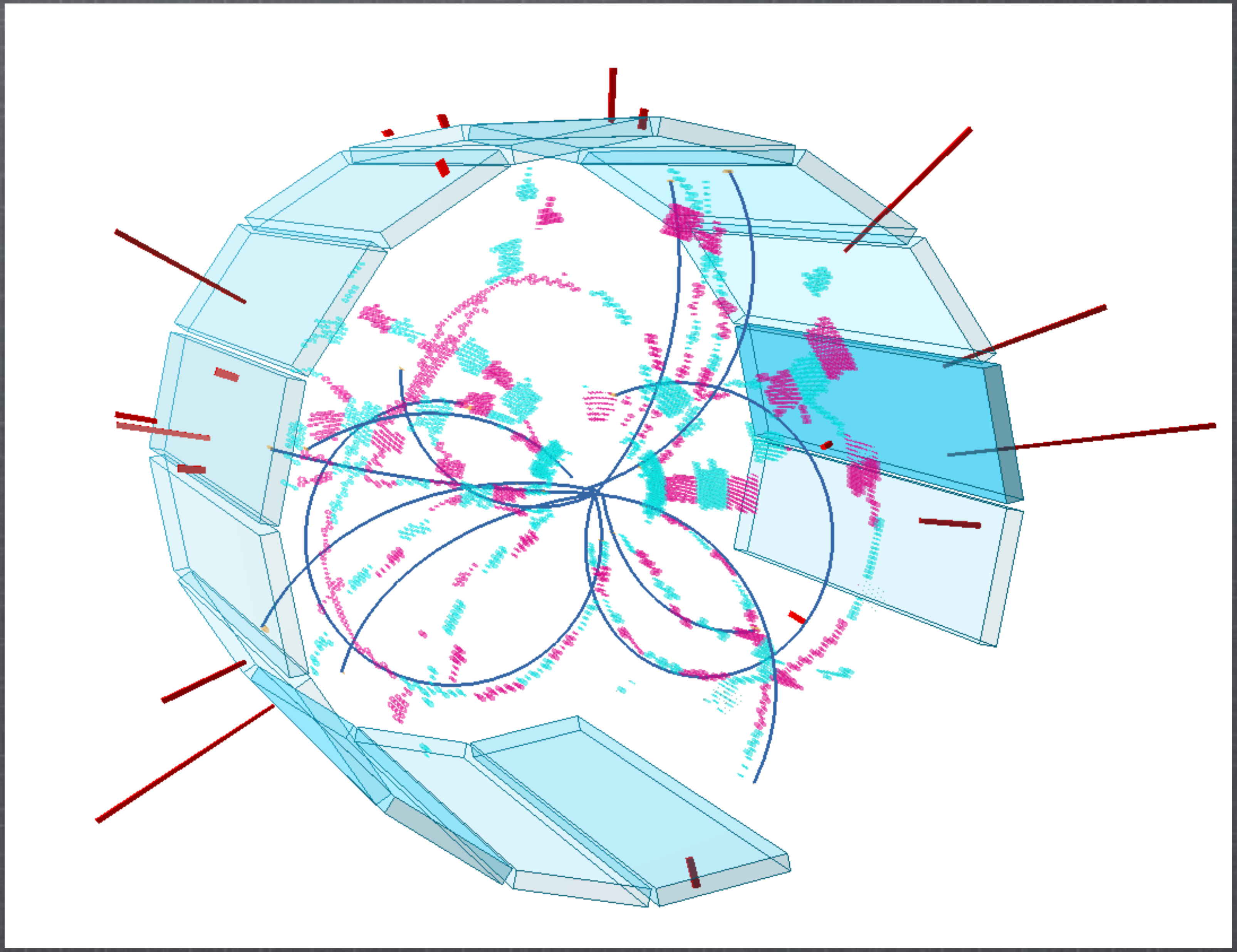
THE BELLE *II* EXPERIMENT AT SUPERKEKB: STATUS AND PROSPECTS

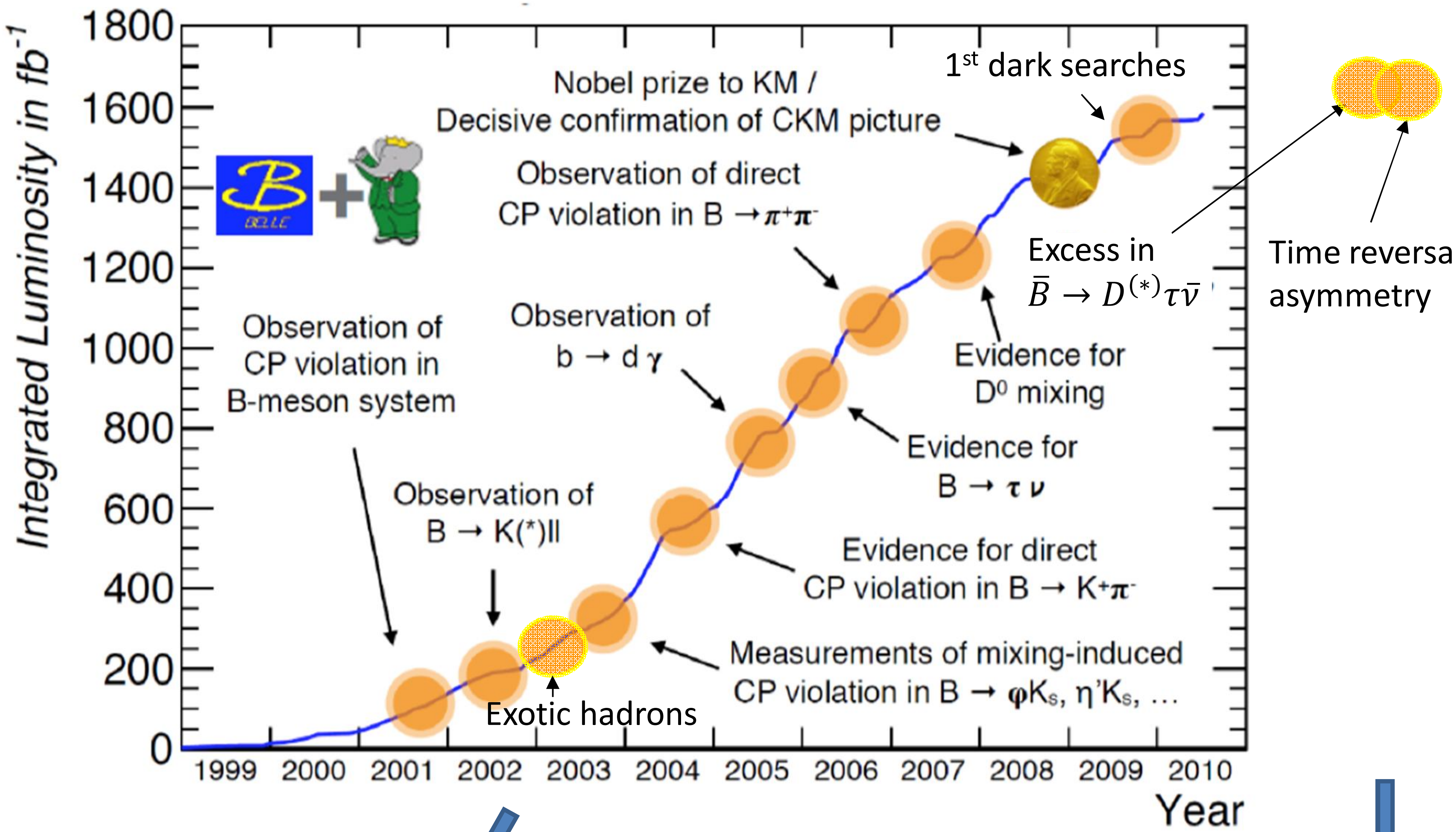
Eugenio Paoloni INFN & Università di Pisa
for the Belle *II collaboration*



Moscow, 22 X 2018

B-Factories Legacy

- 1241 papers (14 Oct. 2018) and counting
  - 670 from BaBar @ PEP-II + 571 from Belle @ KEKB



>100 unique CPV results

~350 papers published after shutdown, 21 in 2018

Keys Of Two Successful Experiments

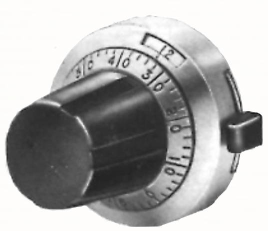
- Large sample (~ 1 billion) of *B* mesons, tau leptons, charmed particles,
  - High luminosity (KEKB exceeded 2 x 10^{34} Hz/cm^2).
- Clean event structure. (e.g. the Y(4S) event is made by just two entangled B mesons decaying in the end on average in:
  11 charged tracks, 5 neutral pions and 1 Klong).
- Asymmetric beam energy:
  longitudinally displaced decay vertices of the *B* mesons.
- Very mild trigger requirements: one tracks and a half from the IP, or some relevant activity in the electromagnetic calorimeter.
- Excellent detector performances.

How To Improve The BaBar & Belle Results?

- Extend the Physics reach and improve the accuracy of the measurement with a larger sample:

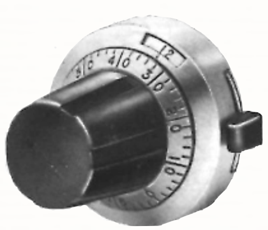
  - *increase in luminosity by a factor 40 by solving:*

$$\mathcal{L} \sim f_{\mathrm{coll}} \frac{N^+ N^-}{4\pi \, \sigma_x \, \sigma_y} = 8 \cdot 10^{35} \, \mathrm{cm}^{-2} \, \mathrm{s}^{-1}$$



A. Brute force: numerator ↗ (Currents) 1.6A/1.2 A ↗3.6/2.6 A

  - Fundamental limit: the wall plug power ~ proportional to current + Longitudinal Fast Instability

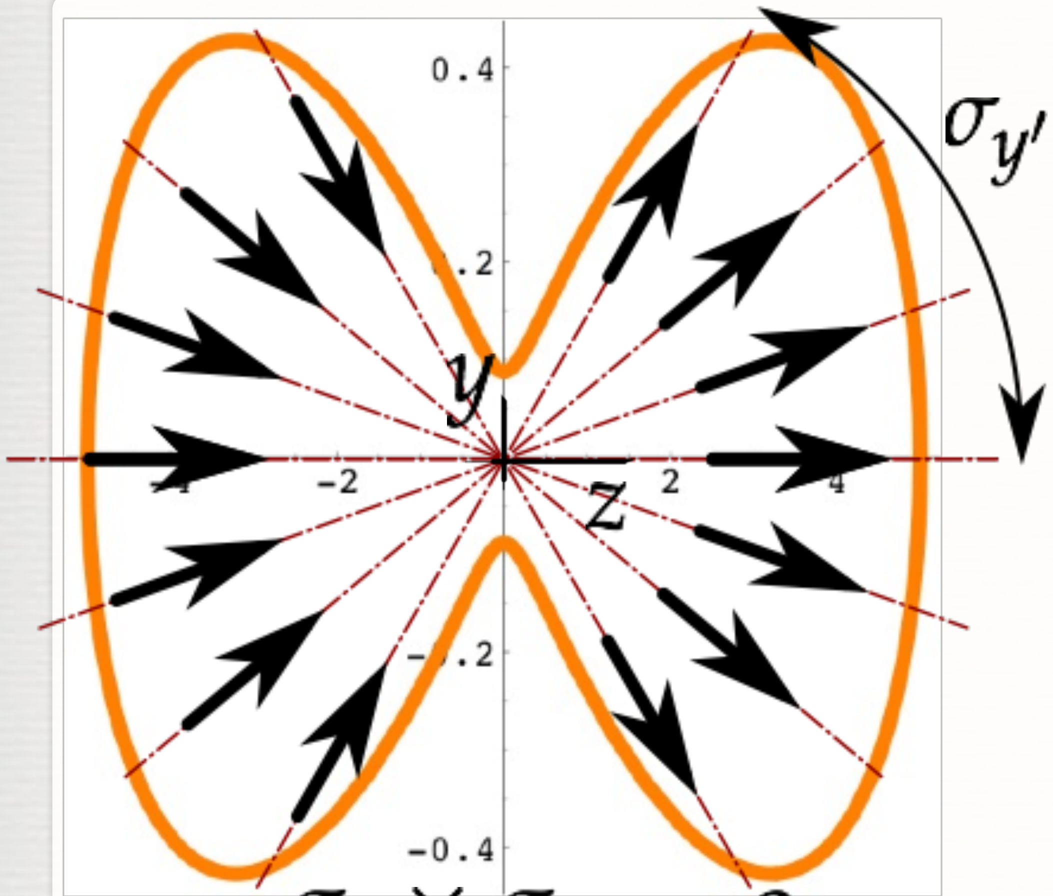


B. Precision: denominator ↘ (luminous region cross section)

KEKB vertical size ~1.1 μm ↘ SuperKEKB ~50 nm

How to squeeze down the bunch to 50 nm?

Down To 50 nm: Hour Glass Effect

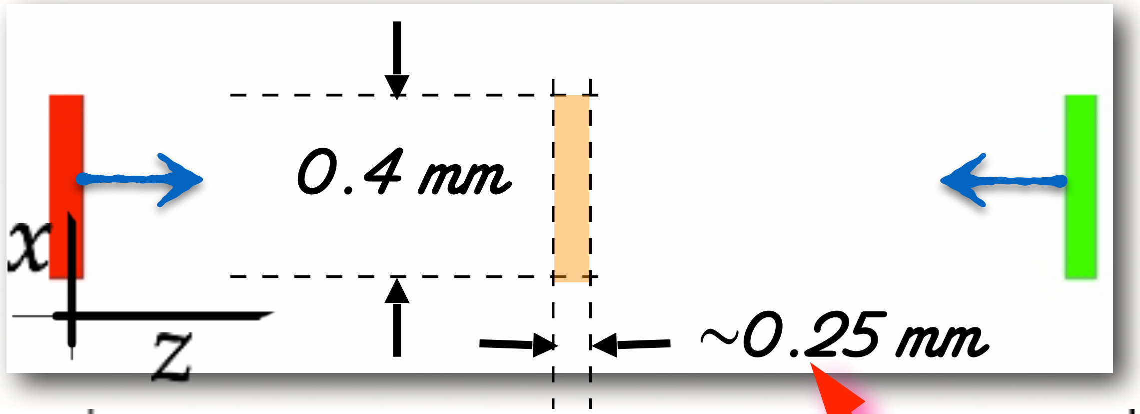


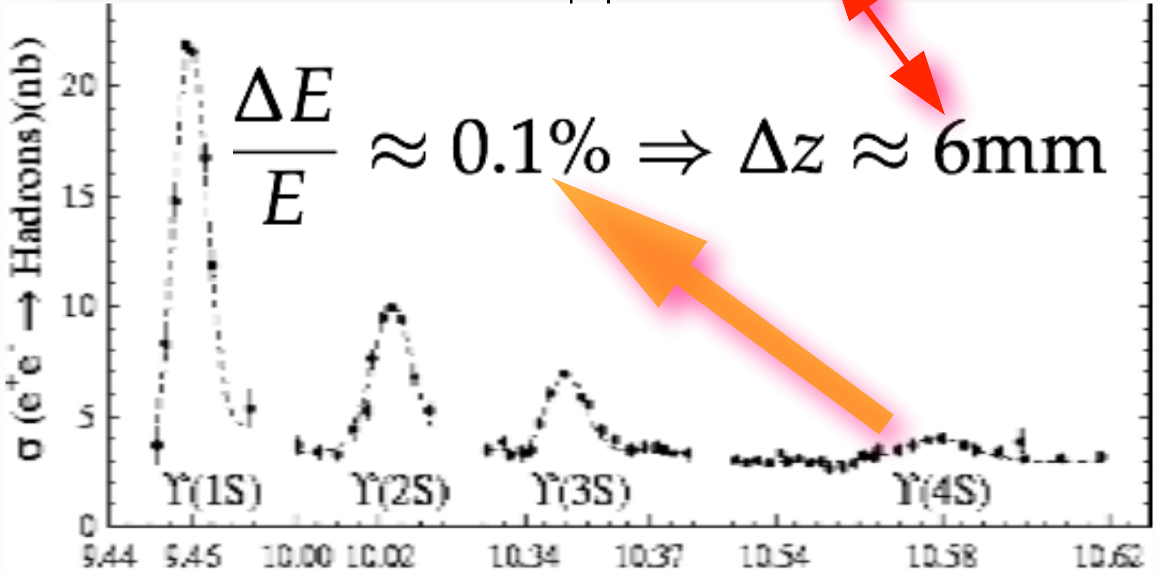
$$\sigma_y \times \sigma_{y'} = \epsilon_y$$

ANGULAR DIVERGENCE
X
CROSS SECTION SIZE @ IP
=
EMITTANCE (CHARACTERISTIC OF THE RING)

- KEKB emittance ~ 0.2nm x radiant
  Angular divergence ~ 4 mradiant = 4000 nm / mm
- SuperKEKB nominal emittance ~ 0.010nm x radiant
  Angular divergence ~ 0.2 mradiant = 200 nm / mm = 50 nm / 0.25mm
  How to collide in a luminous region just 0.25 mm long?

The Nano Beam Collision Scheme





Pantaleo Raimondi's Clever Idea

Bunch Length
x
Energy Spread
=
Characteristic Constant of The Ring

The Nano Beam Collision Scheme

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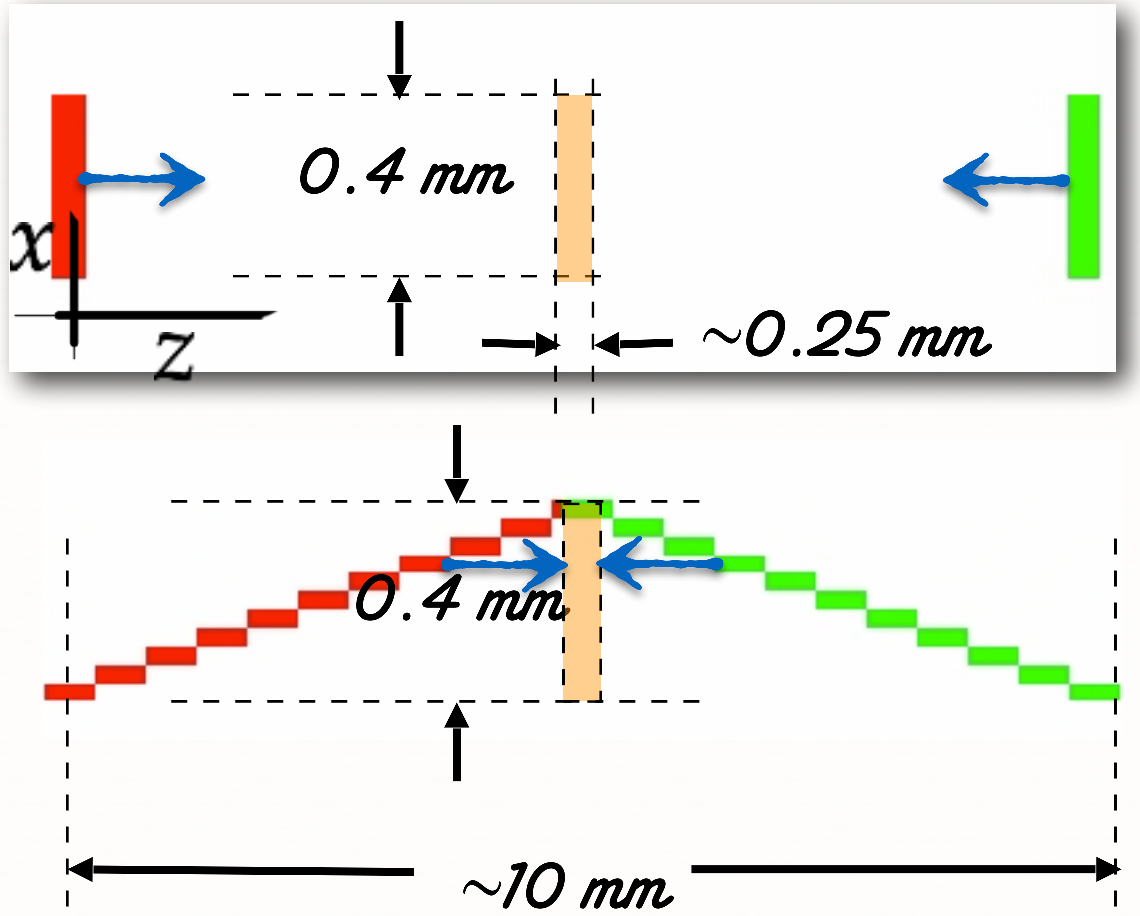

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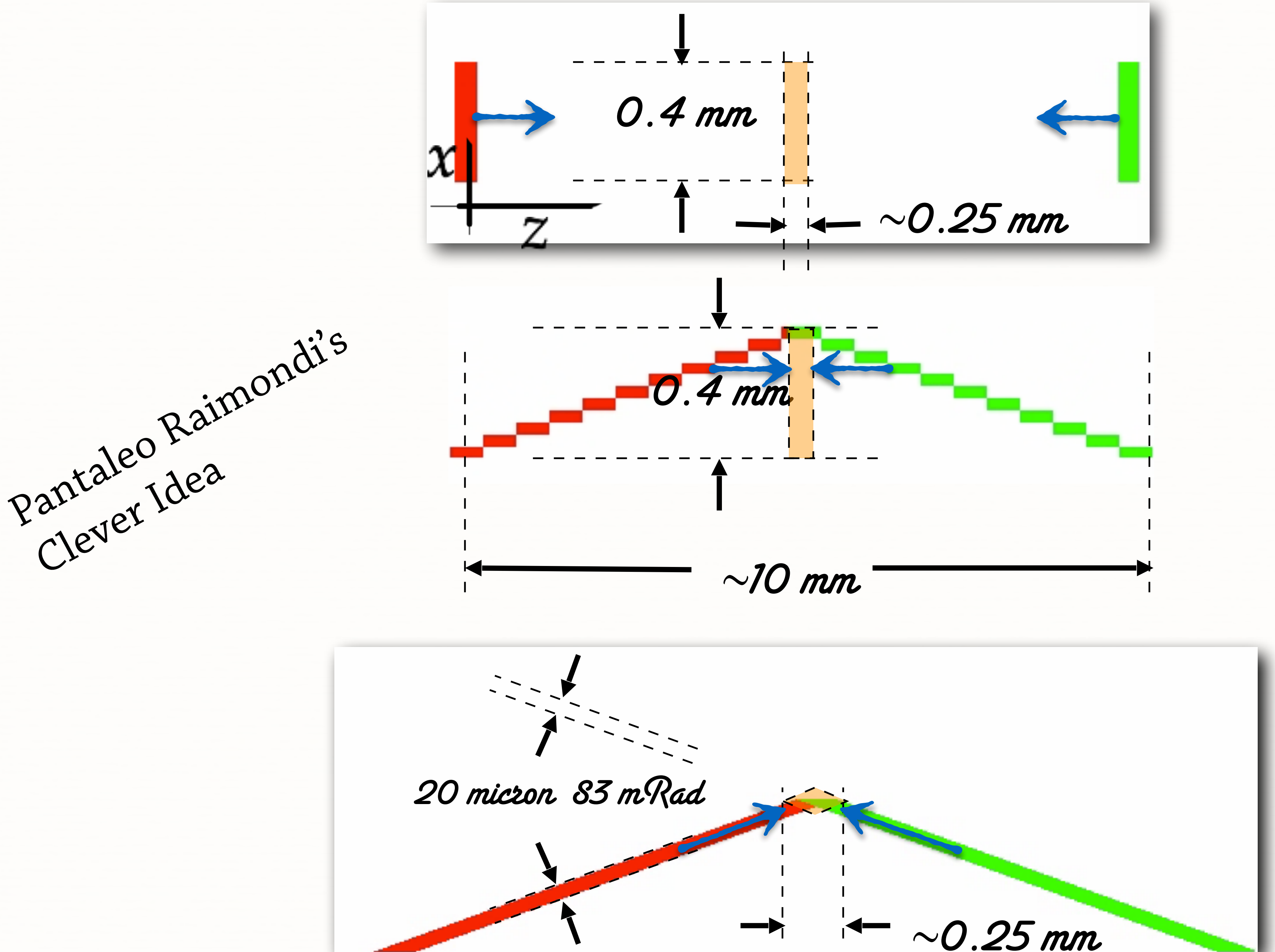

The Nano Beam Collision Scheme

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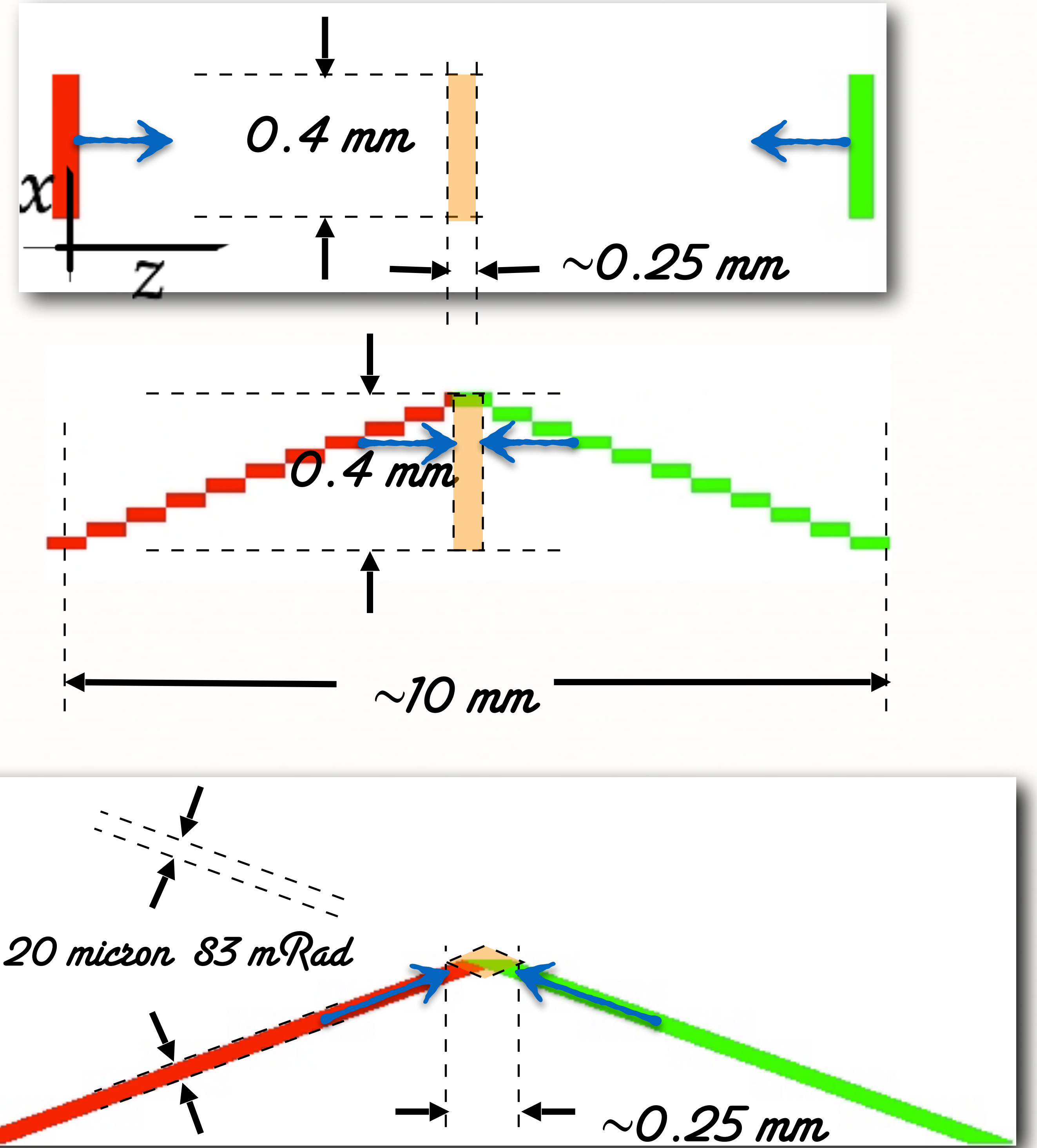
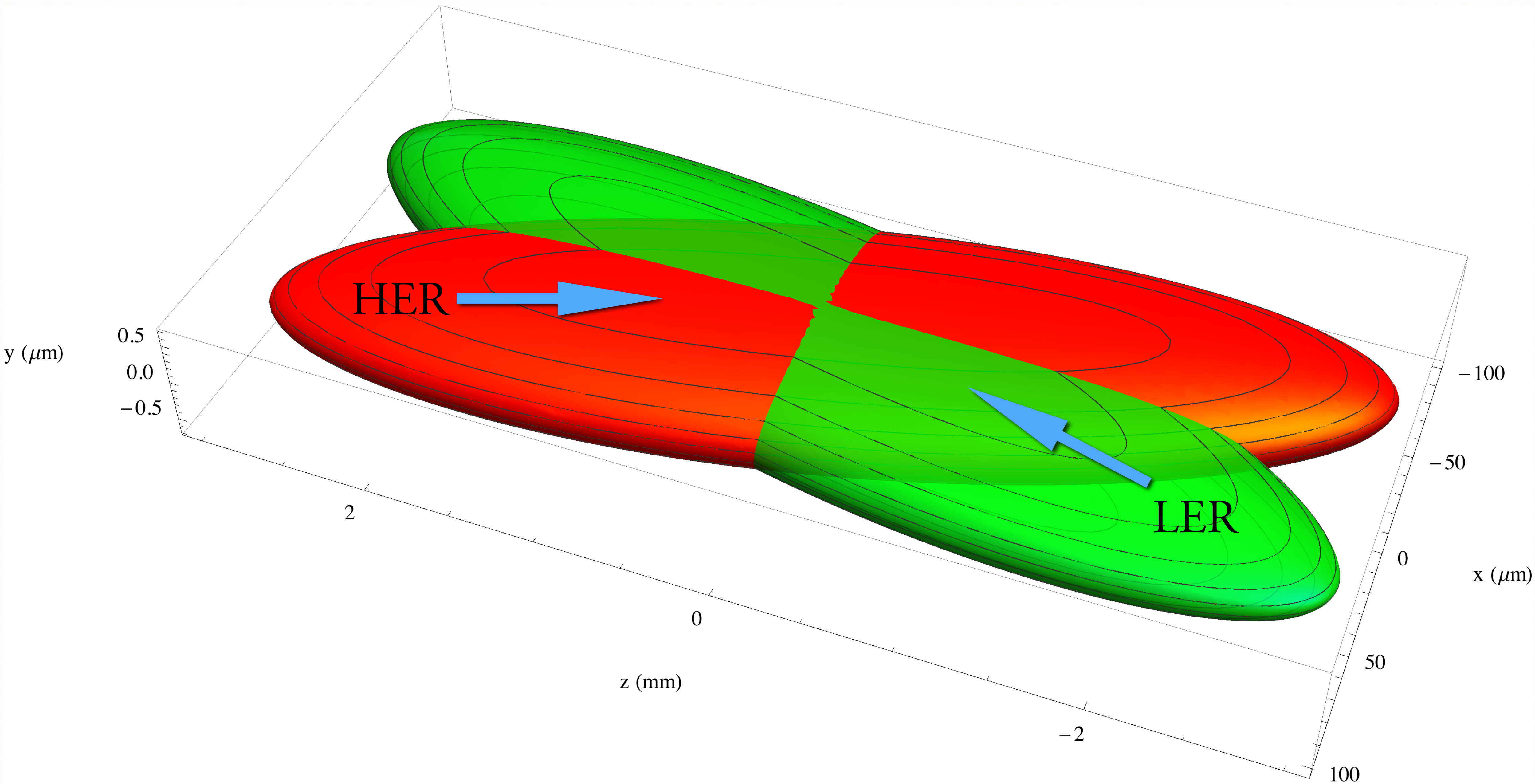


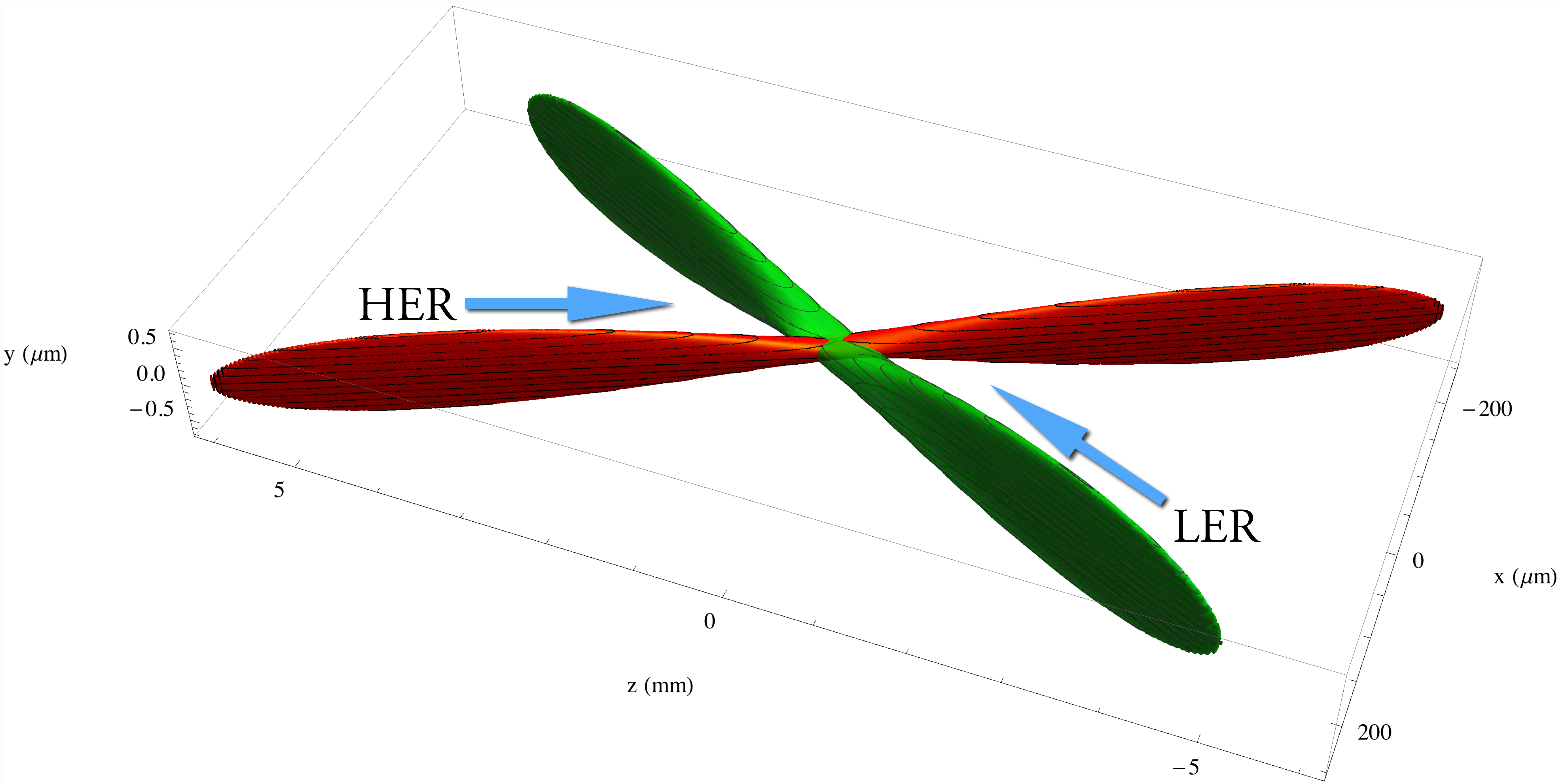
From KEKB

Bunches Constant Density Surfaces at the IP

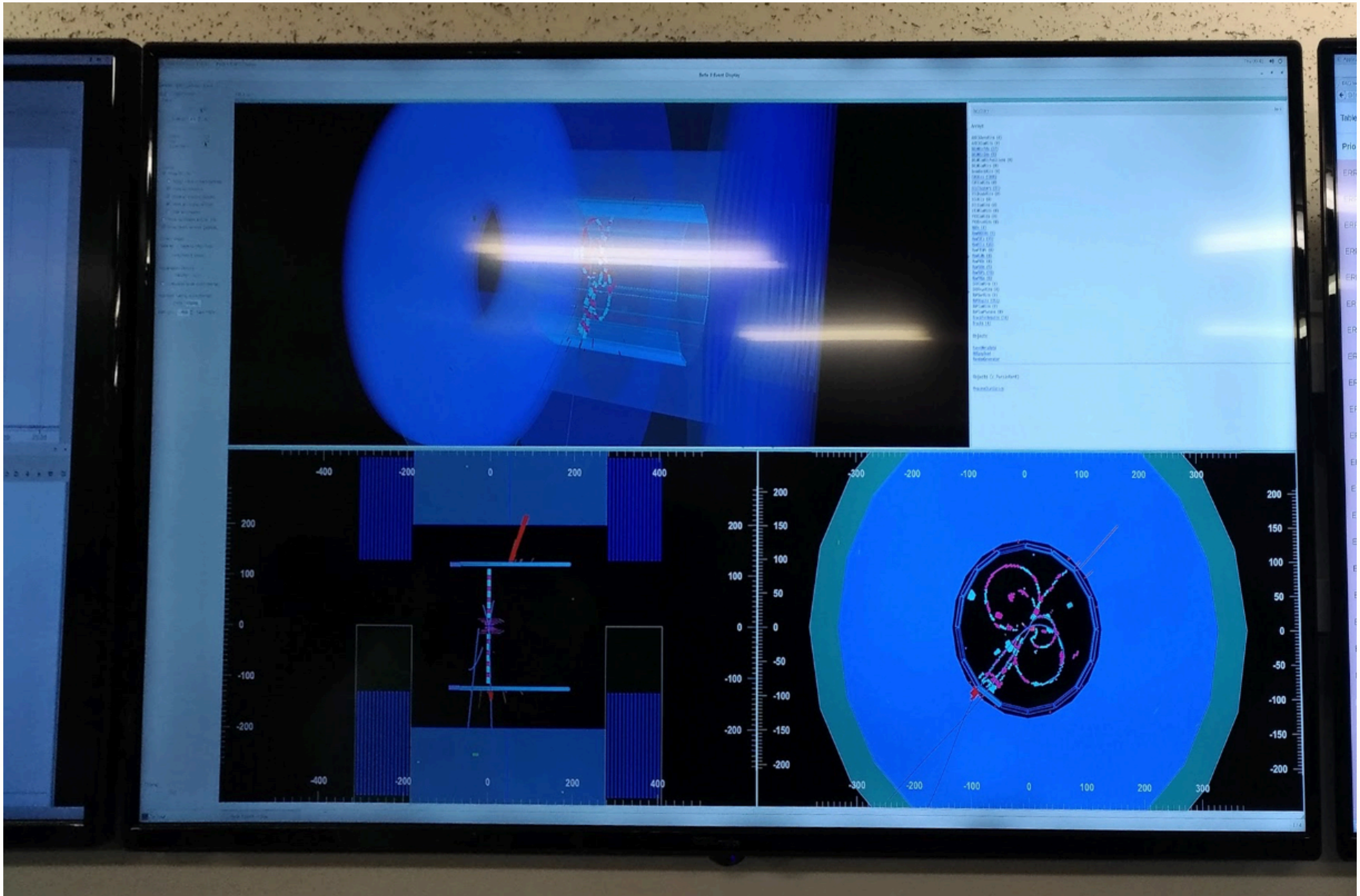


From KEKB to SuperKEKB

Bunches Constant Density Surfaces at the IP

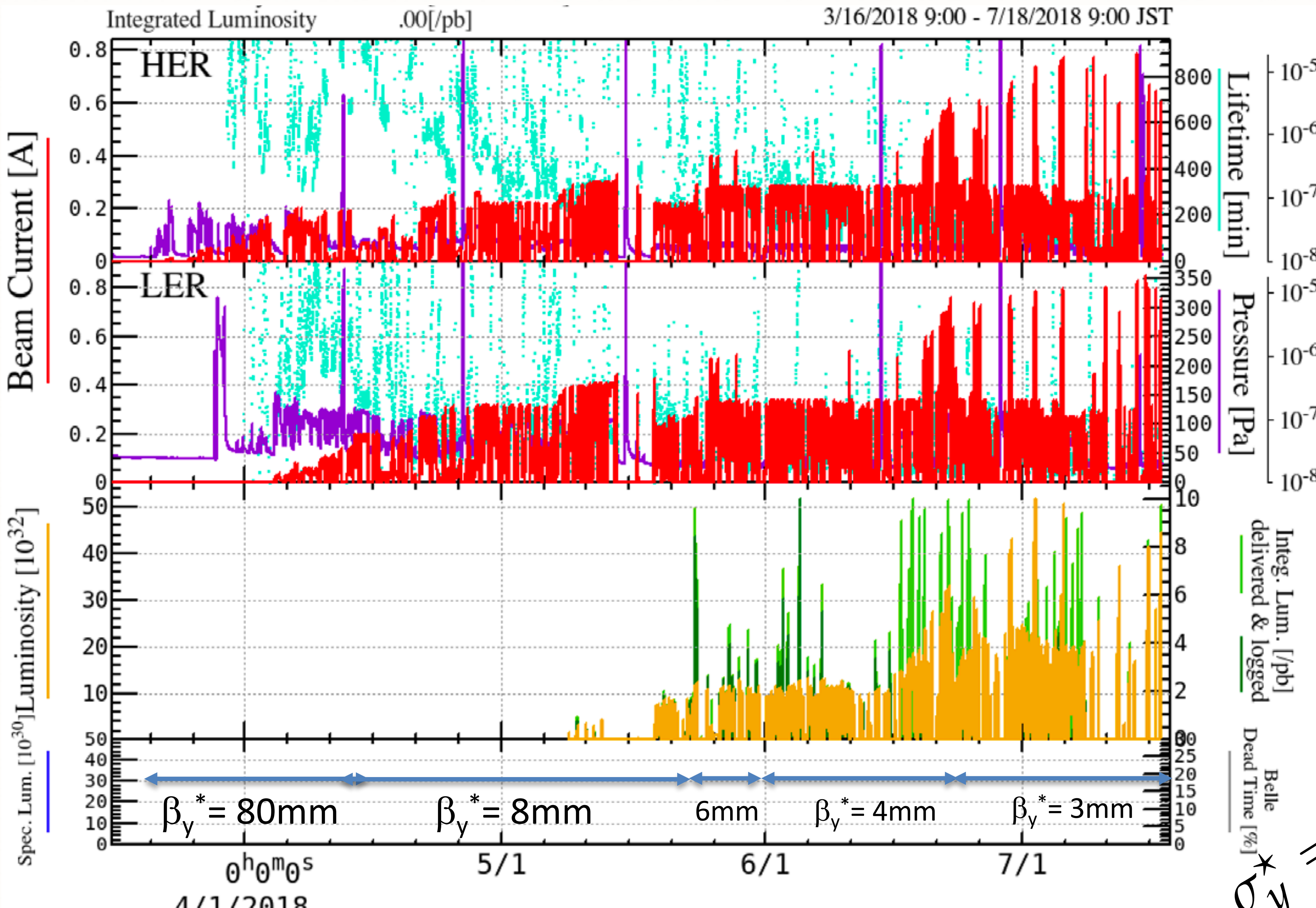


April 26 2018: First Collisions!



April 26 2018: First Collisions!

Phase 2 History In A Nutshell



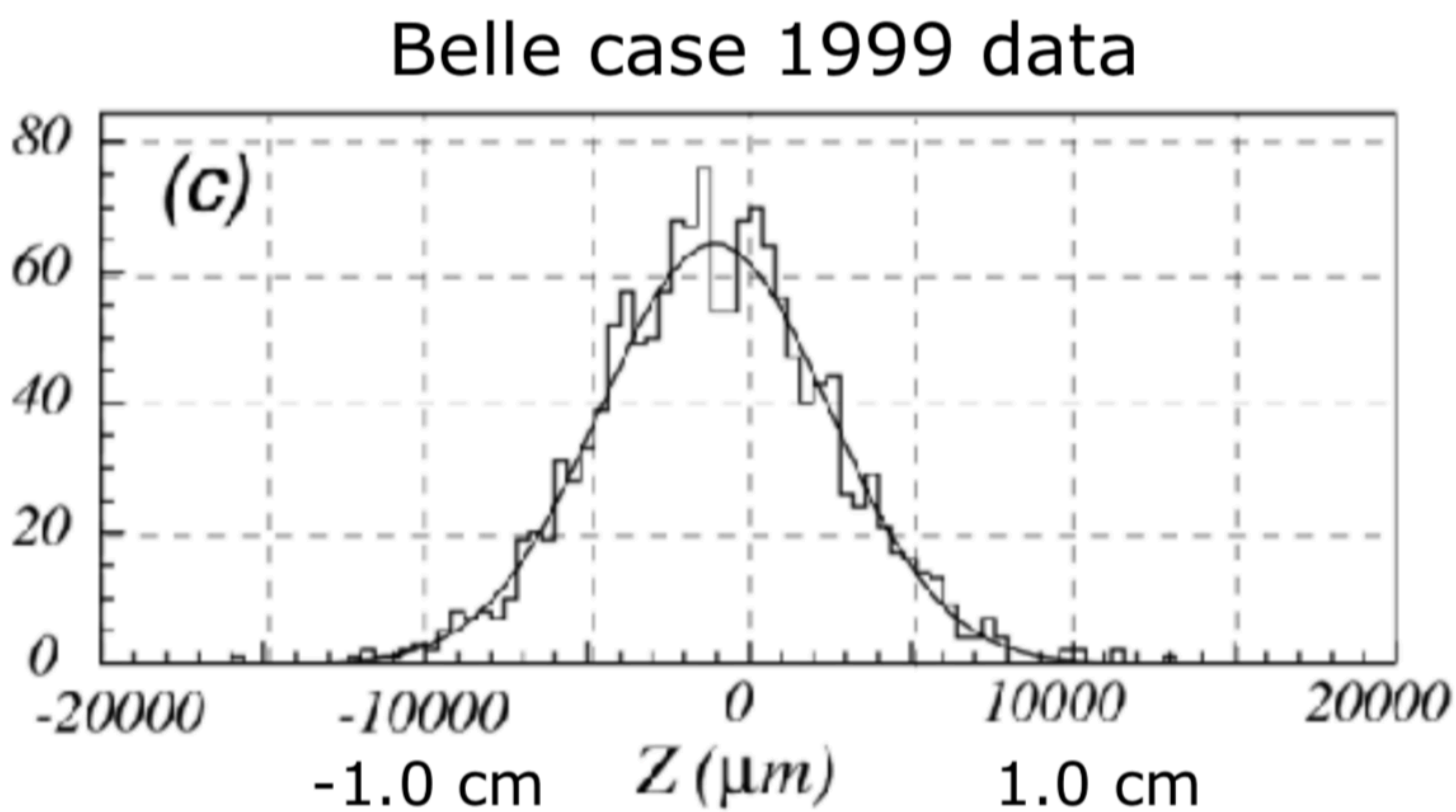
$$\sigma_y^\star = \sqrt{\beta_y^\star \varepsilon_y}$$

5.55 x 10^{33}/cm^2/s (βy*3mm, LER: 800mA, HER: 780mA, 1576 bunches/beam July 5th)
2.29 x 10^{33}/cm^2/s (βy*3mm, LER: 270mA, HER: 225mA, 394 bunches/beam July 3rd)

The World Shortest Luminous Region

- Longitudinal impact parameter of two tracks events:

$$e^+e^- \rightarrow \mu^+\mu^- \qquad e^+e^- \rightarrow e^+e^-$$



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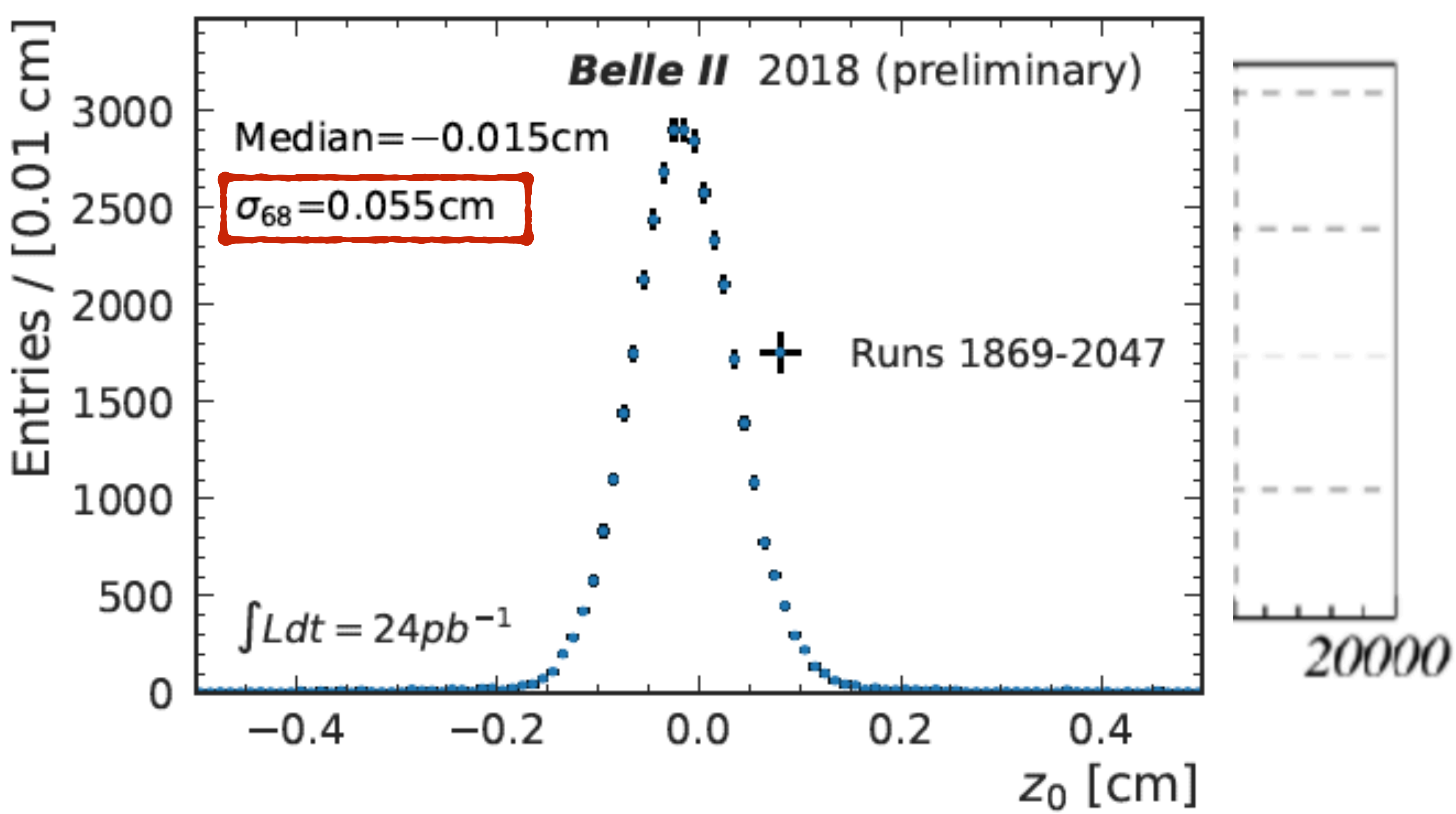
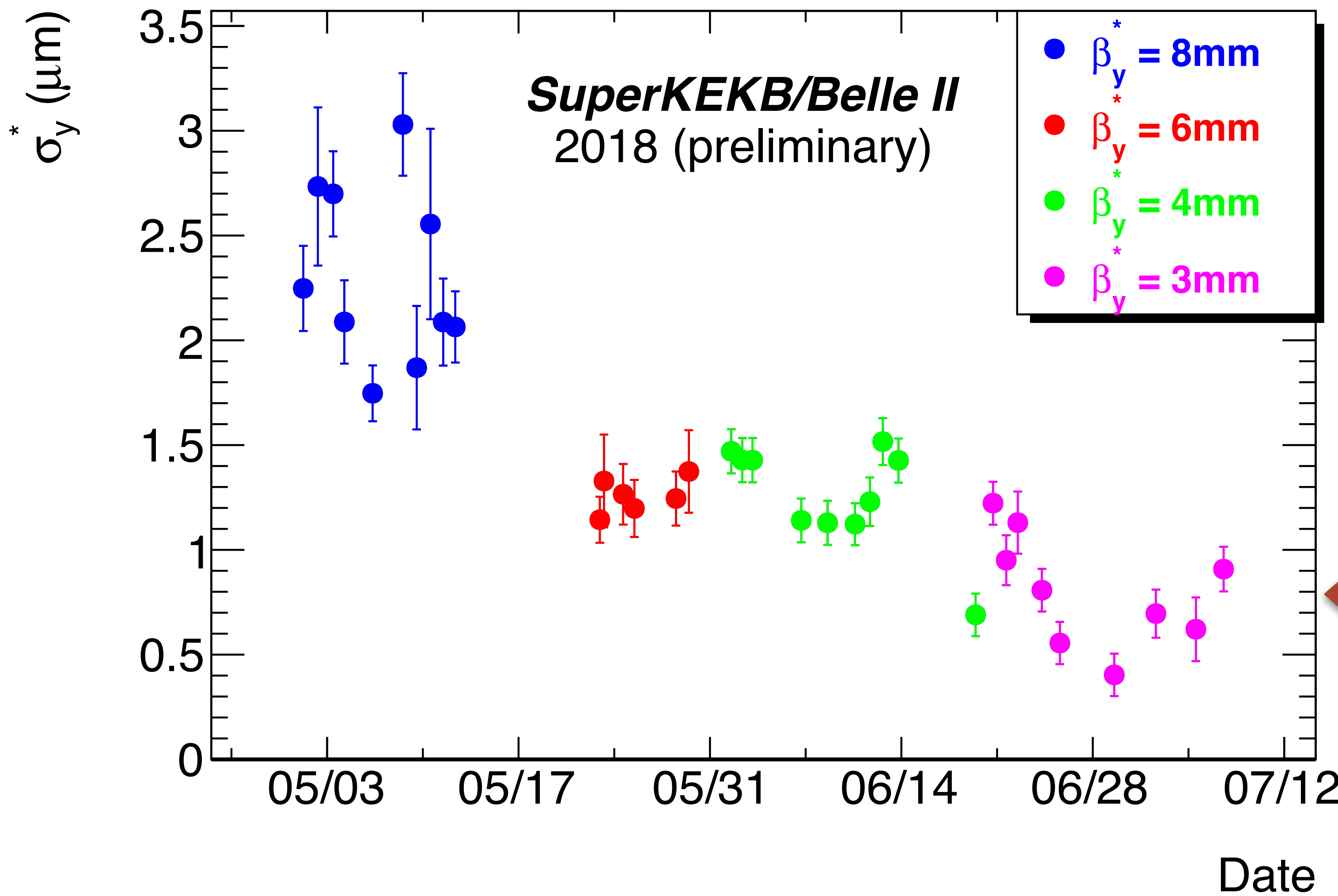


Toward The Smallest Luminous Region

- How to measure the vertical size of the beams?
  - Measure the luminosity with our fast diamond detector while the machine people moves the beam vertically.



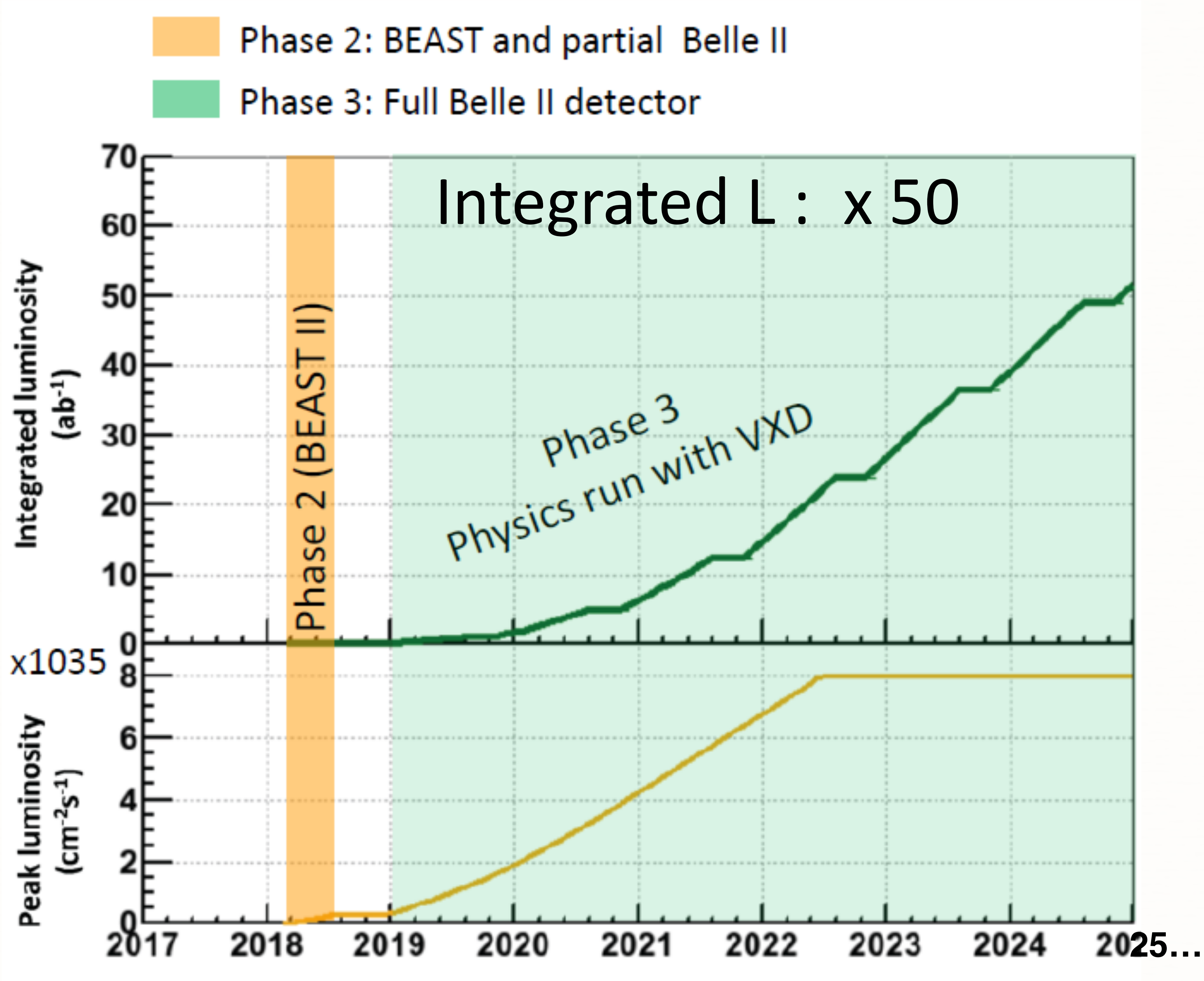
$$\sigma_y^\star = \sqrt{\beta_y^\star \varepsilon_y}$$

less than 500 nm achieved

Next Steps

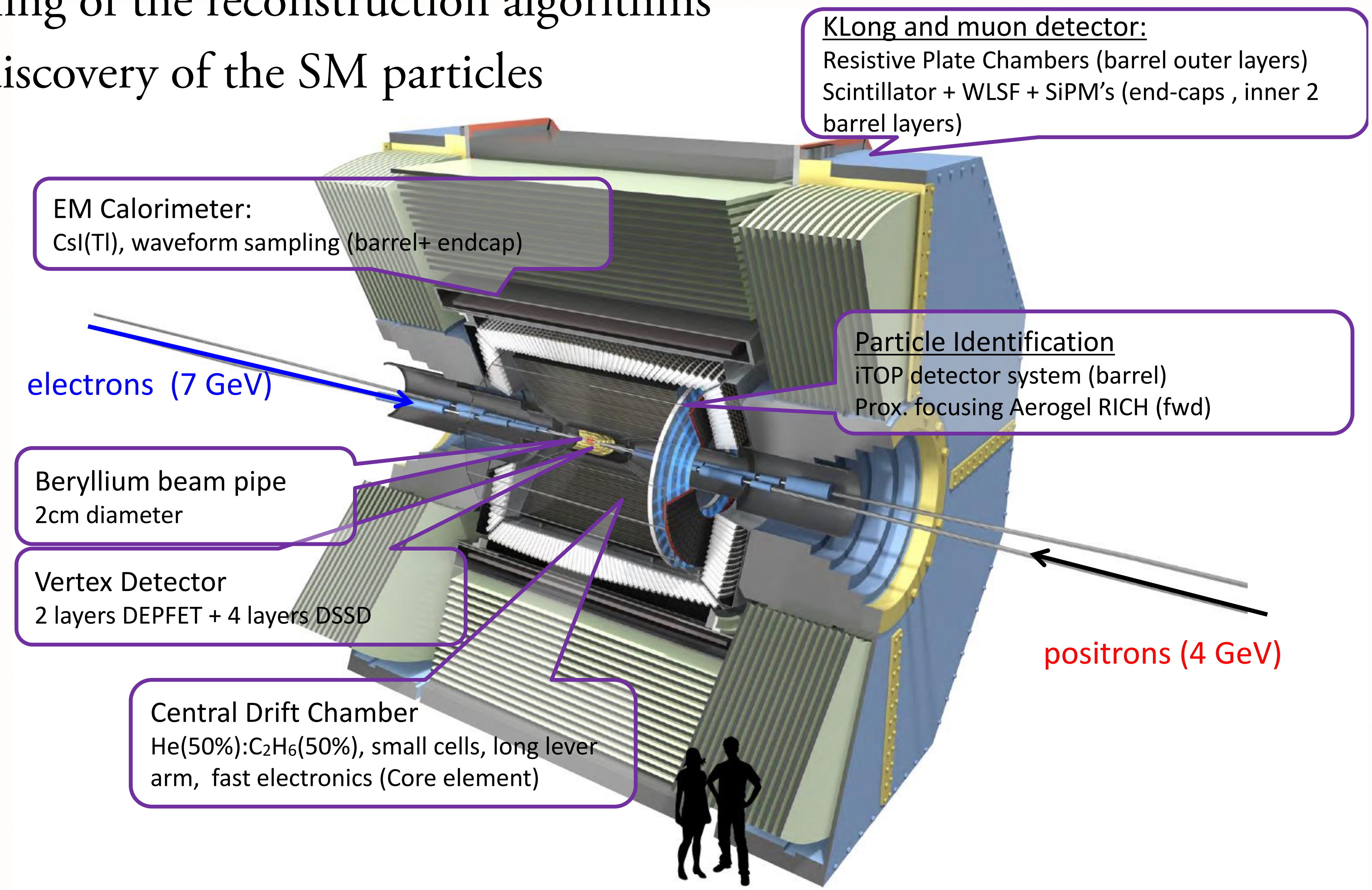
- Install additional collimators to reduce the backgrounds
- Install the whole silicon vertex tracker
- Restart the operations in March 2019
- Tune the optics
- Gradually increase the number of bunches and the bunch current
- Gradually decrease the vertical size of the bunches at the IP

Long Term Plans To Achieve 8 10^{35} Hz/cm^2



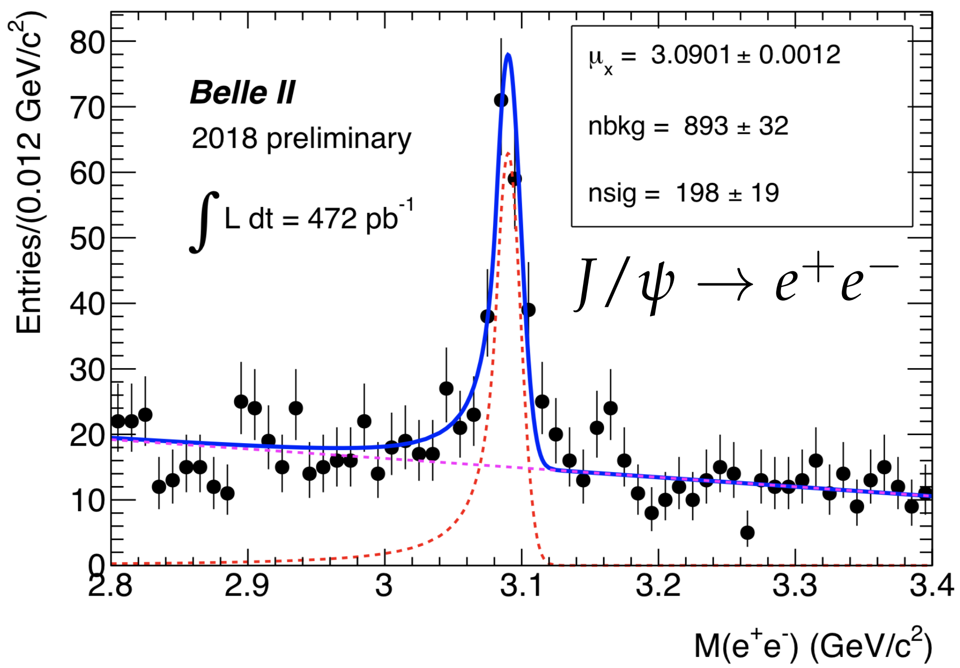
Meanwhile From The Detector Side

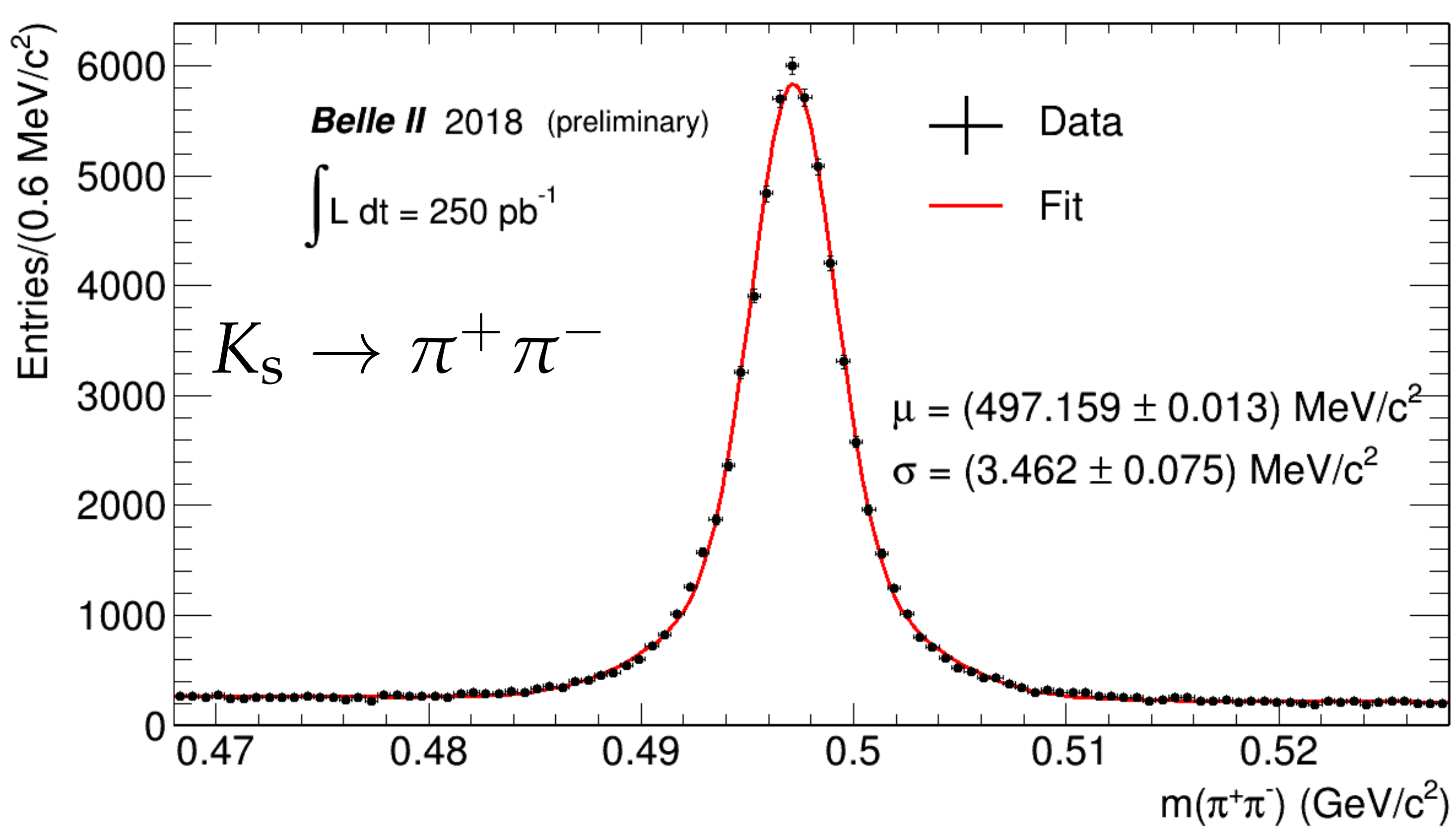
- Detector calibrations
- Tuning of the reconstruction algorithms
- Rediscovery of the SM particles

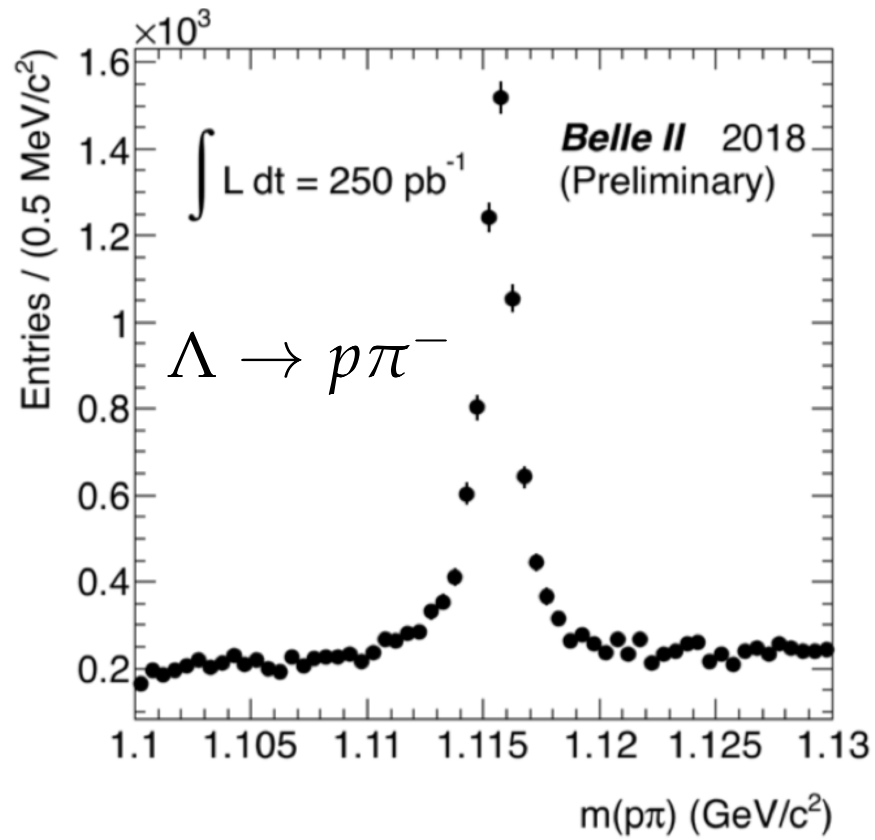


The Tracking Systems Is Working Well

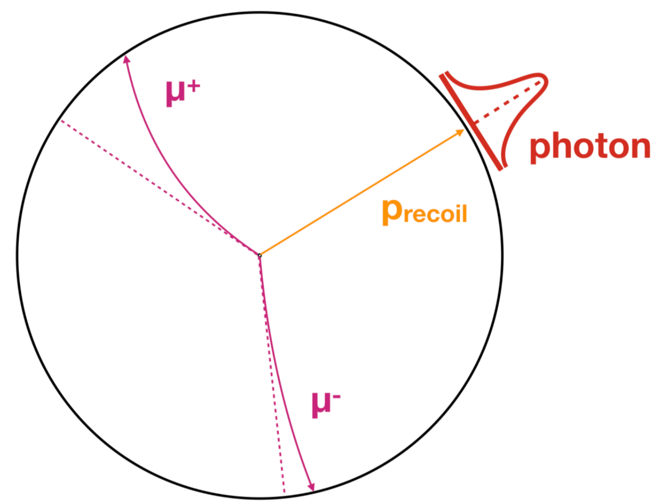
- Tracks from the CDC and the VXD available since the start of collisions
- Detector aligned within few weeks
- B field very well measured
- Mass resolution on data in good agreement with MC predictions, on par with Belle



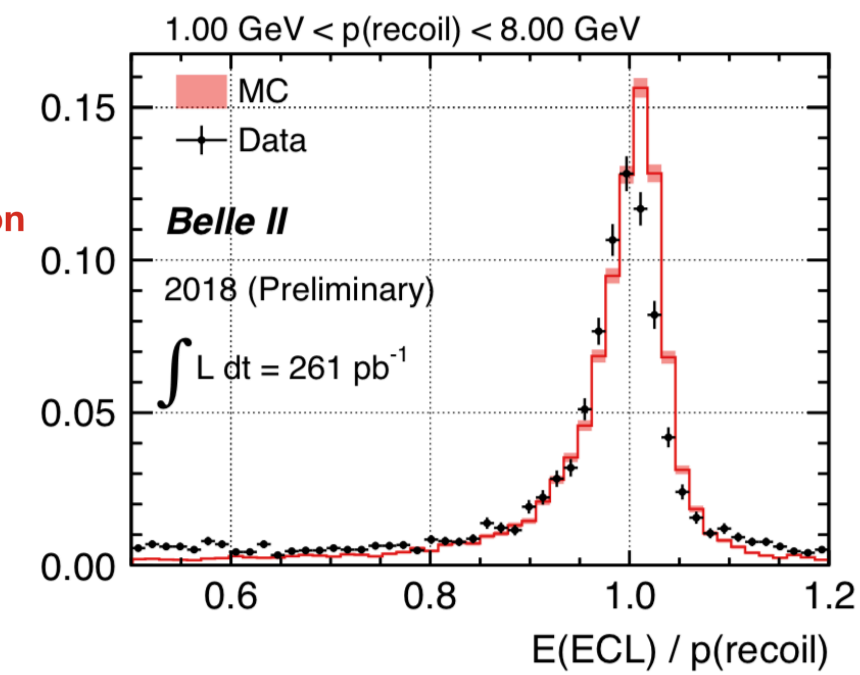


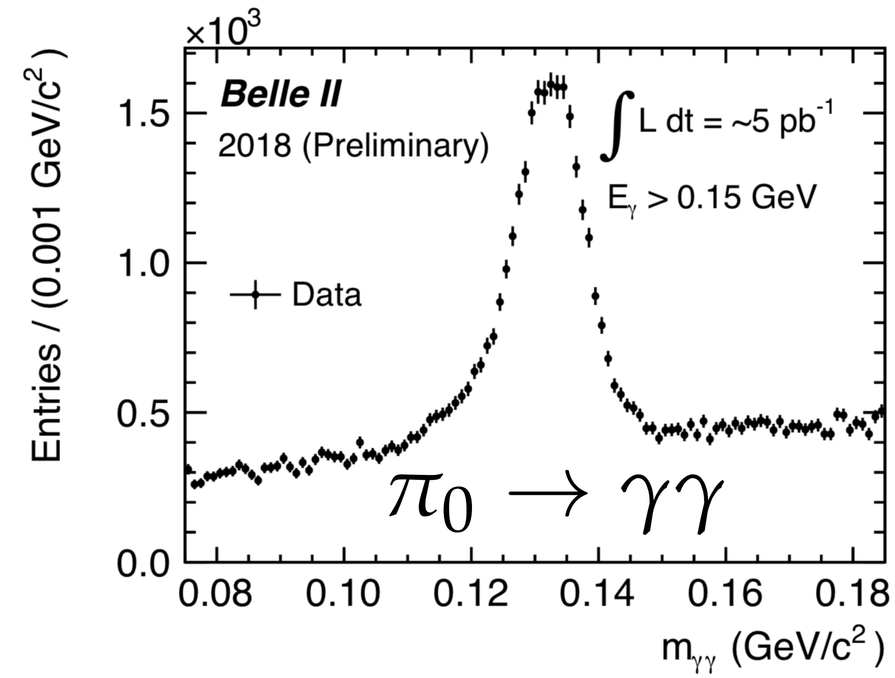


The Neutrals In The ECL Are Very Good Too



$$e^+e^- \to \mu^+\mu^-\gamma$$

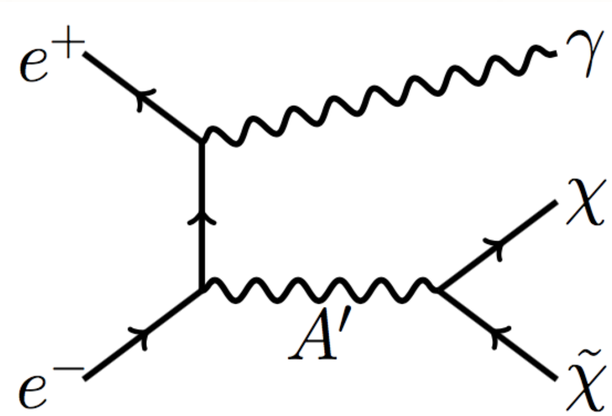


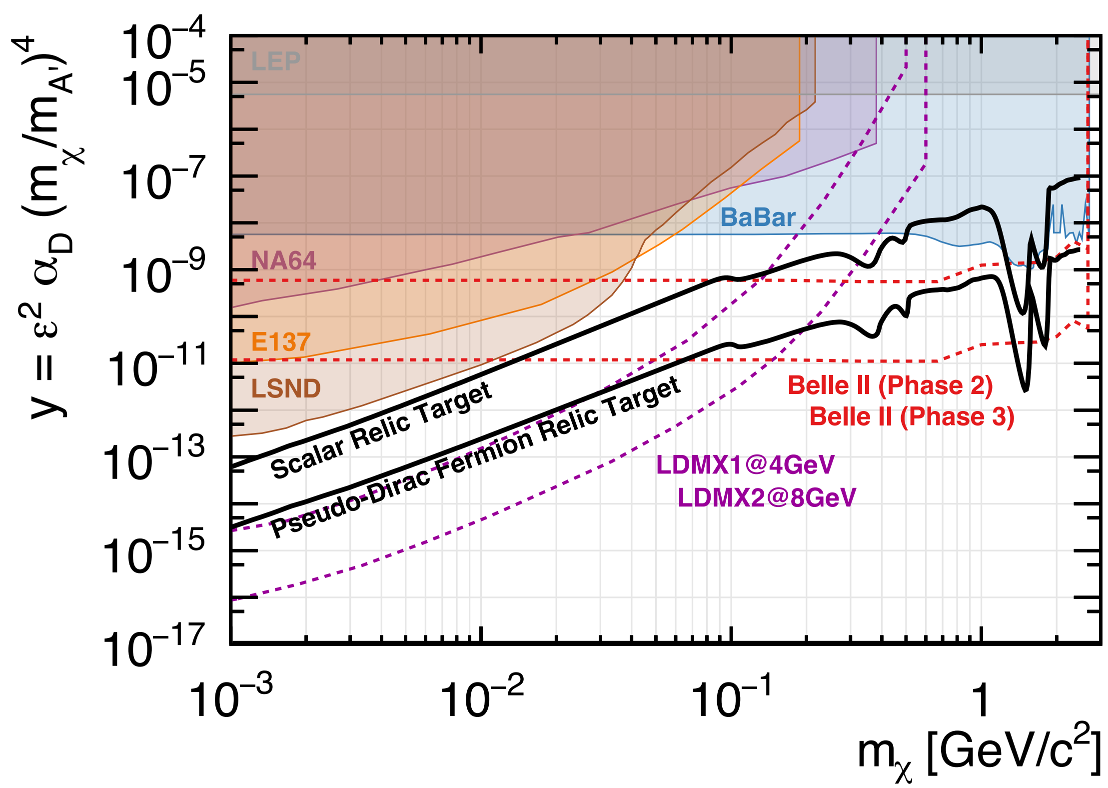


Trigger, detector and software ready for the Dark Sector.

$$e^+e^- \to \gamma\, X$$

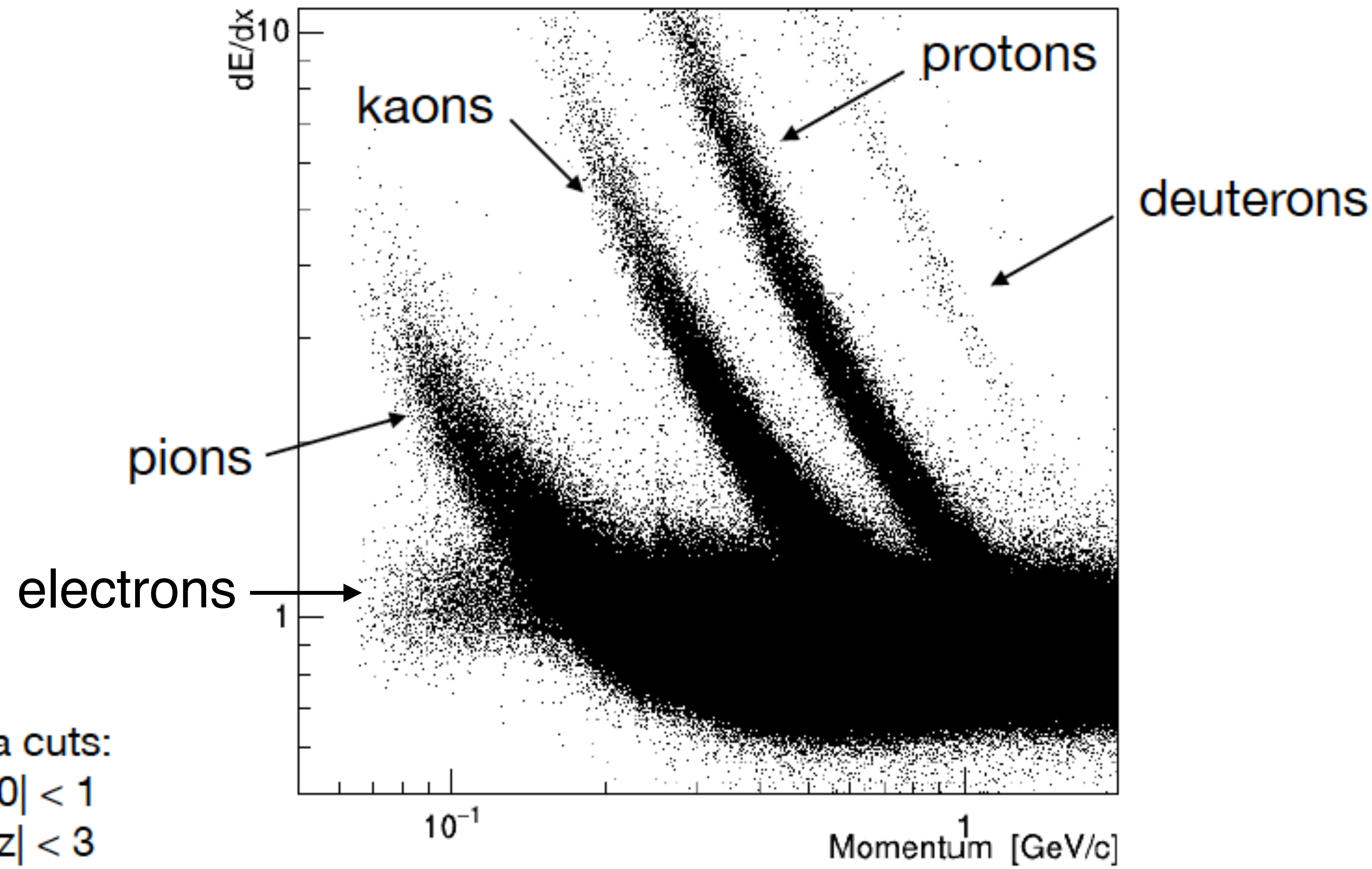
$$e^+e^- \to \gamma\, \mathrm{ALP}(\to \gamma\gamma)$$





Particle Identification In The CDC

Performance of CDC dE/dx particle identification with early calibrations in the hadronic event sample.



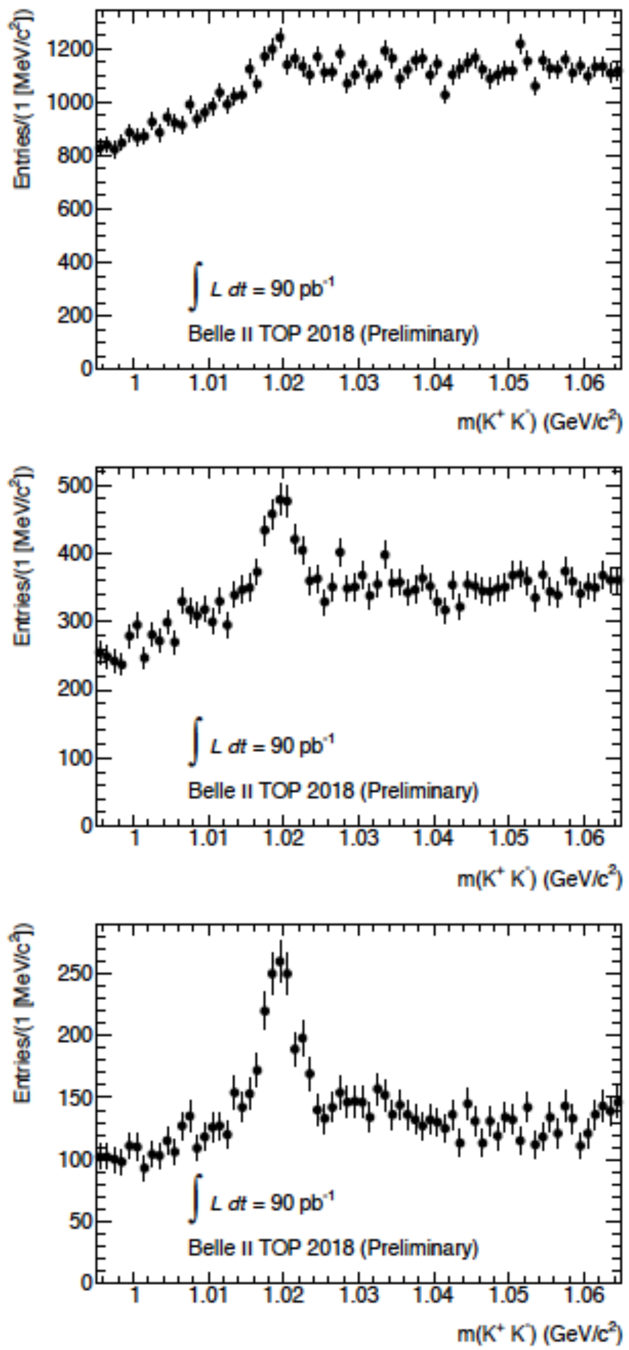
Extra cuts:
- |d0| < 1
- |dz| < 3
- # layers hit > 20

Particle Identification With The TOP

$\Phi \to K^+K^-$

Inclusive sample

Another example of TOP particle identification with early calibration and alignment.



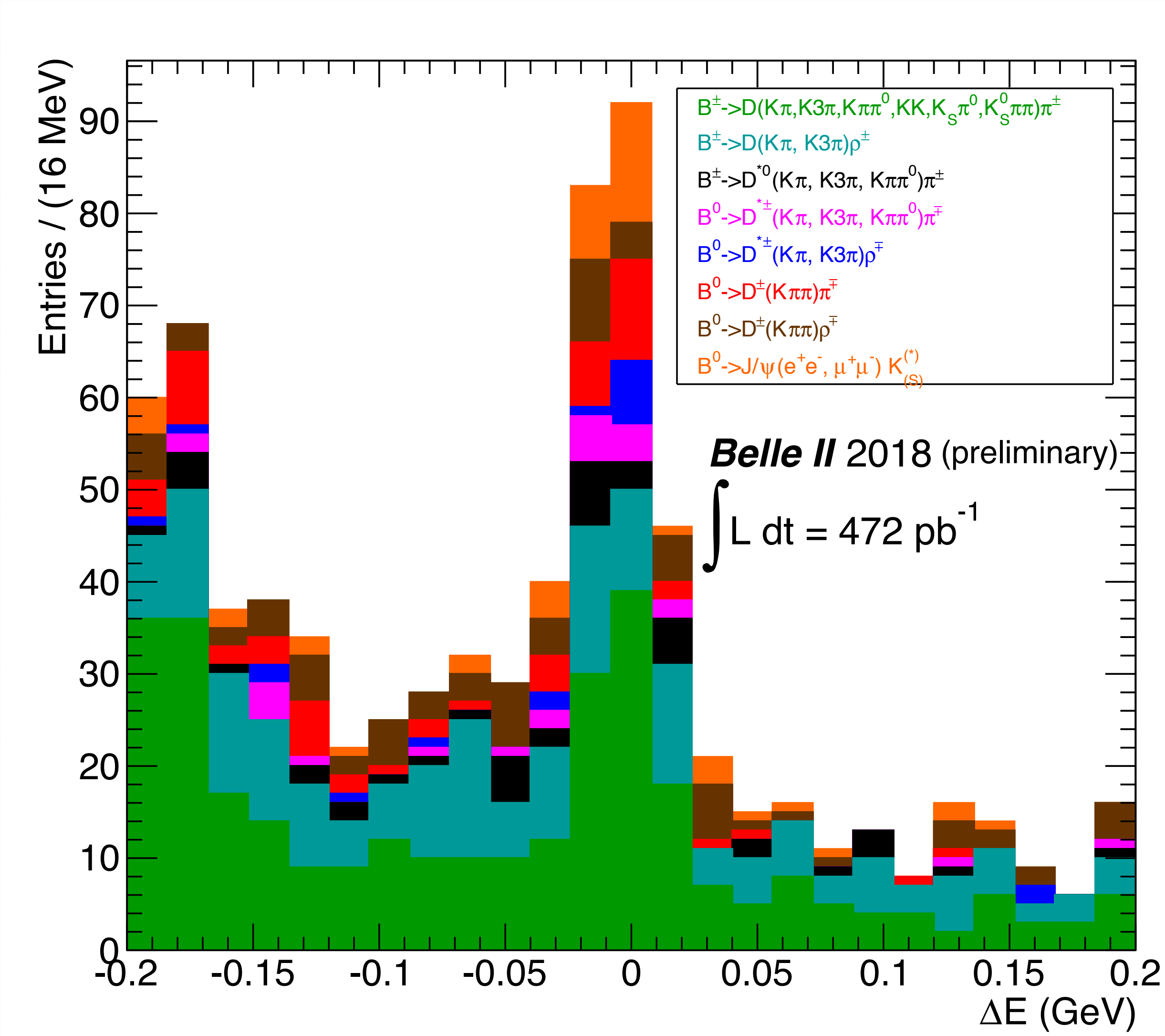
No kaons identified

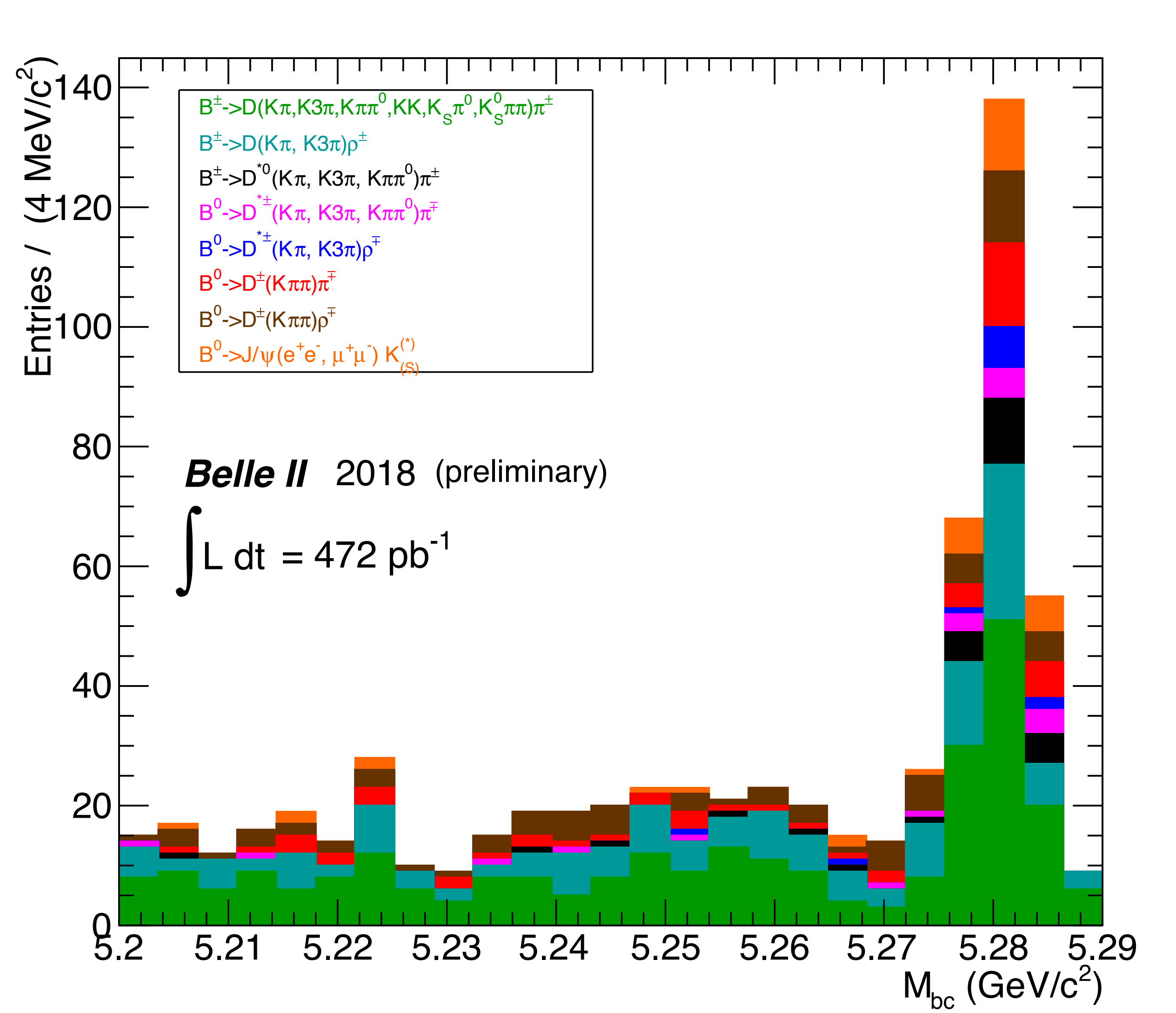
One kaon identified in the TOP.

Both kaons identified in the TOP.

FIG. 7: $m(K^+K^-)$ distributions for runs with TOP calibration (run number up to 2531). Tracks are required to be in the TOP acceptance. Top: No PID requirement. Middle: $LL(K)^{TOP} > LL(\pi)^{TOP}$ for one of the tracks. Bottom: $LL(K)^{TOP} > LL(\pi)^{TOP}$ for both tracks.

B Mesons Rediscovered





History 1983:

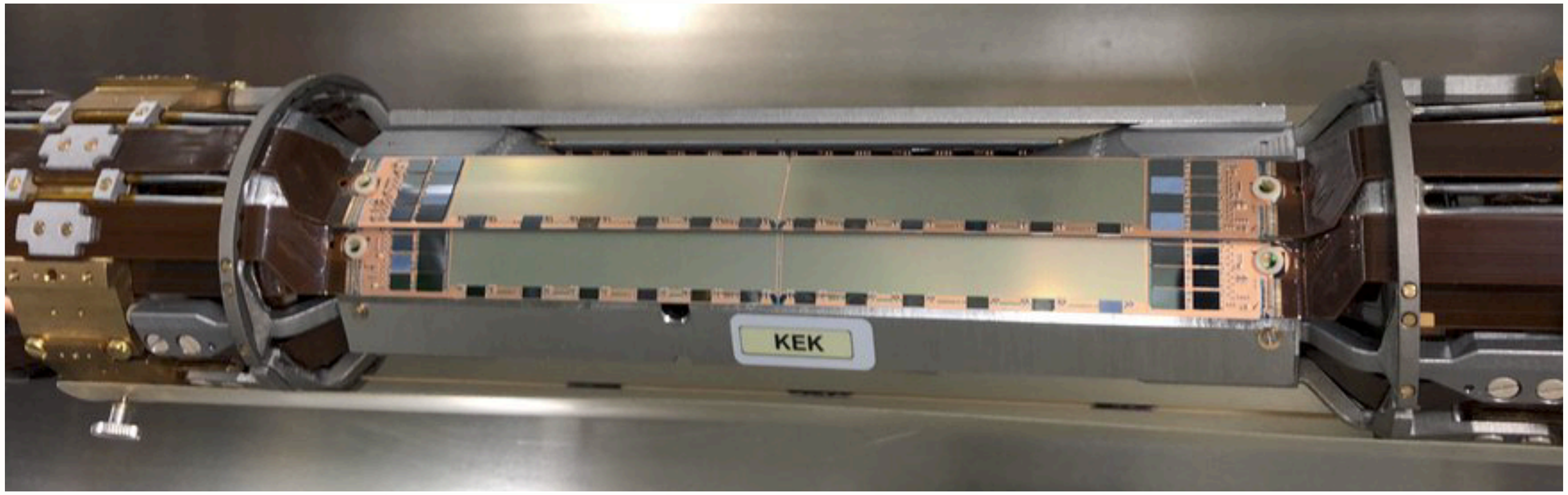
VOLUME 50, NUMBER 12 PHYSICAL REVIEW LETTERS 21 MARCH 1983

Observation of Exclusive Decay Modes of b-Flavored Mesons 40.7 pb^{-1}

B-meson decays to final states consisting of a D^0 or $D^{*\pm}$ and one or two charged pions have been observed. The charged-B mass is $5270.8 \pm 2.3 \pm 2.0$ MeV and the neutral-B mass is $5274.2 \pm 1.9 \pm 2.0$ MeV.

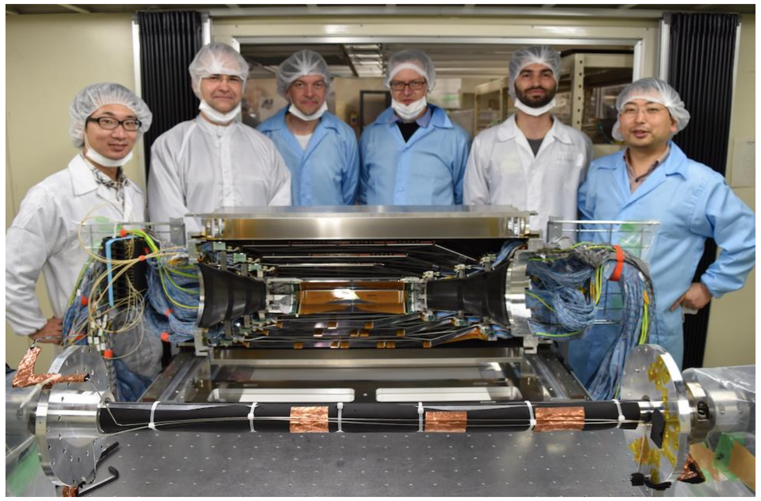
Full Fledged VXD Ready To Go In

- The VXD are almost ready to go in:
  - PXD (1 layer of DEPFET silicon pixel detector)



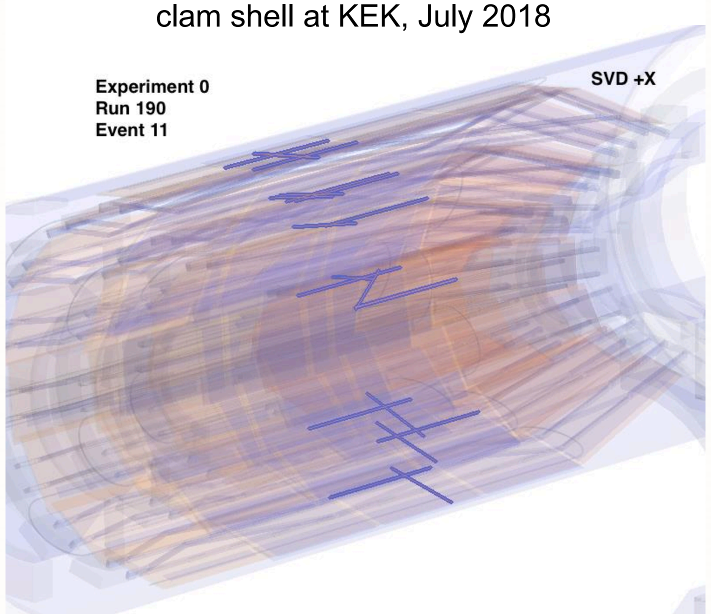
  - SVD (4 layers of double sided silicon strip detector)

SVD +x half-shell, Jan 2018



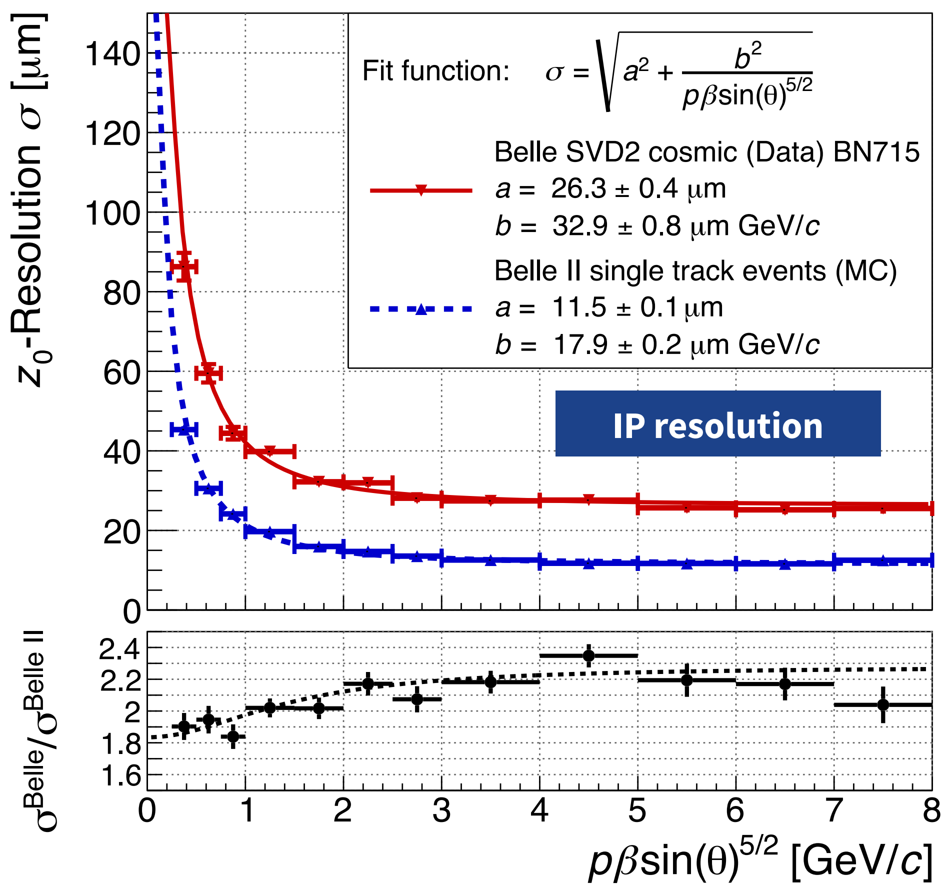
SVD -x half-shell, July 2018

First Cosmic in the +x SVD clam shell at KEK, July 2018

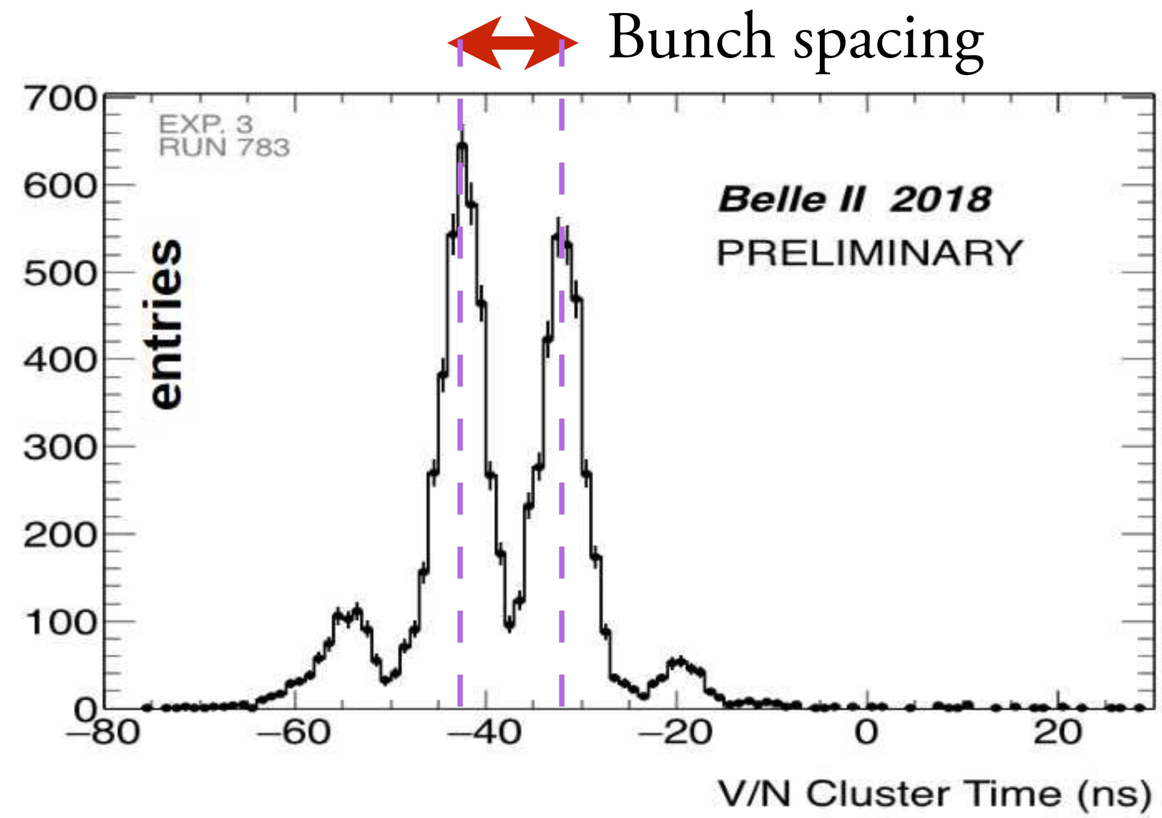


VXD Status

Impact Parameter Resolution provided by the PXD



Time resolution provided by the SVD to reject the machine background



- Impact parameters: σ_{d0} Belle II < 0.5 x σ_{d0} Belle, Mass: σ_M Belle II ~ 0.7 x σ_M Belle

Raw reconstructed time of SVD clusters (N side) associated to tracks.

Conclusions

- The detector collected 488 pb^{-1}
- The collider luminosity exceeded 5 10^{33} Hz/cm^2 with relaxed ring optic and fairly small currents
- The detector behaved quite well providing good data since the start of the collisions
- The collaboration is on track to restart the operations in March 2019 with the full detector and an improved machine
- Lot of fun (and hard work) in front of us

Thank you

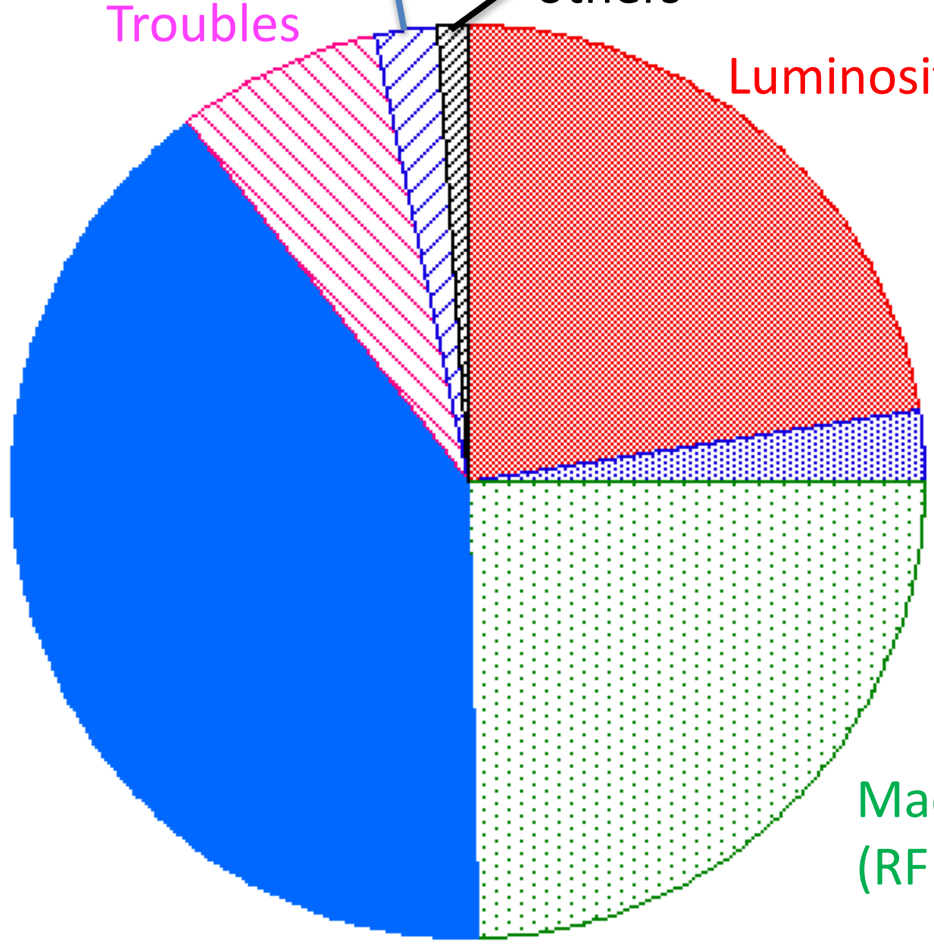
For your

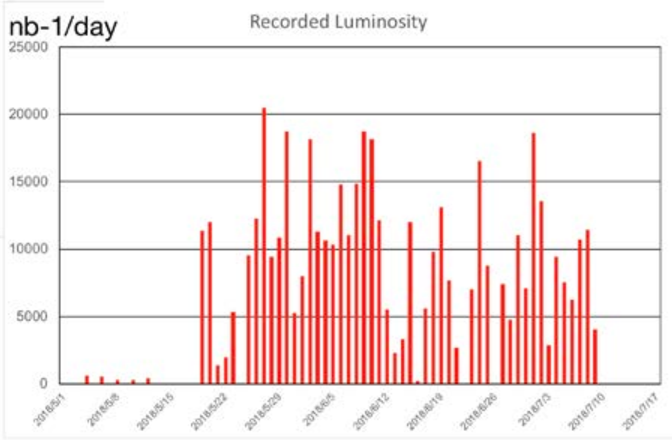
Attention!

BACKUP MATERIAL

Run Time Share

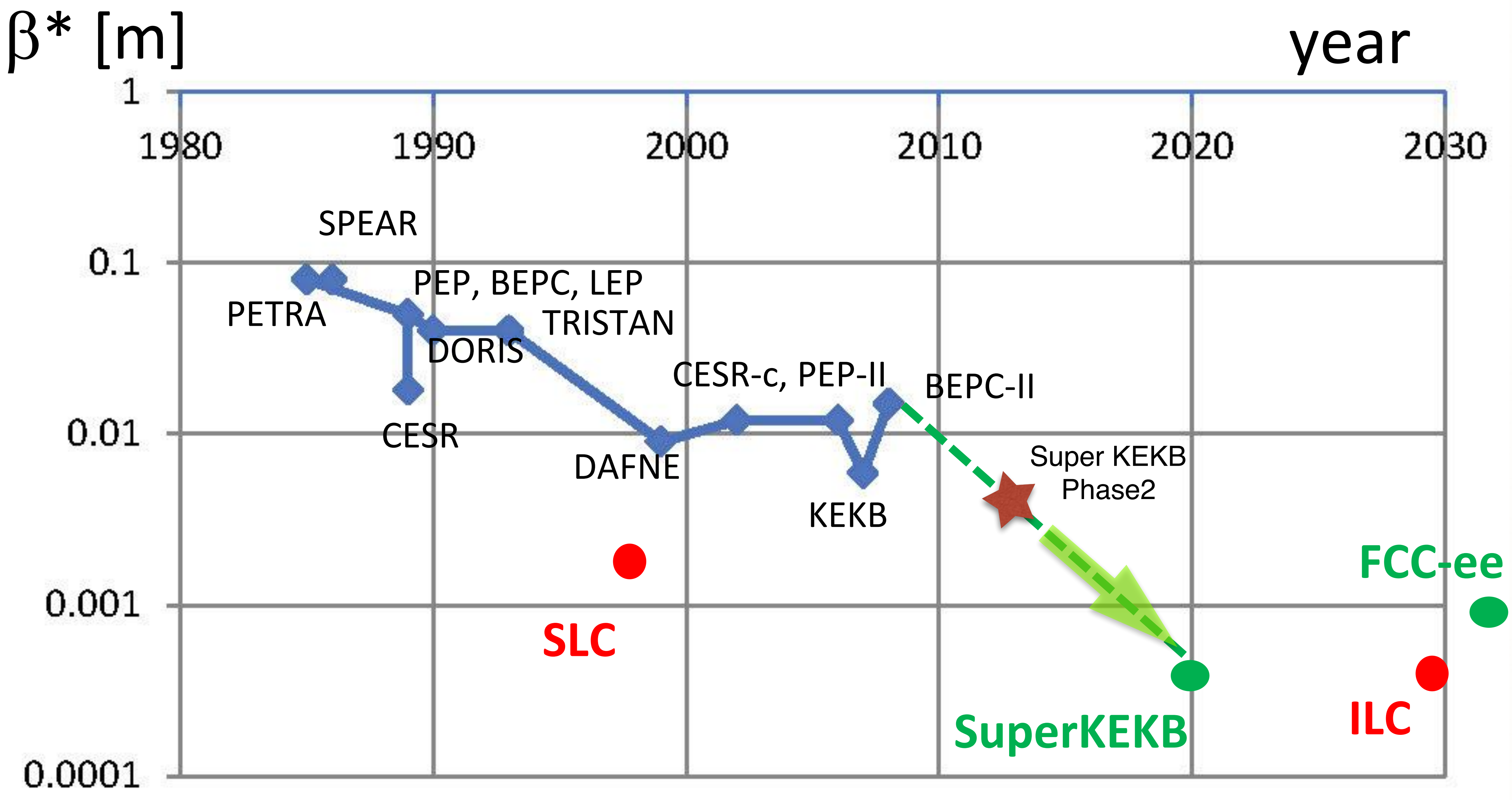
Operation of SuperKEKB (Phase 2) April ~ June 2018





L~ 500/pb

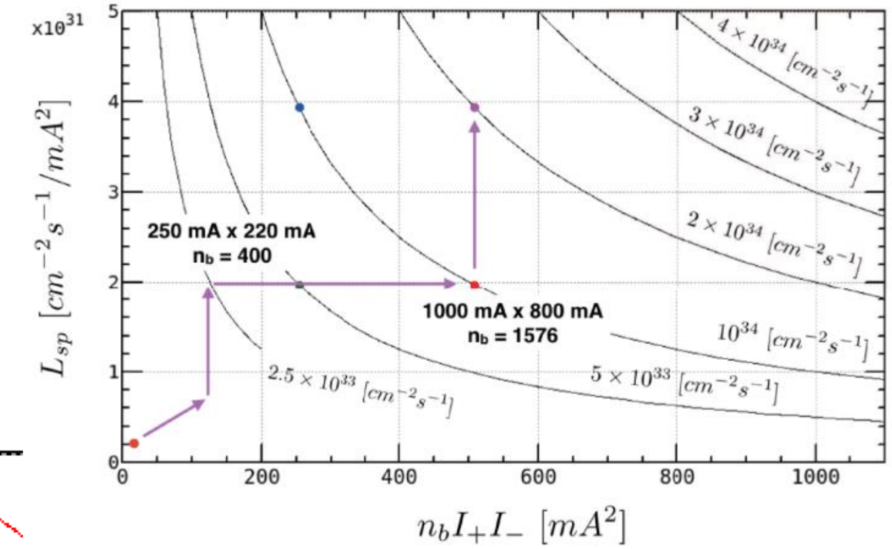
Beta Star y History and Future



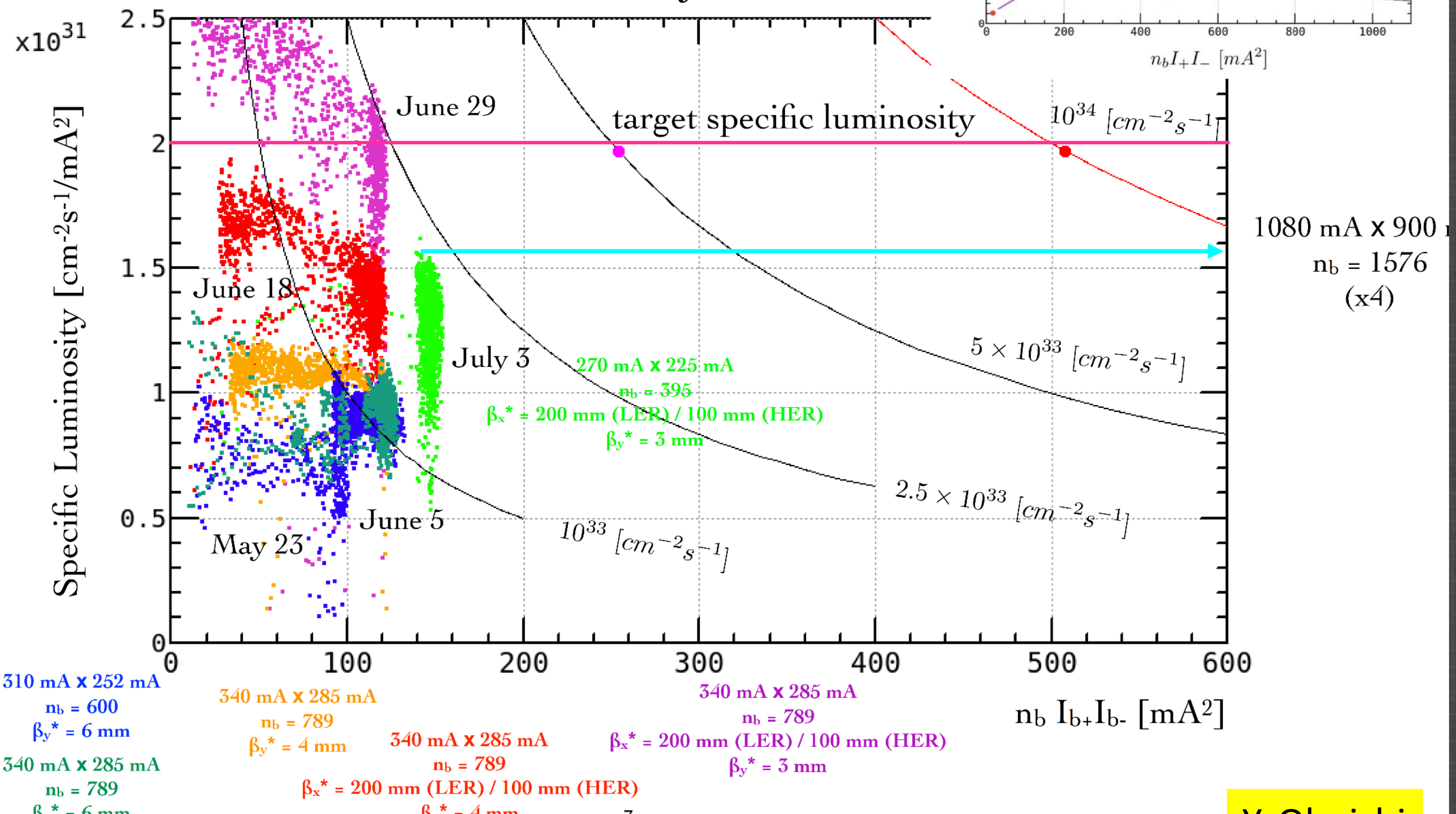
Courtesy Franck Zimmermann

specific luminosity

SuperKEKB Phase 2



Luminosity Contour



Y. Ohnishi