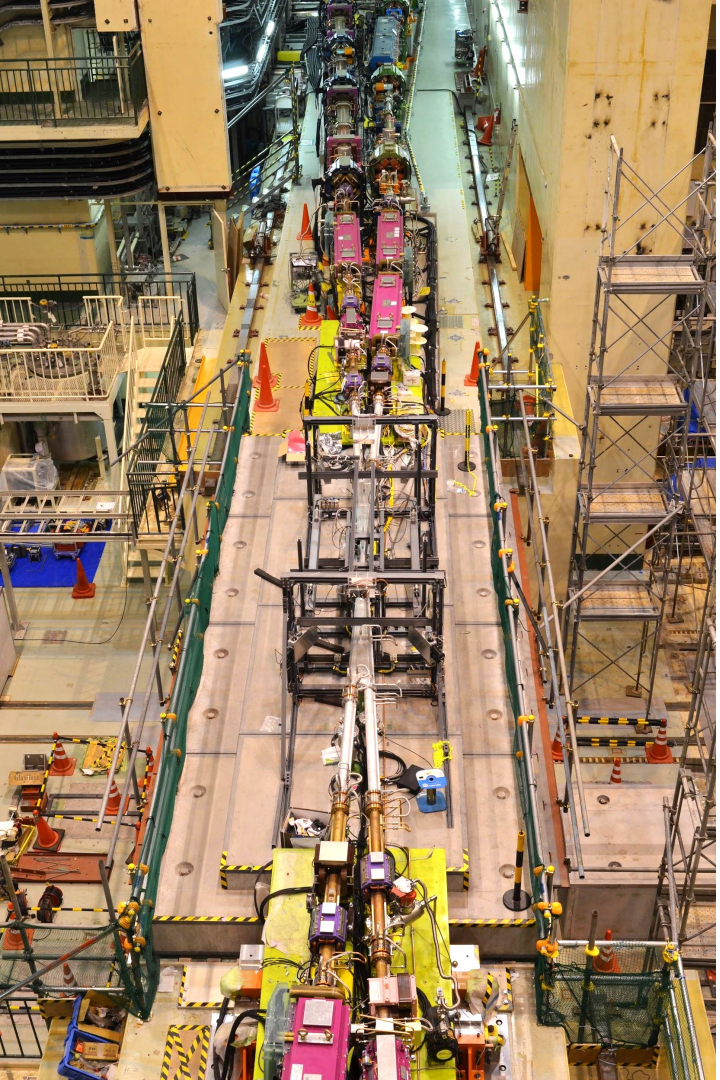


Status of SuperKEKB commissioning and Belle II detector construction

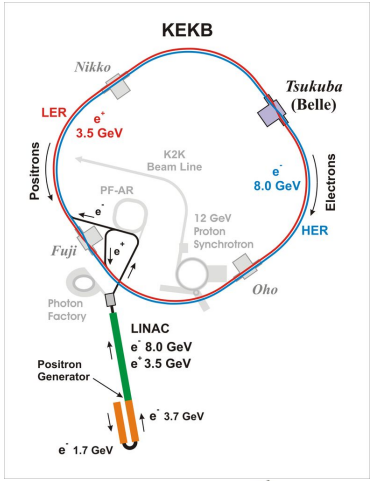
Peter M. Lewis on behalf of the Belle II Collaboration
University of Hawai`i at Manoa

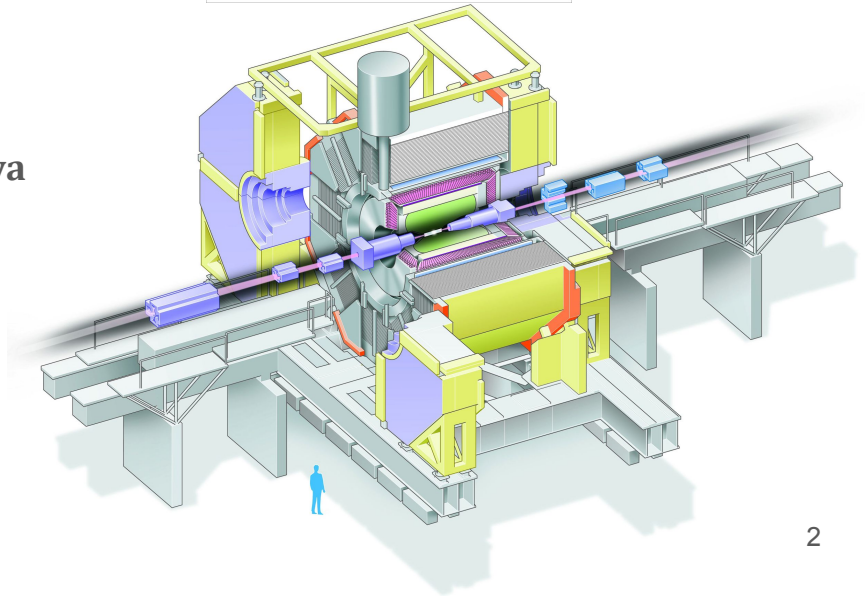
5 August 2016
ICHEP Detector R&D and Performance session

Belle/KEKB

The *B*-factory at KEK (Tsukuba, Ibaraki, Japan)

- Targeted ***CP*-violation** using a huge number of *B* meson pairs
- Operated from **1999 to 2010**
- The KEKB accelerator delivered **over 1ab^{-1}** to the Belle detector, a huge success (mostly at Y(4S) resonance)
- Along with BaBar, **confirmed Kobayashi and Maskawa theories** about *CP* asymmetries in *B* decays, directly leading to 2008 Nobel Prize
- Collected additional unique datasets at Y(1S), Y(2S), Y(5S) resonances, leading to **unexpectedly rich additional results** (some shown this week)

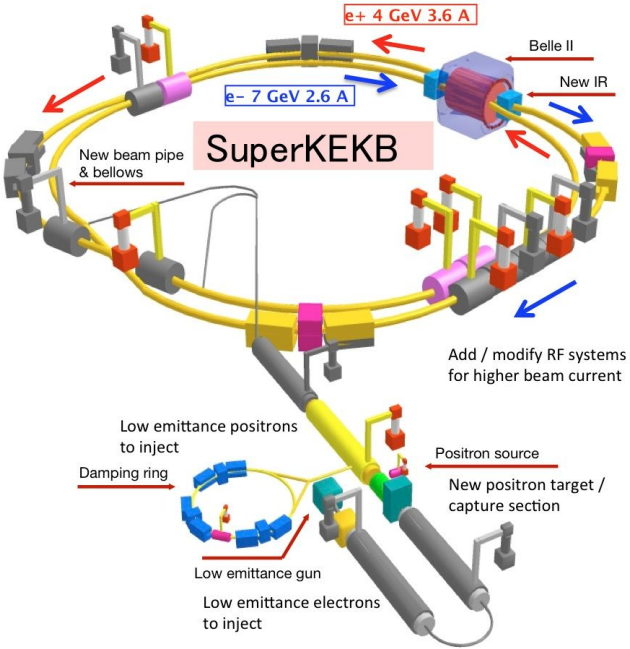


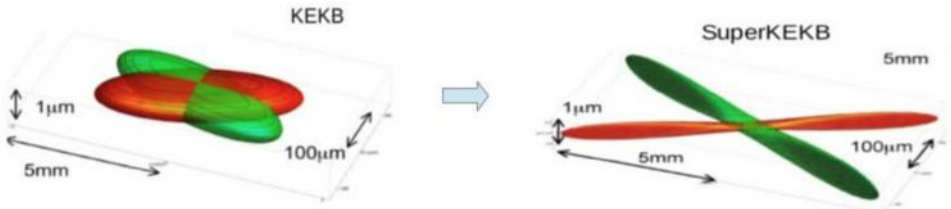


SuperKEKB

The super *B*-factory at KEK (2018 start)

- A planned 40-fold increase in luminosity over KEKB (target: 8×10^{35} $cm^{-2}s^{-1}$ instantaneous, **$50ab^{-1}$** integrated), due to major upgrades:
  - **"Nano-beam" scheme** (below)
  - **Doubled beam currents**
  - (large number of upgrades to RF, magnet, vacuum, etc. systems)
- **First turns Feb. 10. 2016! Exciting times!**





~x2 in beam current

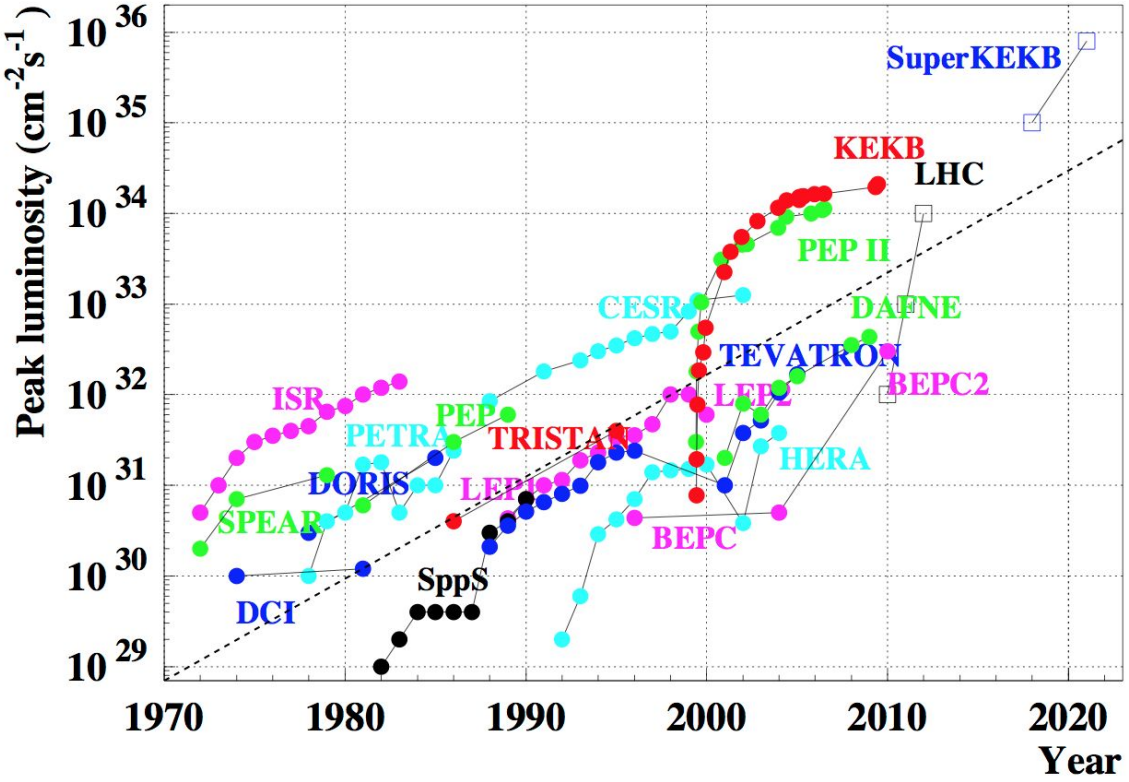
$$L = \frac{\gamma_\pm}{2er_e}\left(1+\frac{\sigma_y^*}{\sigma_x^*}\right)\left(\frac{I_{\pm}\xi_{\pm y}}{\beta_y^*}\right)\left(\frac{R_L}{R_y}\right) = 8\times10^{35}\,cm^2s^{-1}$$

Vertical beta function reduction (5.9→0.3 mm) gives x20

Beam Energies 8.0/3.5→7.0/4.0

See Y. Onishi, ICHEP highlights, 8/08 12:10

SuperKEKB is the next luminosity frontier

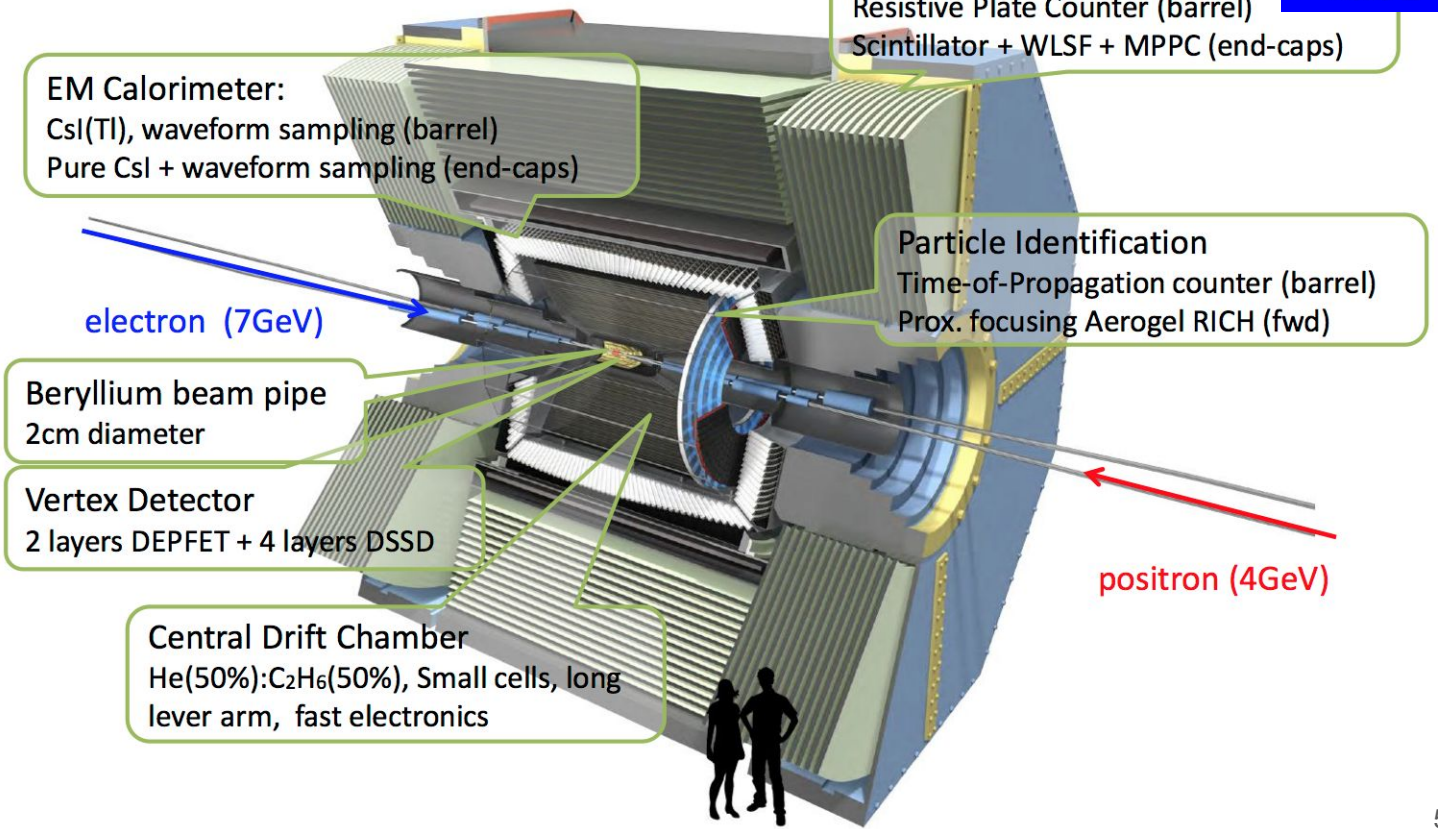


Belle II major upgrades

Belle II at ICHEP:

Detectors:
DEPFET: L. Andricek, Poster 8th 18:30
SVD: A. Paladino, Detector 4th 17:00
EMC: Y. Jin, Poster 6th 18:00
iTOP: A. Schwartz, Detector 6th 14:30
iTOP: K. Inami, Poster 6th 18:00
CPU: M. Schram, Computing 4th 12:50

Physics:
Prospects: B. Fulsom, Flavor 5th 14:30
Dark: G. Inguglia, BSM 4th 17:40
Bottomonia: K. Miyabayashi, Poster 6th 18:00



Commissioning of SuperKEKB

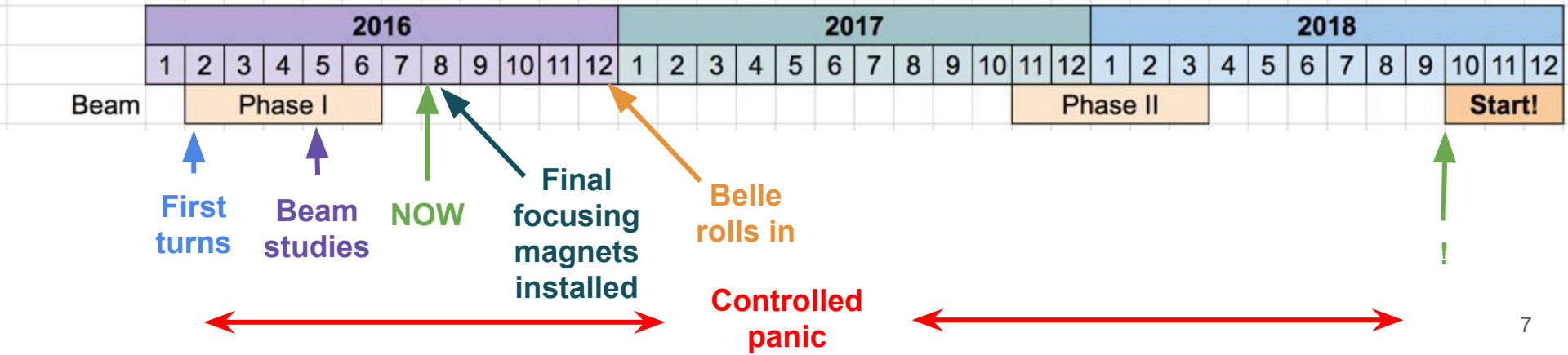
Schedule: beam commissioning phases

Phase I (completed)

- Circulate both beams; no collisions
- Tune accelerator optics, etc.
- Vacuum scrub
- **Beam studies**

Phase II (2017-18)

- First collisions
- Develop beam abort
- Tune accelerator optics, etc. (nano-beam)
- Detailed beam studies



Commissioning requirements

SuperKEKB

- Real-time **monitoring** of beam conditions
- **Quantify** effects of tuning (for example, collimator adjustments) on beam loss
- Isolate the **type and source** of beam loss
- Inform beam loss **simulations** to optimize performance

Belle II

- Guarantee a **safe**-enough radiation environment for Belle II
- **Mitigate** beam backgrounds (with physical shielding, electronic gating, magnet tuning, etc.) around interaction point
- Inform beam background **simulations** so they are properly accounted for in physics analysis

→ **We need a "commissioning detector": a stand-in for Belle II to provide diverse real-time measurements of beam conditions...**

Enter the BEAST

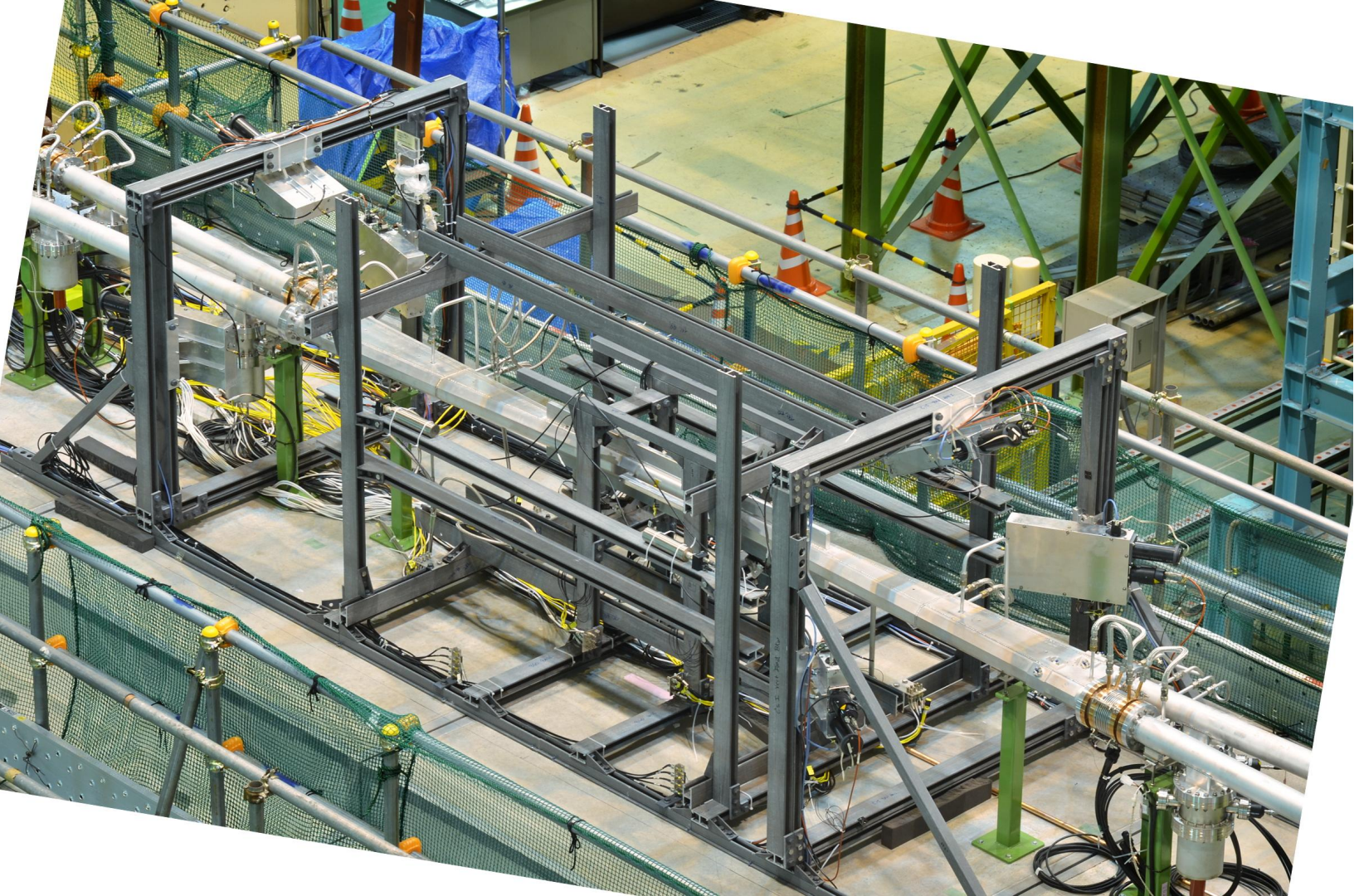
Primary detectors in BEAST II* for phase I:

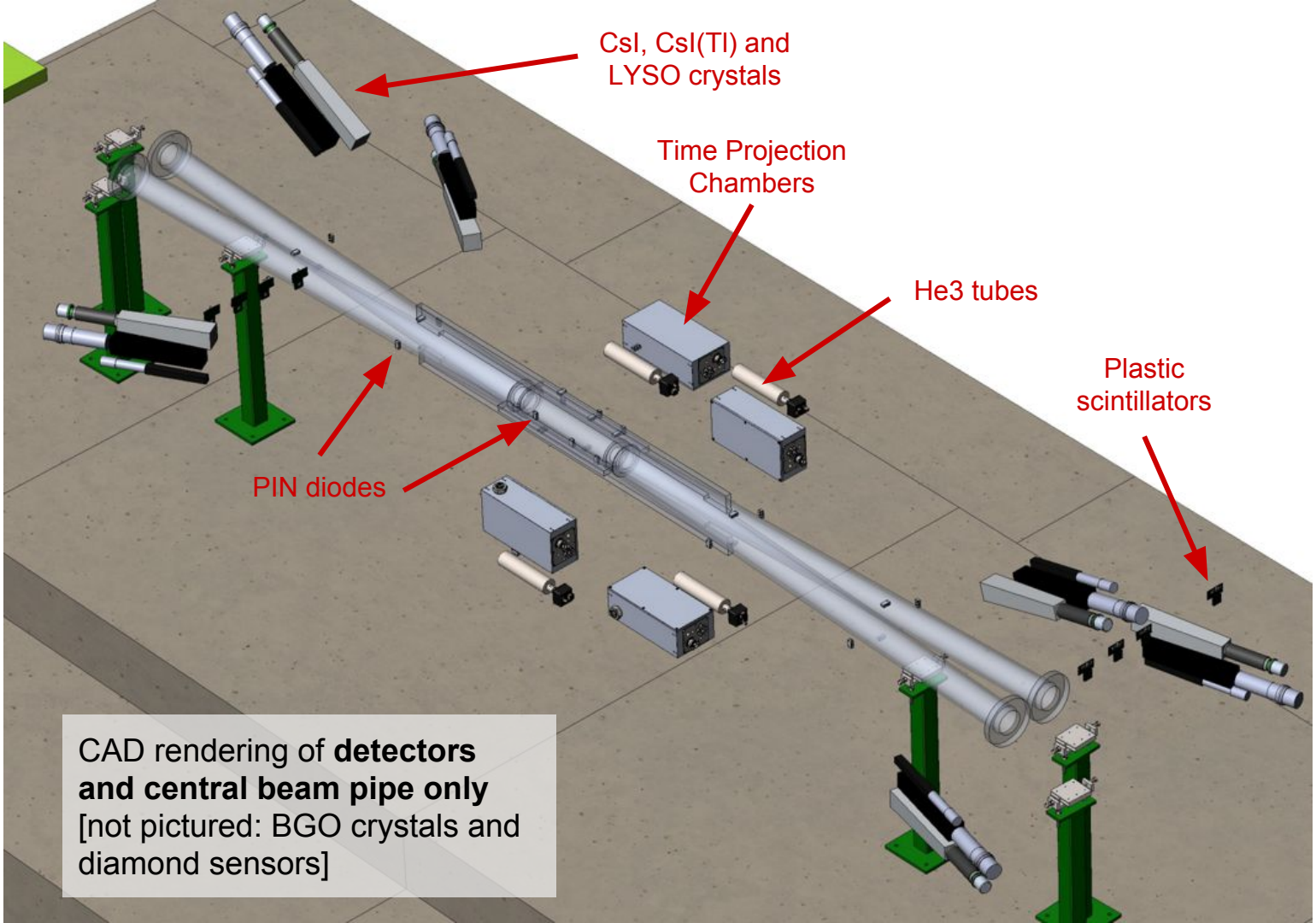
System	Institution	#	Unique measurement
PIN diodes	Wayne St.	64	Neutral vs. charged dose rate
Time Projection Chambers	U. Hawaii	4	Fast neutron flux and tracking
Diamonds	INFN Trieste	4	Beam abort
He3 tubes	U. Victoria	4	Thermal neutron rate
CsI(Tl) crystals	U. Victoria	6	EM energy spectrum, injection backgrounds
CsI+LYSO crystals	INFN Frascati	6+6	
BGO crystals	National Taiwan U.	8	Luminosity and EM rate
CLAWS plastic scintillators	MPI Munich	8	Fast injection backgrounds

*Belle had its own BEAST

Belle and the BEAST

Belle II will eventually roll in on a pair of railroad tracks





CAD rendering of **detectors and central beam pipe only** [not pictured: BGO crystals and diamond sensors]

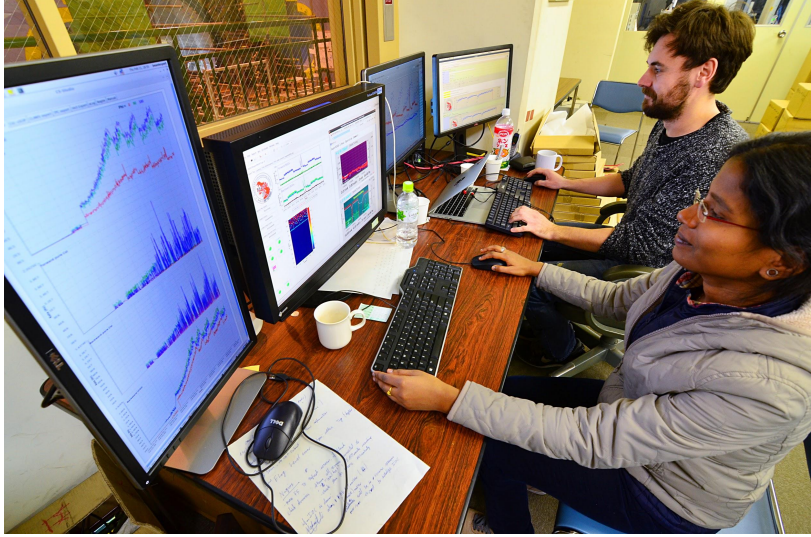
BEAST operation: phase I

Real-time monitoring (via EPICS)

- BEAST systems and SuperKEKB conditions monitored by shifters (**top**)
- BEAST live monitors shared with SuperKEKB control room (**bottom**)
- BEAST liaison in SuperKEKB control room during key beam study days

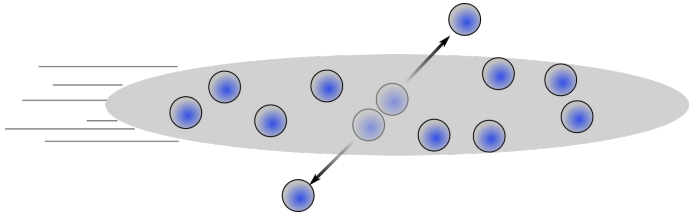
Offline

- Collected ~20 TB of data throughout phase I
- Simulation of loss distribution and detectors ongoing
- Analysis ongoing; main goal is to **inform simulations with data**



Beam backgrounds and preliminary results from BEAST

Preliminary results



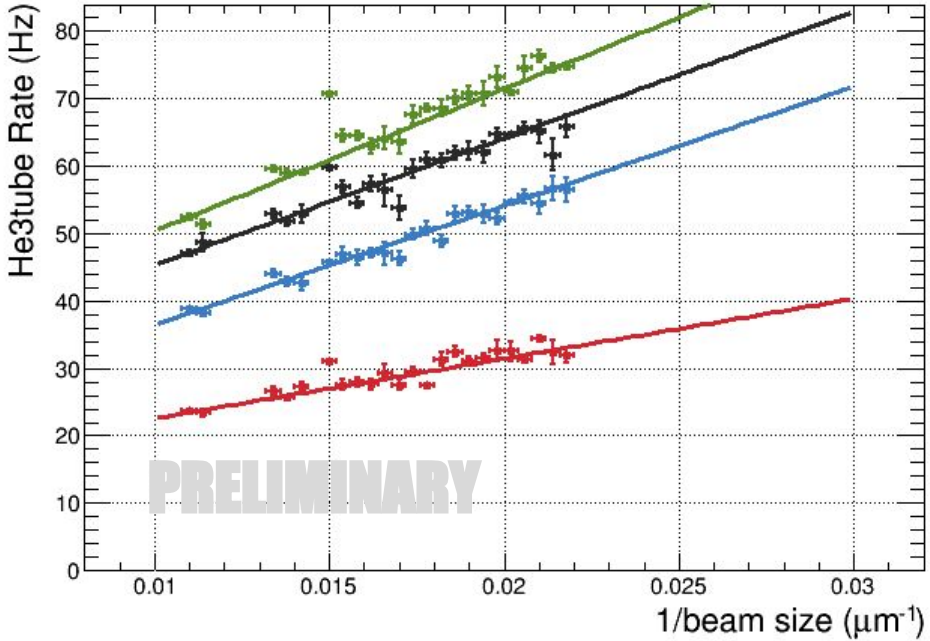
Touschek scattering

- Coulomb scattering between two particles in the same bunch
- Inverse lifetime is inversely proportional to the bunch size:

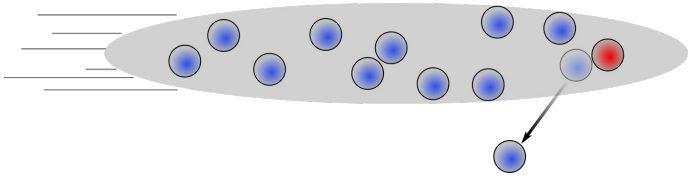
$$\frac{1}{\tau_T} \propto \frac{1}{\sigma_x \sigma_y \sigma_z}$$

- To measure, **hold beam currents constant and vary beam size [right]**

He3 tube thermal neutron rate vs. inverse beam size (Touschek is linear component)



Preliminary results

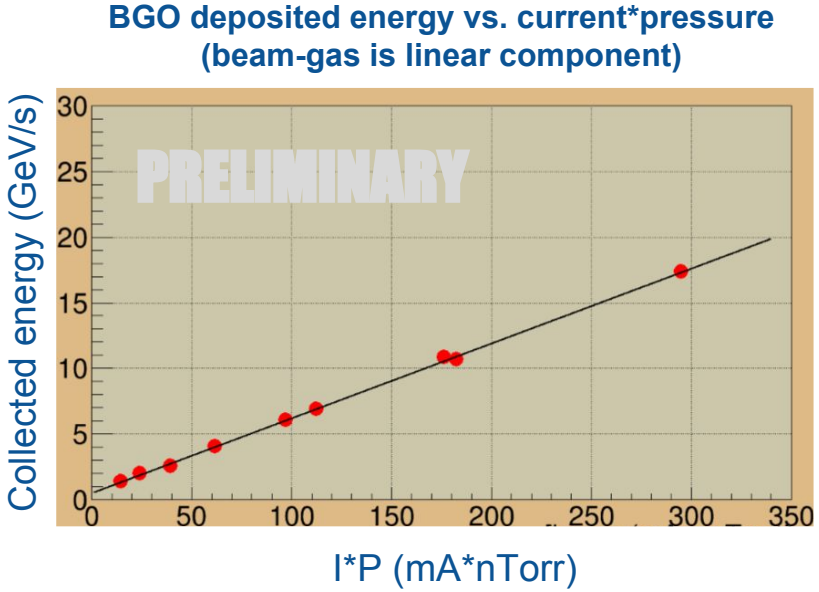


Beam-gas

- Coulomb scattering off residual gas in beam pipe
- Phase I consisted of mostly **beam scrubbing**
- Scattering rate is proportional to current times pressure:

$$R_{BG} \propto I \cdot P$$

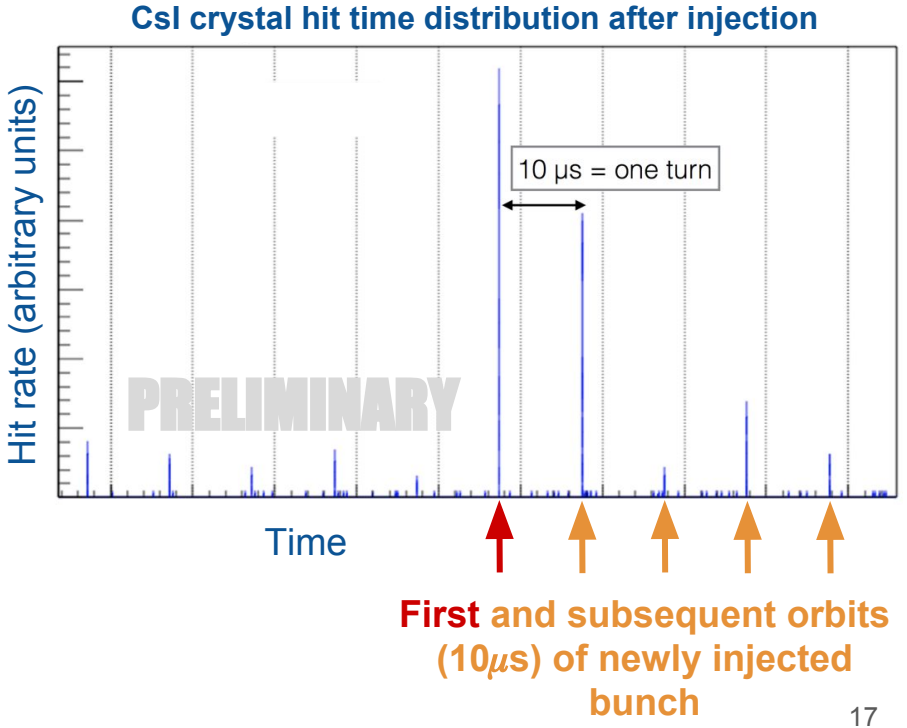
- **To measure, heat vacuum pump to inject gas [right]**



Preliminary results

Injection

- Charge is regularly injected into stored beam to counteract beam loss
- For <1ms after injection, **topped-off bunches are messy**; off-orbit particles can slam into pipe walls and spawn EM showers
- CLAWS (plastic scintillators) and CsI/LYSO crystals have time resolution to see **bunch-by-bunch structure**
- **To measure, trigger on injection timing signal [right]**

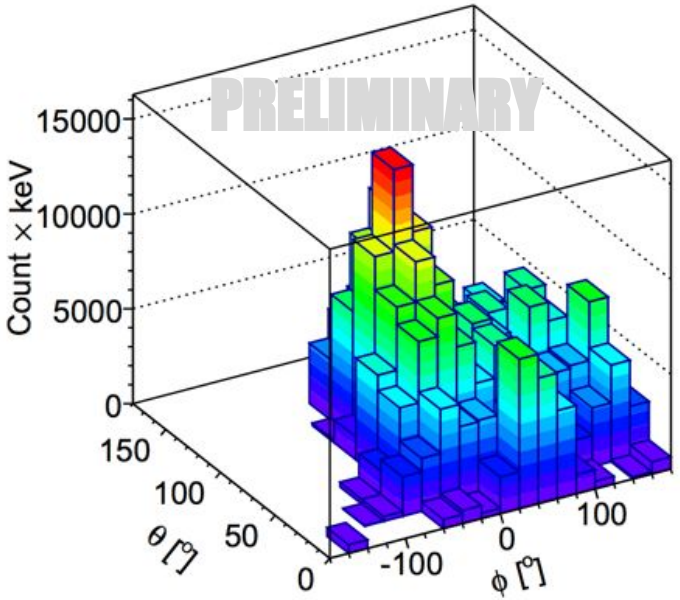


Preliminary results

Other

- Detailed spatial distribution from PIN diodes
- Directional fast neutrons from TPCs pointing to loss positions (**right**)
- Beam abort tuning for inner detectors in later phases using the diamond sensors
- Confirmation of integrated doses using dosimeters
- Effects of collimator positions

Fast neutron spatial distribution



Status and milestones

SuperKEKB status and milestones

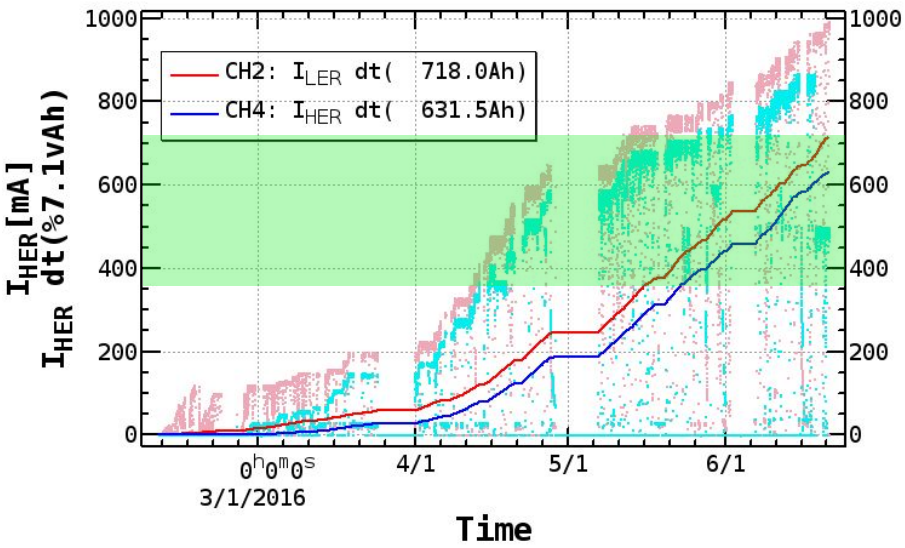
Phase I success

- Smooth startup. Compared to KEKB:
  - 2-3 times the currents after 3 months
  - Fewer machine troubles/downtime
- New hardware (RF, magnet and vacuum) systems are all working successfully
- Target 360-720mA*hours beam scrubbing **met**

Phase II

- Prepare for nano-beam: install focusing magnets, tuning and feedback systems, new damping ring
- Low beta tuning with upgraded BEAST

SuperKEKB integrated and instantaneous currents in Phase I, with target

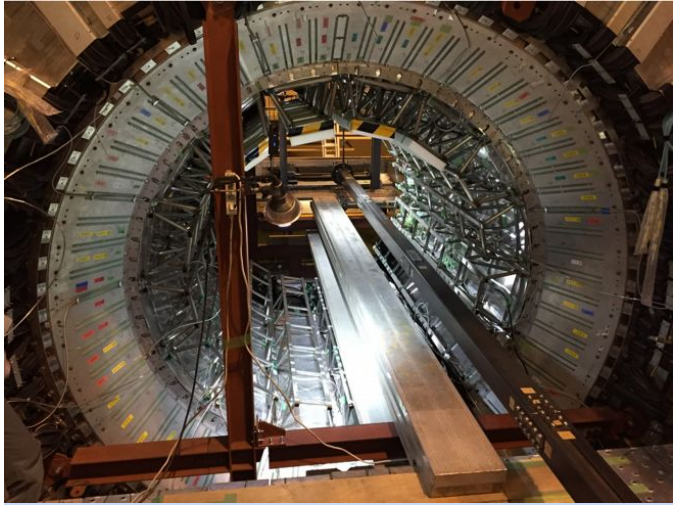


See Y. Onishi, ICHEP highlights, 8/08 12:10

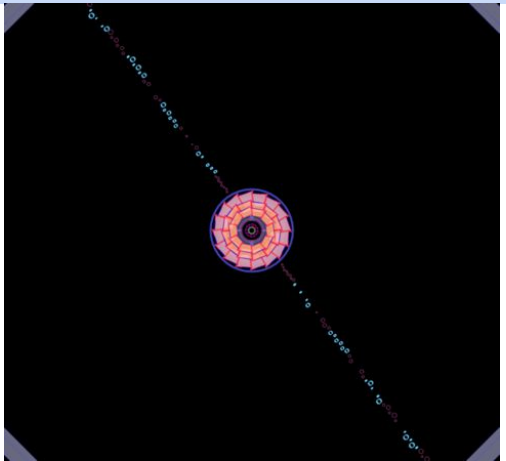
Belle II status and milestones

Detector upgrades, very briefly:

- Time of propagation (TOP) Cherenkov detector modules all **installed, testing** ongoing (top)
- Drift chamber (CDC) strung and **observing cosmics** (bottom)
- VXD (inner pixel/strip silicon vertexing) completed **successful beam test** at DESY with full Belle II DAQ chain
- ECL (crystal EM calorimeter) electronics **installed in summer**, test with new firmware and software ongoing
- Aerogel Ring-Imaging Cherenkov (ARICH) endplate detector tiles cut, **installation almost complete**
- K_L and muon system (KLM): installation of DAQ infrastructure in progress, **first cosmics seen** June 2016



TOP modules installed in Belle barrel (top)
CDC cosmic data visualized (bottom)



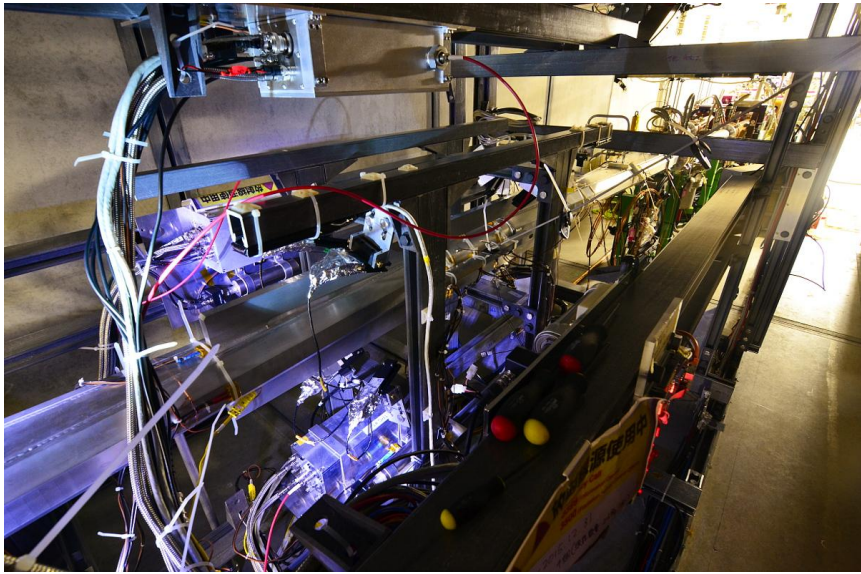
BEAST II status and milestones

Phase I success

- **Measurements** of all primary beam backgrounds
- **Live feedback** to SuperKEKB informed injector tuning, verification of vacuum scrubbing progress, etc.
- Detailed **tuning and verification of simulation** essential for Belle II operation; ongoing
- Analysis ongoing; look for a **paper in late 2016**

Phase II

- **4 new detector systems** to be embedded in inner region of Belle (see additional slides)
- Physical integration with Belle begins **October 2016**



The BEAST cave with BEAST, Feb. 2016

BEAST II status and milestones

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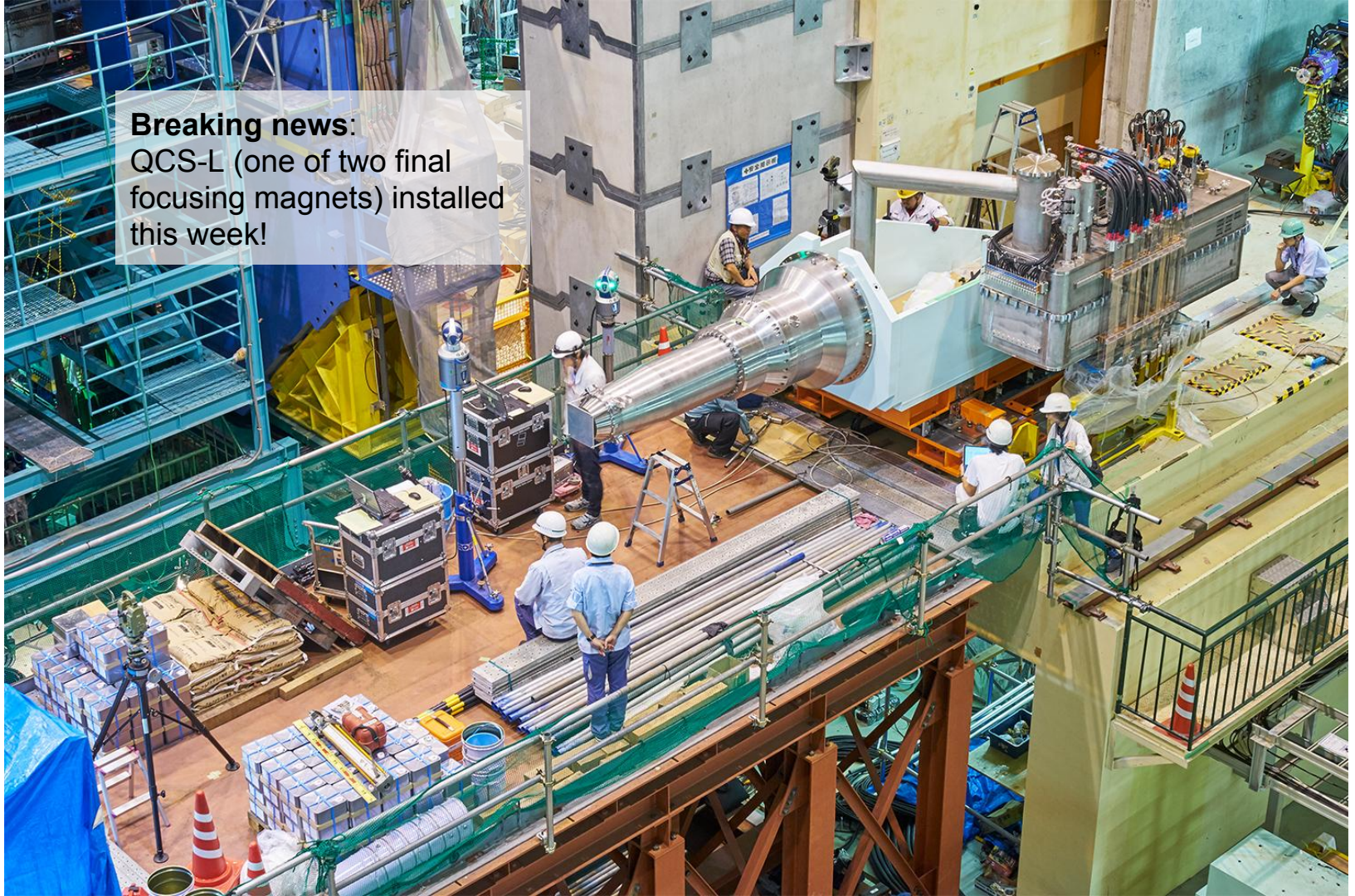
The BEAST cave without BEAST, July 2016


Breaking news:
QCS-L (one of two final focusing magnets) installed this week!


Belle II


Super
KEKB


SuperKEKB Commissioning Detector
BEAST II
獣
Belle II Collaboration

Thank you!

Additional slides

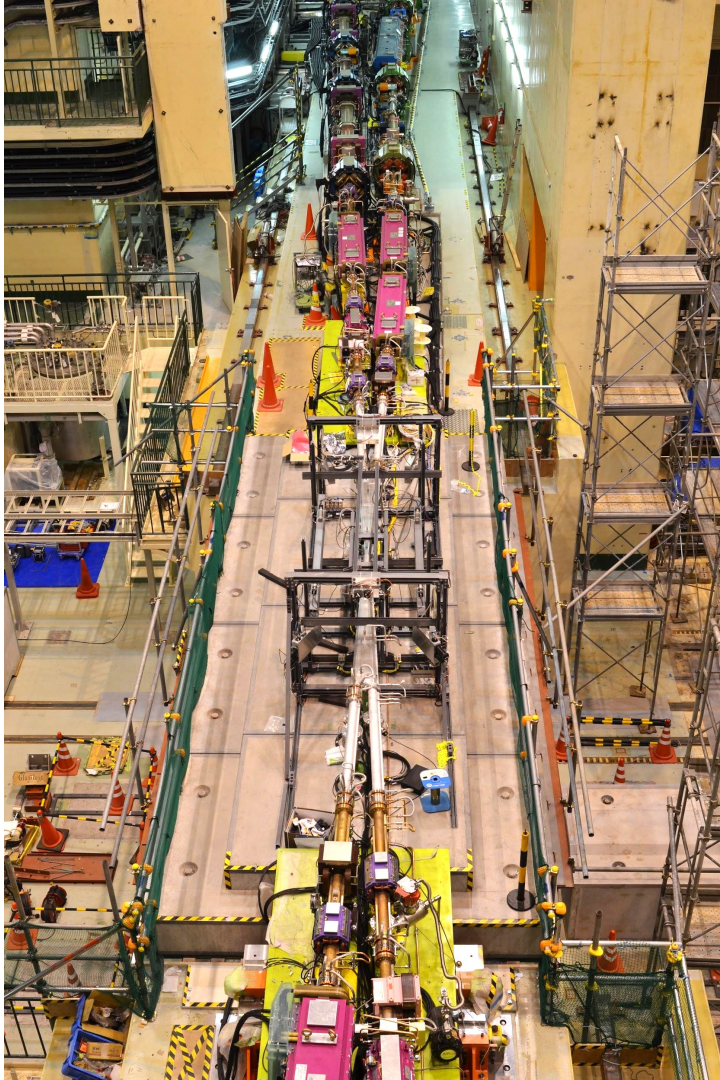
BEAST II: from the top

Location

- Crossing point of **electron beam** and **positron beam** (**interaction point, or “IP”**)
- Belle II will roll into the same location in phases II+III

Structure

- Detectors mounted on non-magnetic fiberglass structure
- Aluminum central beam pipe



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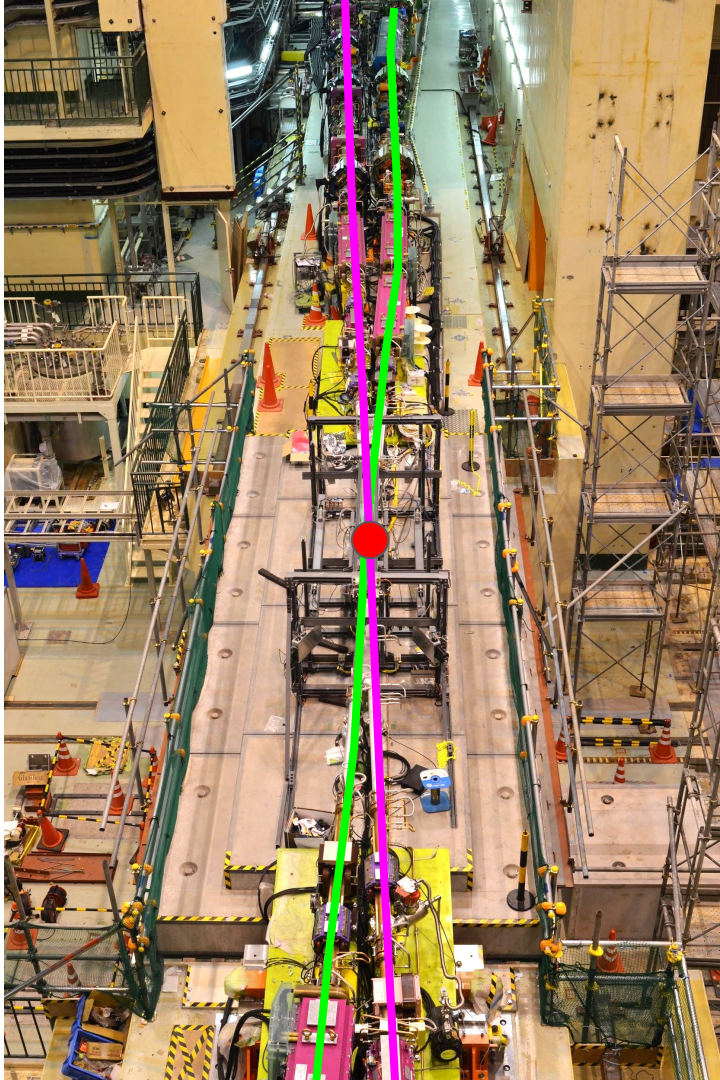


BEAST II: the commissioning detector

Primary detectors in BEAST II for phase **II**:

System	Institution	#	Unique measurement
PIN diodes	KEK	~~64~~80	Neutral vs. charged dose rate
"Micro" Time Projection Chambers	U. Hawaii	~~4~~8	Fast neutron flux and tracking
Diamonds	INFN Trieste	~~4~~8	Ionizing radiation rate
He3 tubes	U. Victoria	4	Thermal neutron rate
CLAWS plastic scintillators	MPI Munich	~~8~~2 ladders	Fast injection backgrounds

...continued

BEAST II: the commissioning detector

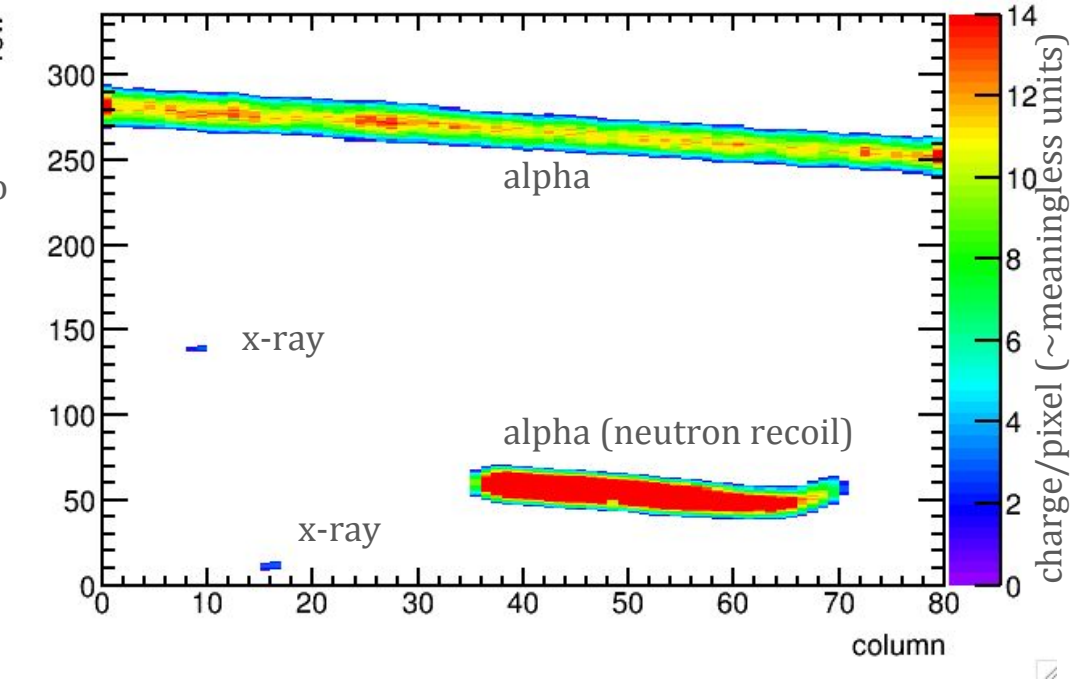
Primary detectors in BEAST II for phase **II**:

System	Institution	#	Unique measurement
Belle II PXD	U. Bonn	2 ladders	Radiation tolerance for phase III
Belle II SVD	KEK	4 ladders	Radiation tolerance for phase III
FANGS	U. Bonn	15	Silicon pixel sensors (synchrotron x-ray spectrum)
PLUME	Strasbourg	2 ladders	Silicon pixel sensors (collimator adjustment)

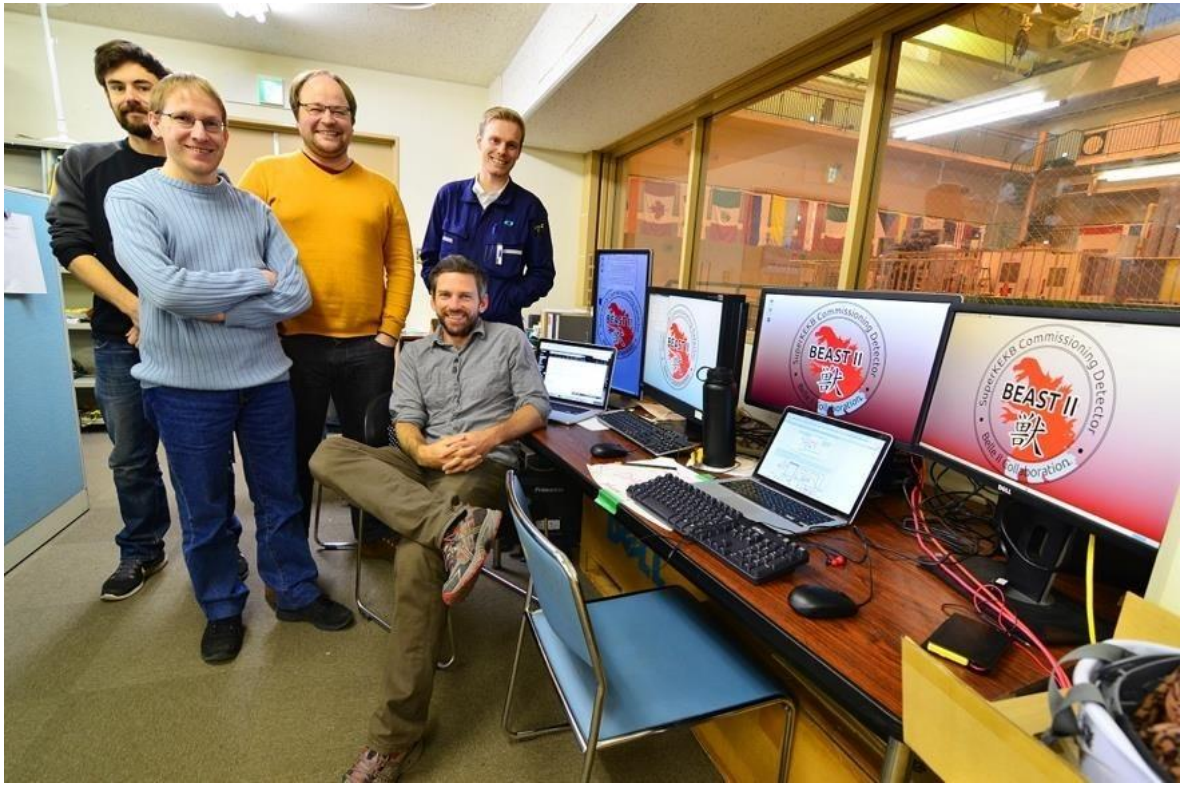
TPCs

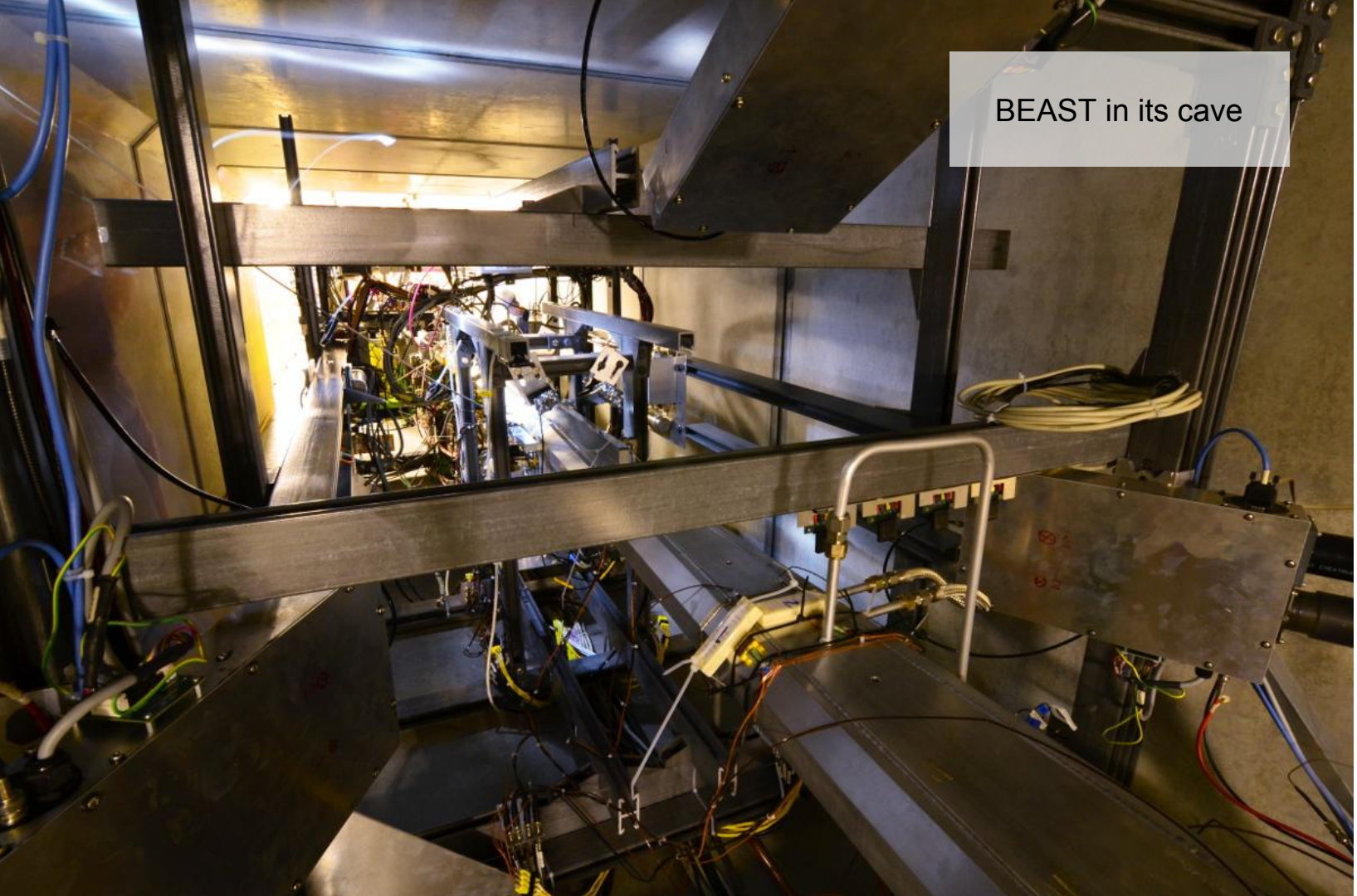
Data

- Pixel chip data is like taking multiple pictures of charge cloud as it drifts, with each “exposure” corresponding to a new slice of the cloud
- 3D reconstruction of ionization cloud from an alpha particle (color encodes total ionization collected per pixel)
- Right: 3D plot of three different characteristic event types in TPC
  - Alpha
  - x-ray
  - Neutron recoil



BEAST shifting room





BEAST in its cave

BEAST's guts and decommissioning team, July 2016.