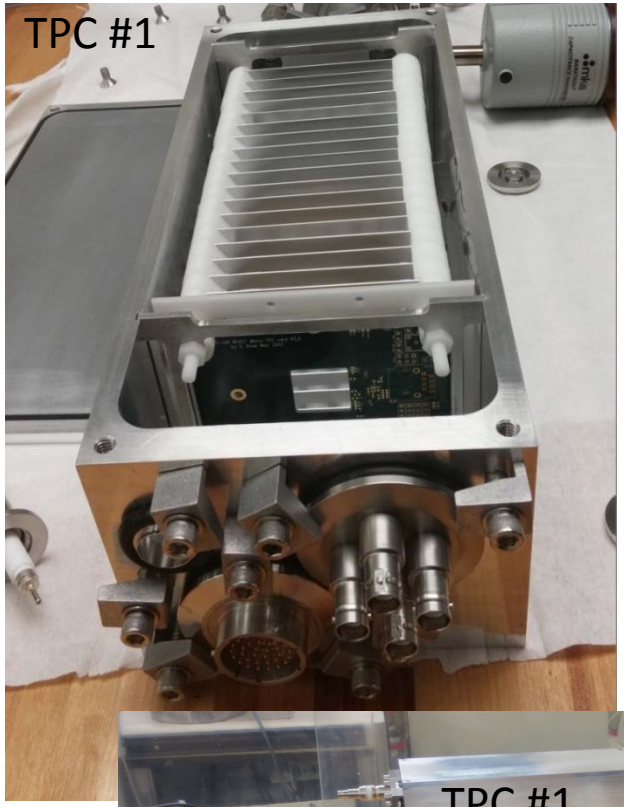
Clear excess & peaks in expected direction!

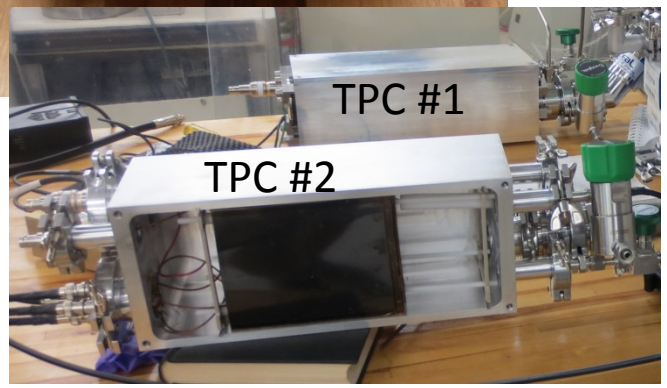
Tiny pre-prototype demonstrated detection principle.

micro-Time Projection Chambers

Hawaii

- Two constructed (for phase 1)
  - Excellent performance in lab tests
  - Working on improved x-ray rejection and better cable shielding to be ready for the tough commissioning environment
- Eight remaining (for phase 2)
  - Construct in 2015, to KEK March 2016 (needed approx. January 2017)

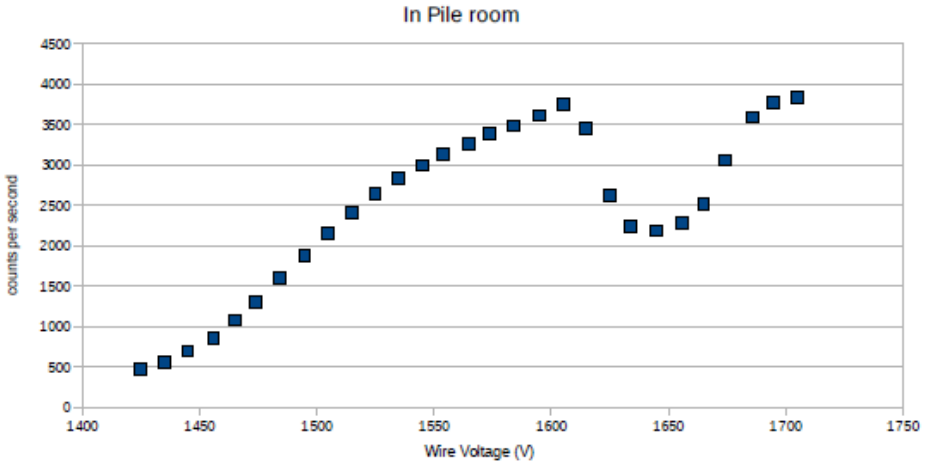


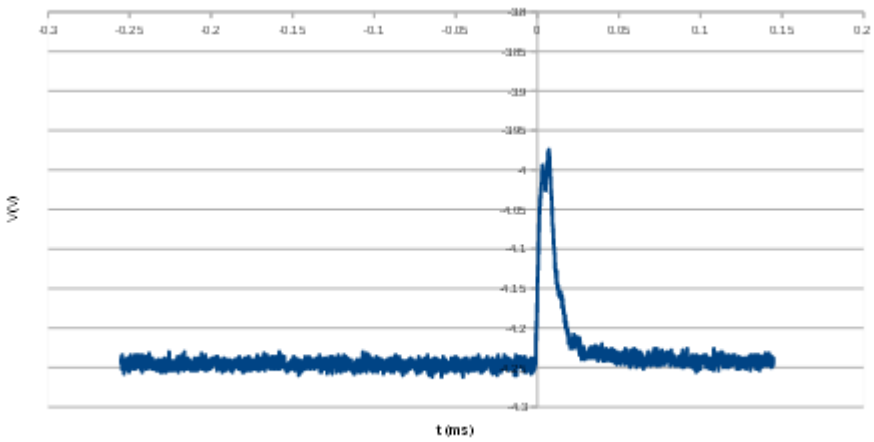


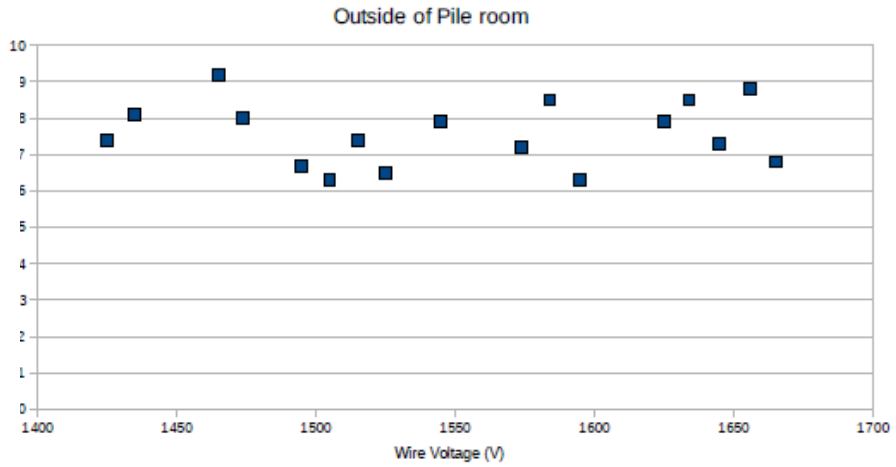
Phase 2

He-3 Tubes

Victoria





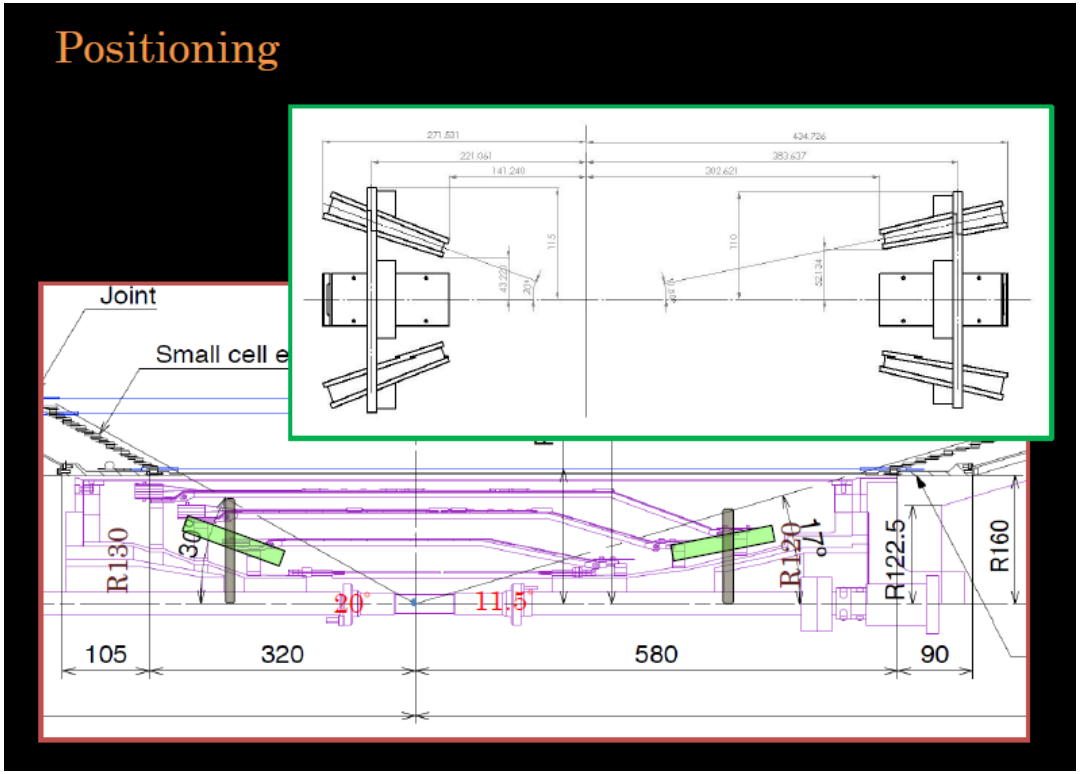


Clear response to neutron source observed. First tube being shipped to Hawaii *now*.

Phase 2

BGO luminosity monitors

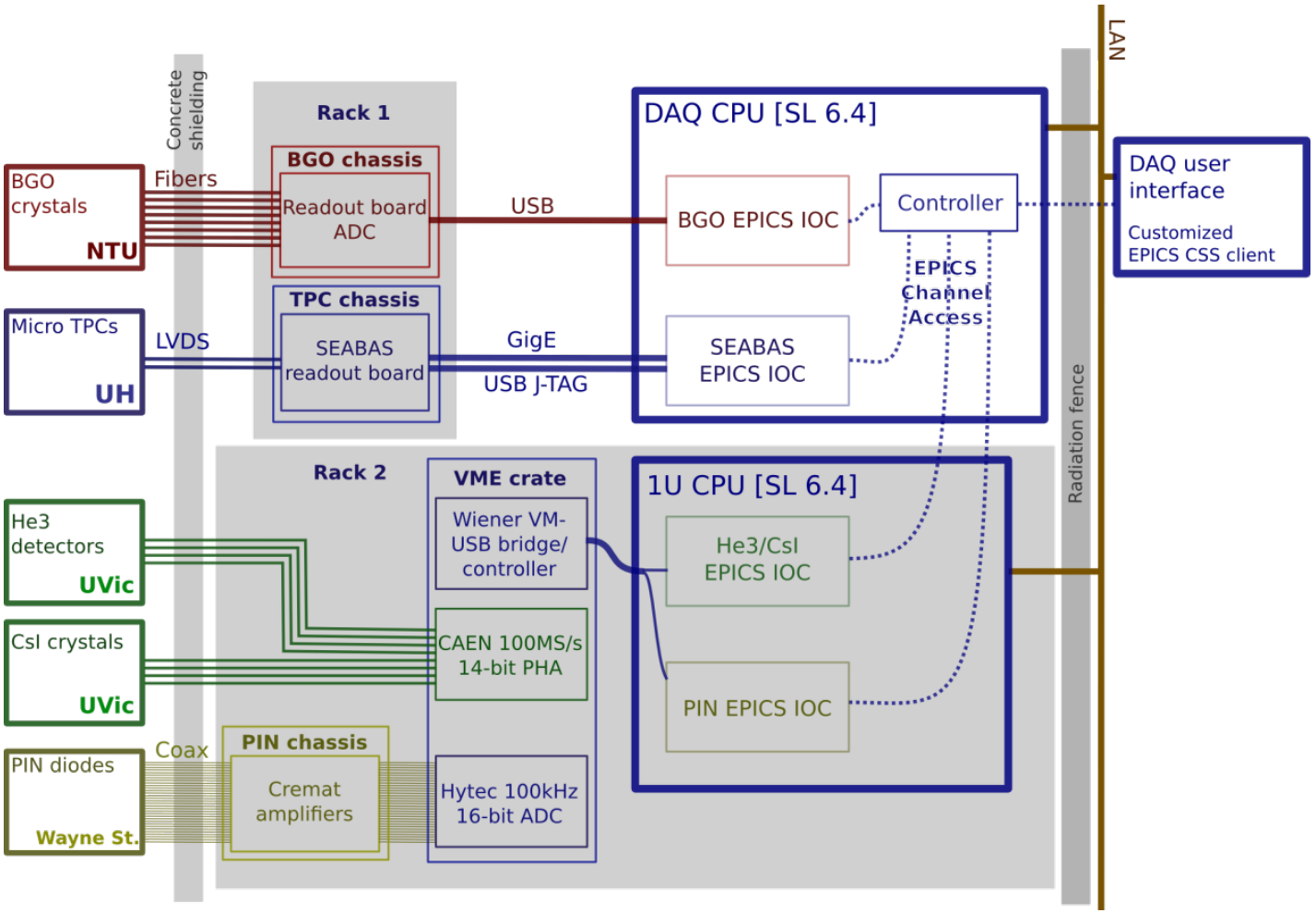
NTU



- Eight BGO crystals (from Belle Extreme forward Calorimater)
- To provide independent luminosity measurement via electron coincidence, radiative Bhabha events
- Also can provide analog (real-time) back-ground level to SuperKEKB
- Working prototype w/ electronics exists
- NTU student visiting Hawaii *tomorrow* for integration first two BGO crystals into MiniBEAST
- Need to finalize phase II mechanical mounts (SVD endrings)

BEAST DAQ

P. Lewis (Hawaii)



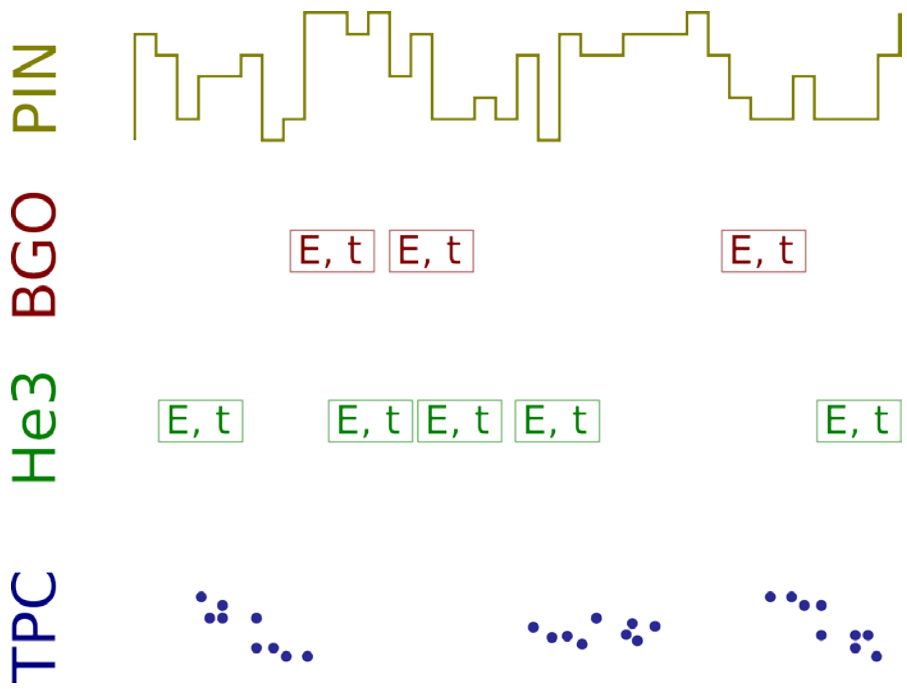
- Build pseudo-events *independently of Belle*
  - **to accelerator EPICs at 1Hz. Also to mask control?**
  - timestamp for off-line comparison with Belle/accelerator data

Raw and processed BEAST2 data

P. Lewis (Hawaii)

BEAST2 has **no trigger** and **no events**. DAQ is asynchronous and slow:

- **PIN**: raw ADC output **sampled** at 100kHz, averaged to ~1Hz
- **BGO**: fitted **event** peak amplitude with timestamps, ~0.1s-level timing
- **He3**: Pulses with time information, timing resolution unknown
- **TPC**: triggered **events** with pixel data (time, coordinates and charge), ms-level timing



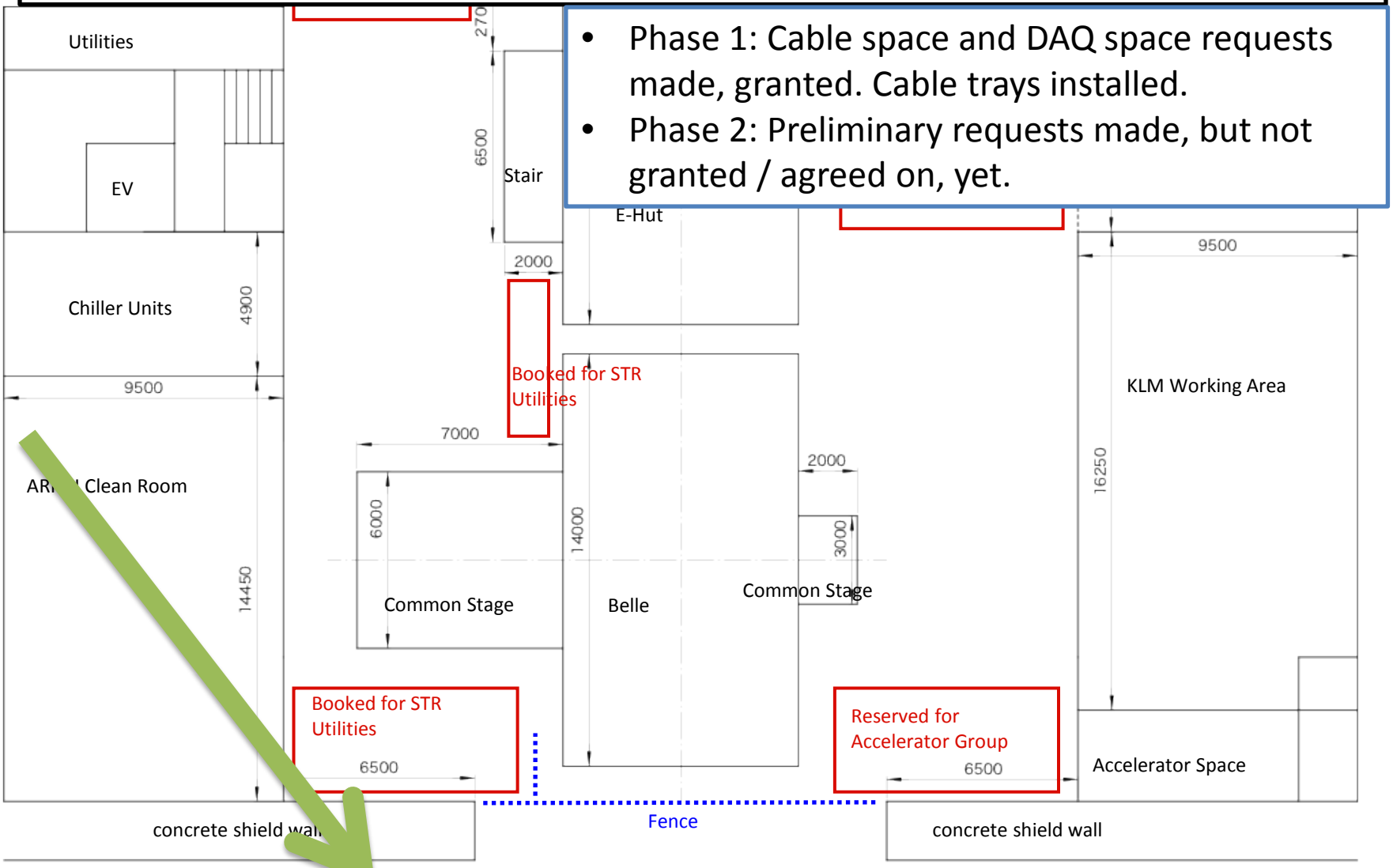
Consequently, BEAST2 data will consist of:

- Independent databases of raw detector data [ROOT files]
- Summaries and human-readable processed data in “pseudo-events” in a ROOT file
- Pseudo-events will summarize detector data for a fixed interval of time, i.e. 1 second

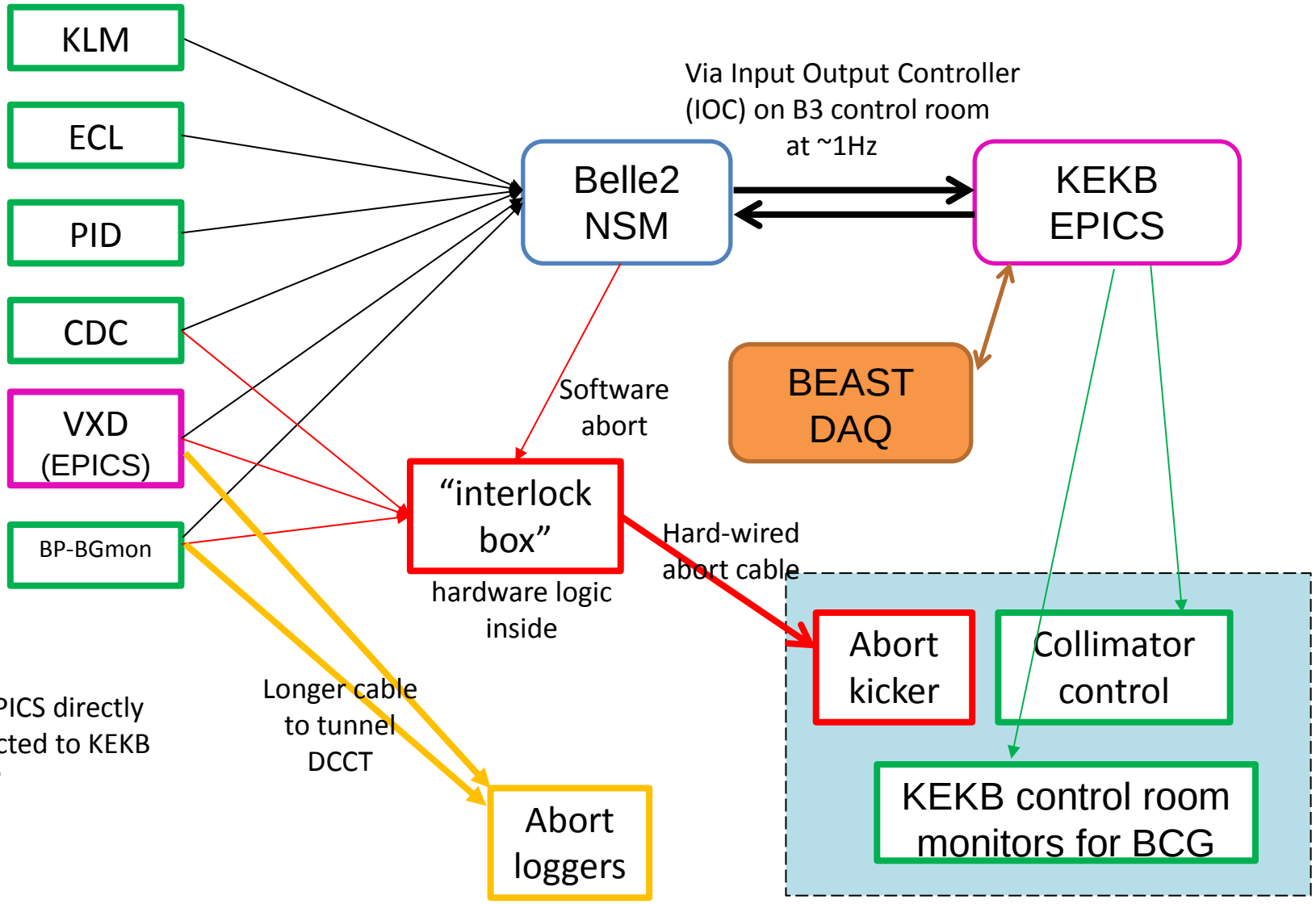
Note: **If we want MHz rate sensor data, e.g. to study injection backgrounds, it will need to go via a different DAQ path.** E.g. beam abort diamond sensors, ATLAS pixel modules.

BEAST DAQ Location – 20-30 m from IP

- Phase 1: Cable space and DAQ space requests made, granted. Cable trays installed.
- Phase 2: Preliminary requests made, but not granted / agreed on, yet.



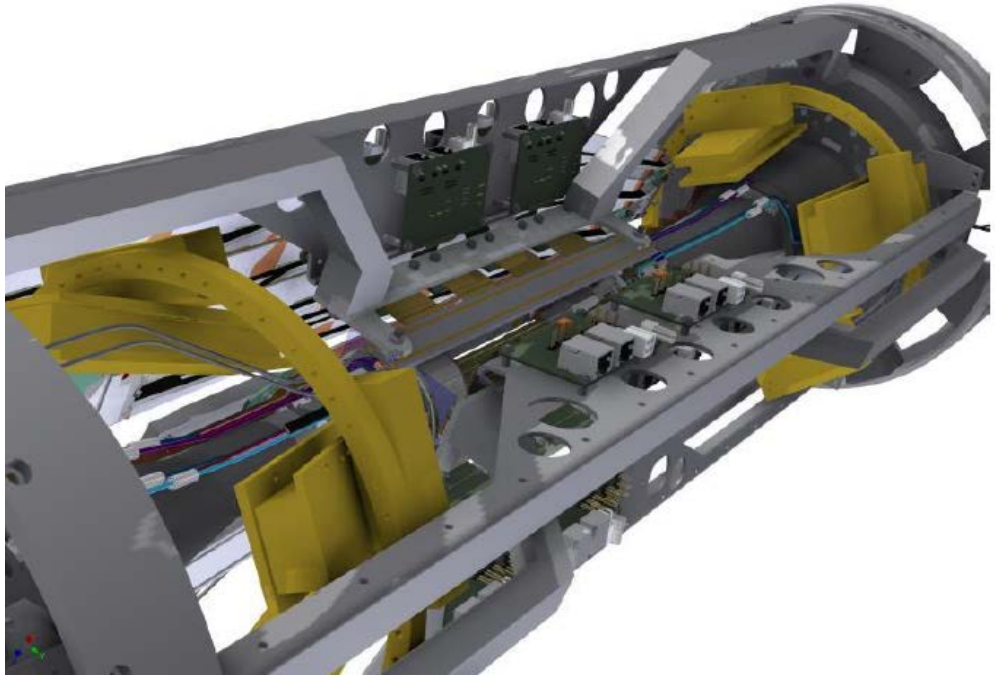
Monitor DAQ diagram (outdated?)



Topics I Skipped

The following topics are critical, but I did not really discuss them today. I think/assume they are covered in the talks by Nakayama, Tanaka, and Marinas:

- BEAST II VXD
  - Synchrotron radiation detection
  - Beam abort system
- Mask / Collimator control



Conclusion & Outlook

- BEAST detectors to provide a rich set of measurements
- Next Major Milestones
  - MiniBEAST at U. Hawaii: Jan 2015
  - Install BEAST at IP: approx. Sep 2015
  - Operate with first beams: mid Jan 2016
- Next Challenges
  - Include PLUME? Urgent to decide. Has impact on rack space, cable space, VXD mechanics. Which DAQ path?
  - Finalize VXD space mechanics (material?)
  - Deliver subsystems to Hawaii on time
  - Finalize cable routing through dock space
  - Develop phase 2 installation plan w/ schedule
  - Develop measurement plan (incl. with accelerator group)

Mini-workshop at KEK Feb 4th

BACKUP SLIDES