# Update on HVMAP Electron Detector Development for

# Electron Beam Polarimetry at SuperKEKB

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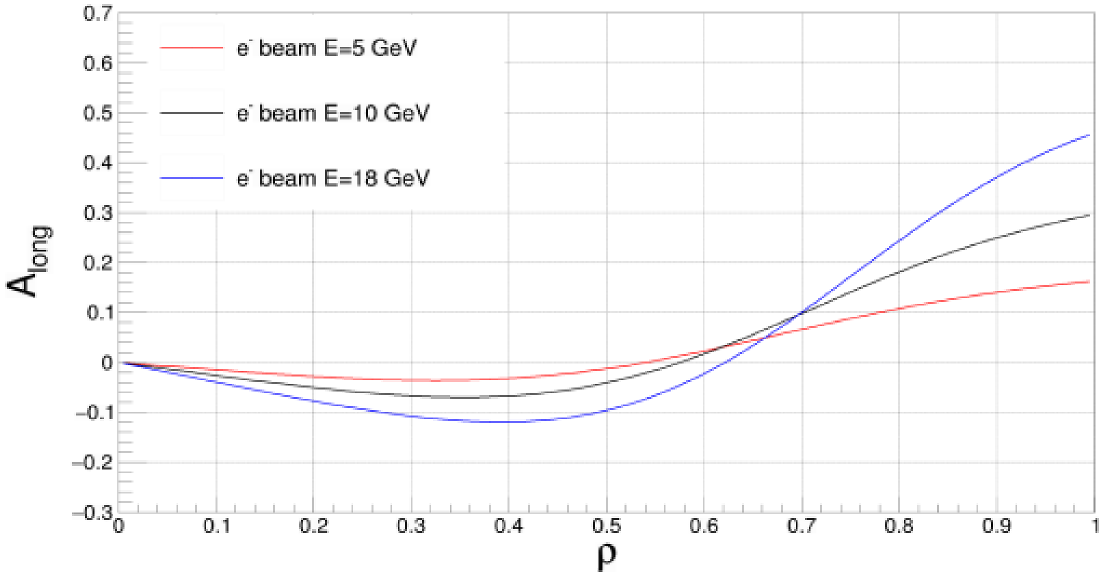
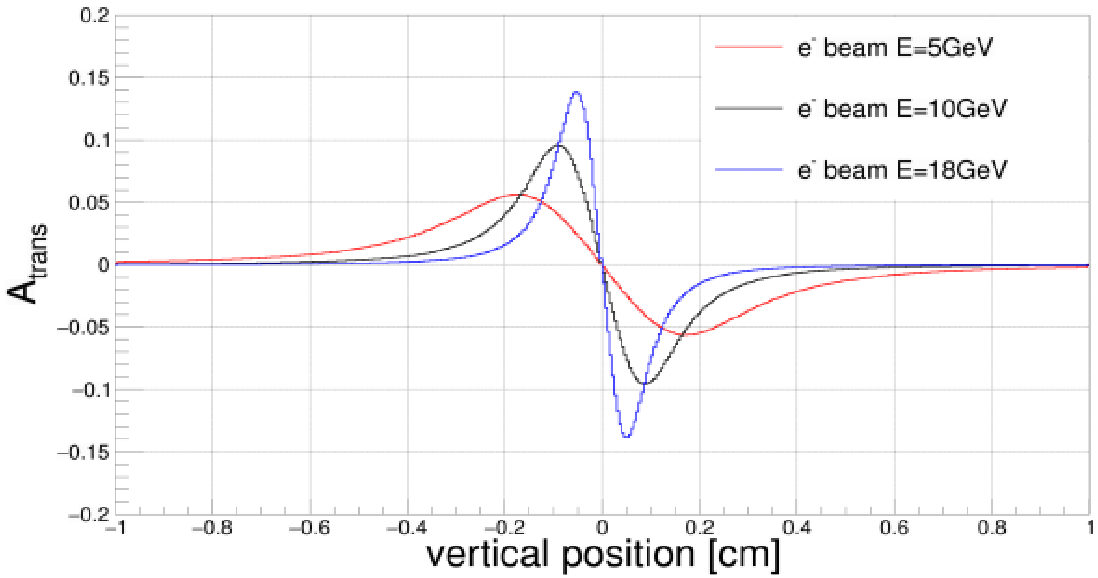
Belle II Collaboration Meeting – Polarimetry Upgrade Sessions
February 10, 2021

Apologies:
Most of the slides here are copied from other presentations I gave.
I did not have time to make a new set.

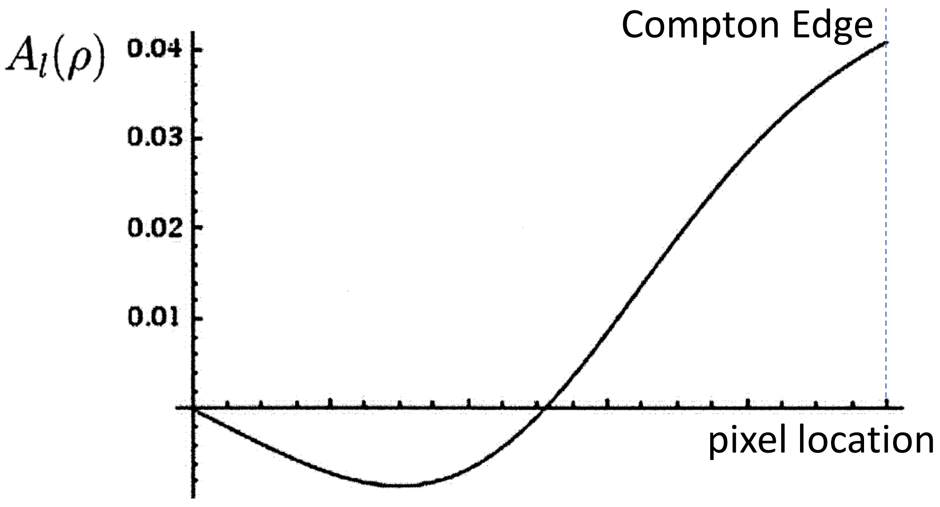
# Recap of the measurement:

Stole these from the EIC Yellow Report (I don't actually know what these look like for SuperKEKB)



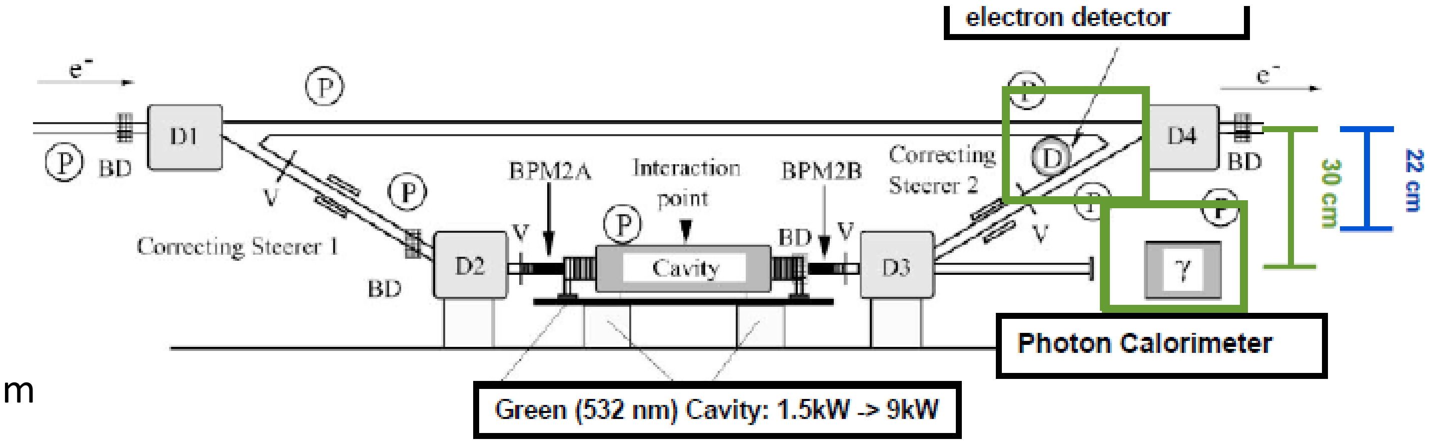

- For the electrons – energy is related to recoil momentum
- Measure scattered electron energy by dispersion in magnetic field
- Need to build a detector that can accurately measure electron position
- Either strip or pixel detector located close beam trajectory

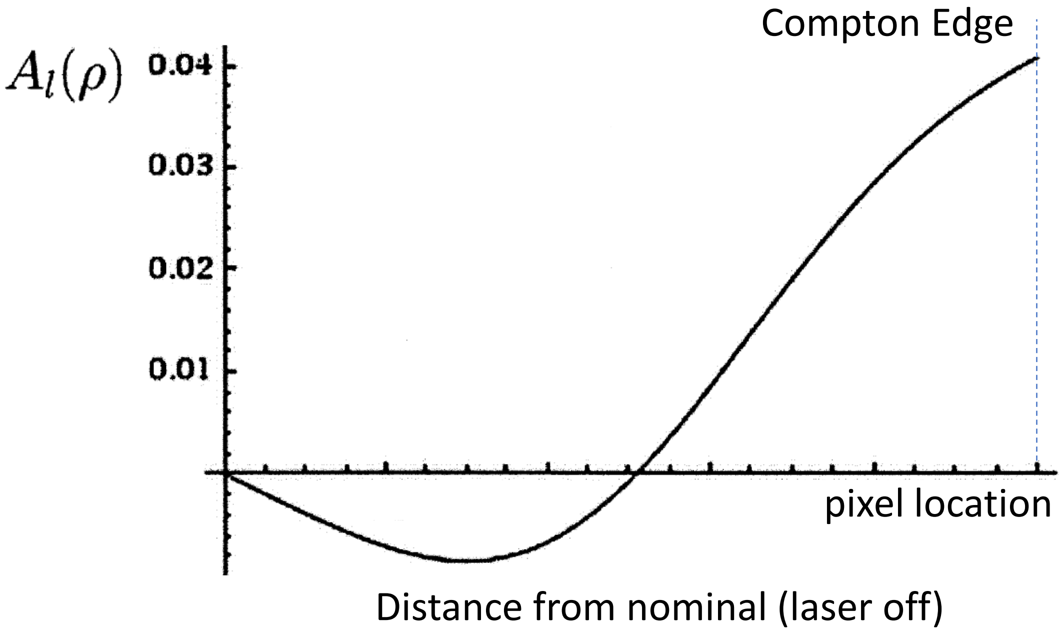



Distance from nominal (laser off)

Compton Polarimetry Work for JLab:

- Have to measure the polarization as a function of scattered photon and/or electron energy
- For the electrons – energy is related to recoil momentum
- Measure scattered electron energy by deflection in magnetic dipole field (D3)
  - Higher photon energy → lower electron energy
  - Lower electron energy → more bending away from primary beam
- Need to build a detector that can accurately measure electron deflection (distance away from primary beam at some specified distance)
- Either strip or pixel detector located close to the un-scattered (laser off) beam trajectory



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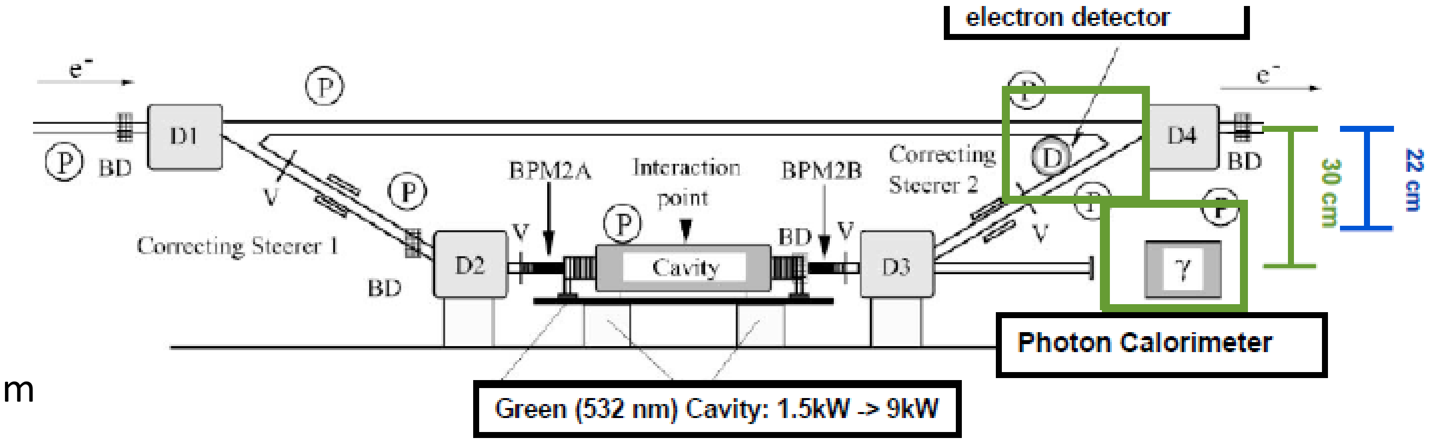
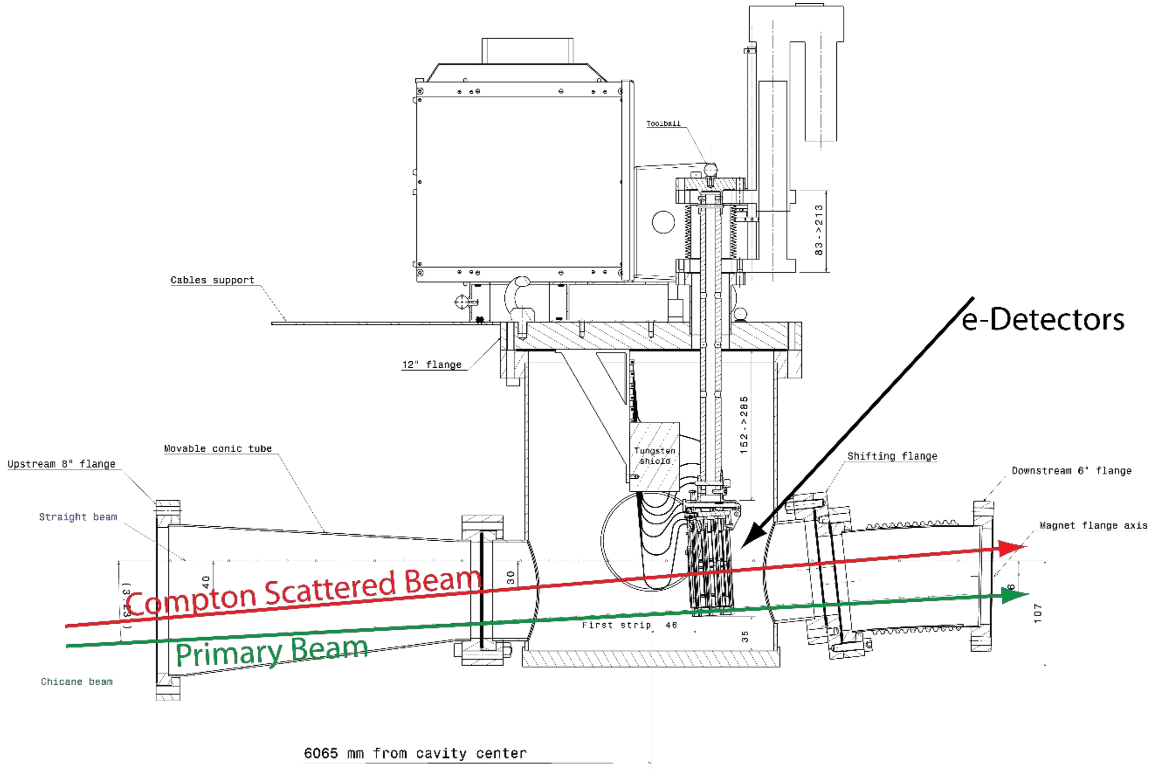
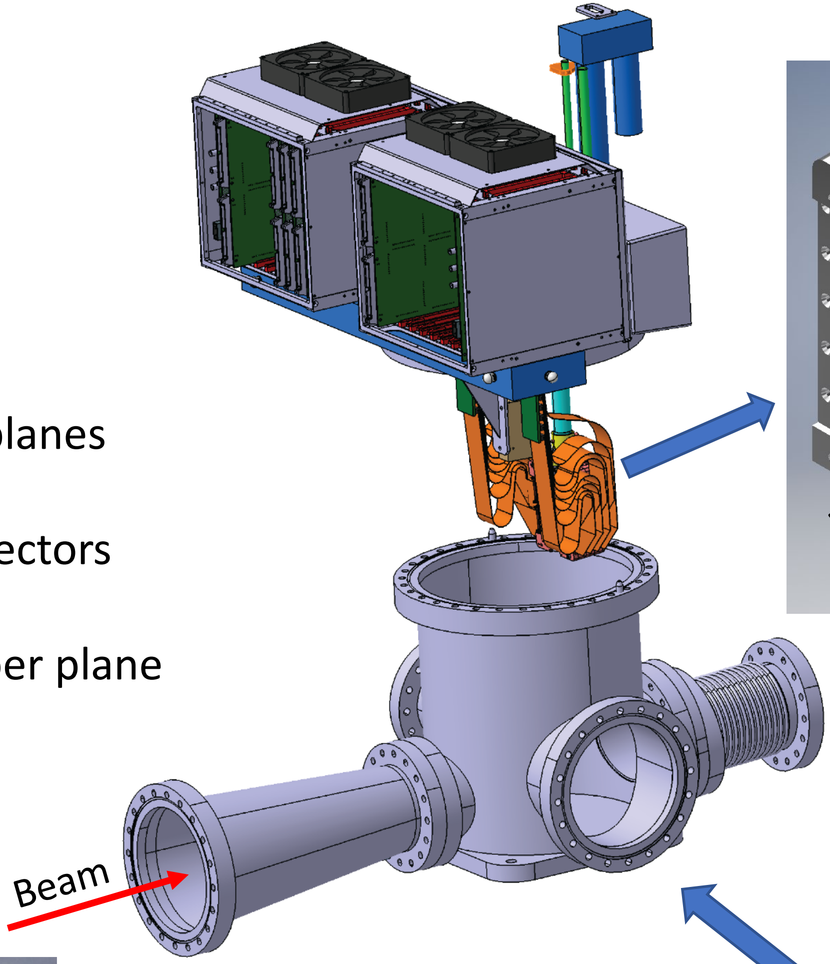


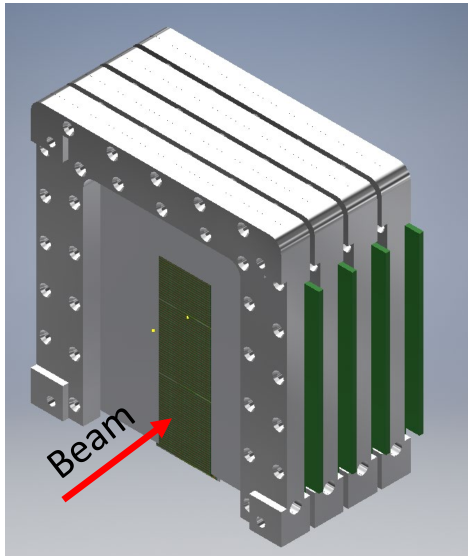



Compton Polarimetry:

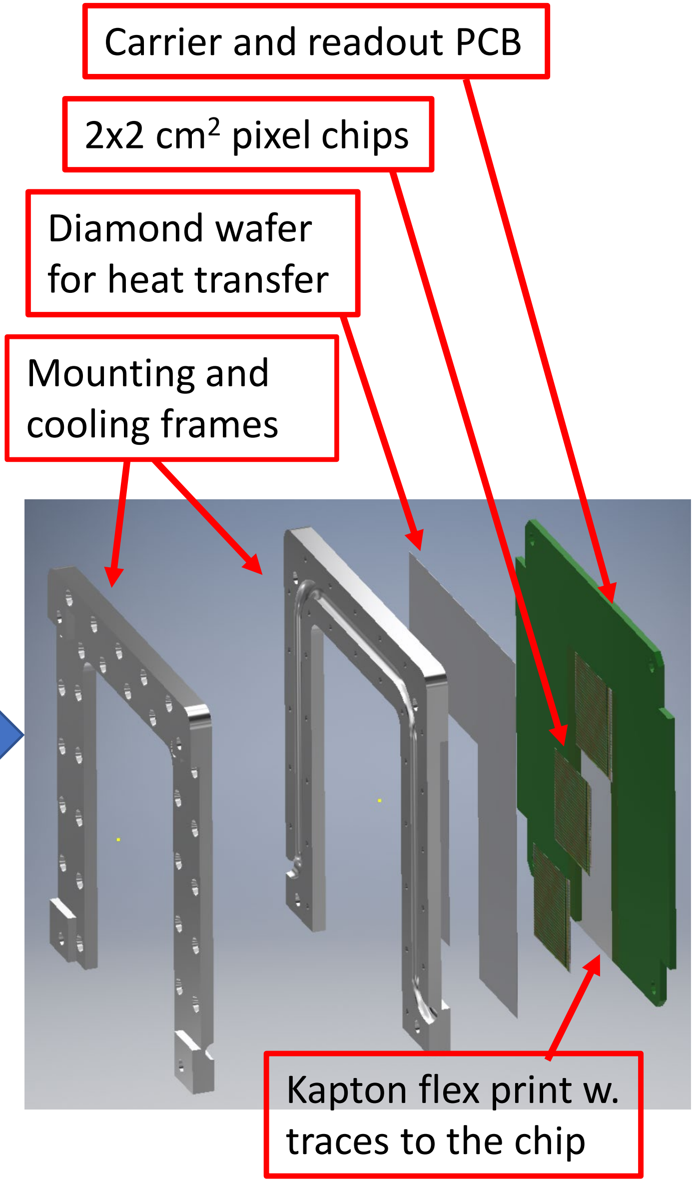
Electron detectors

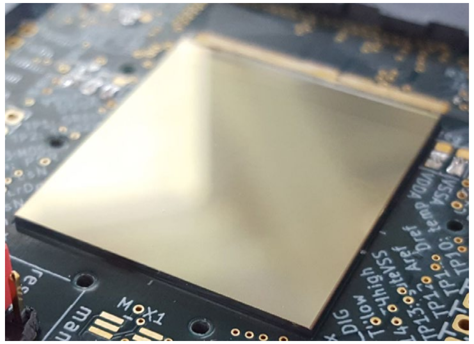
- 4 pixel detector planes
- HVMAP pixel detectors
- 3 2x2 cm$^2$ chips per plane
- 80x80 µm pixels

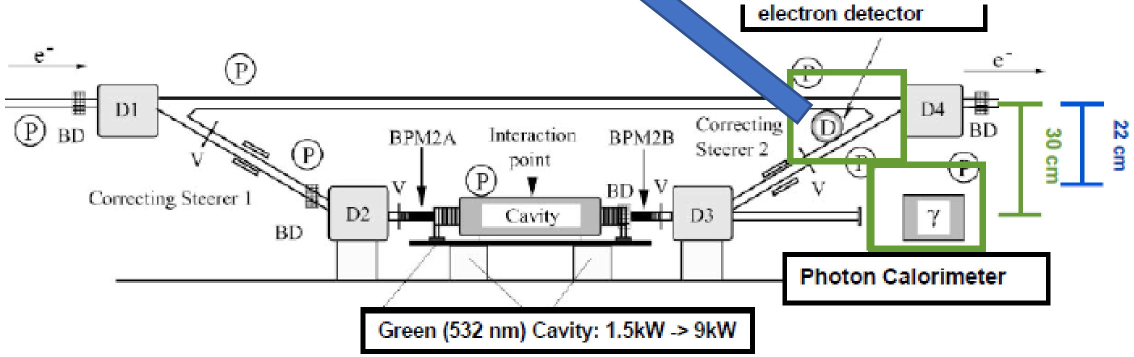



4 pixel planes together.
Each plane consists of



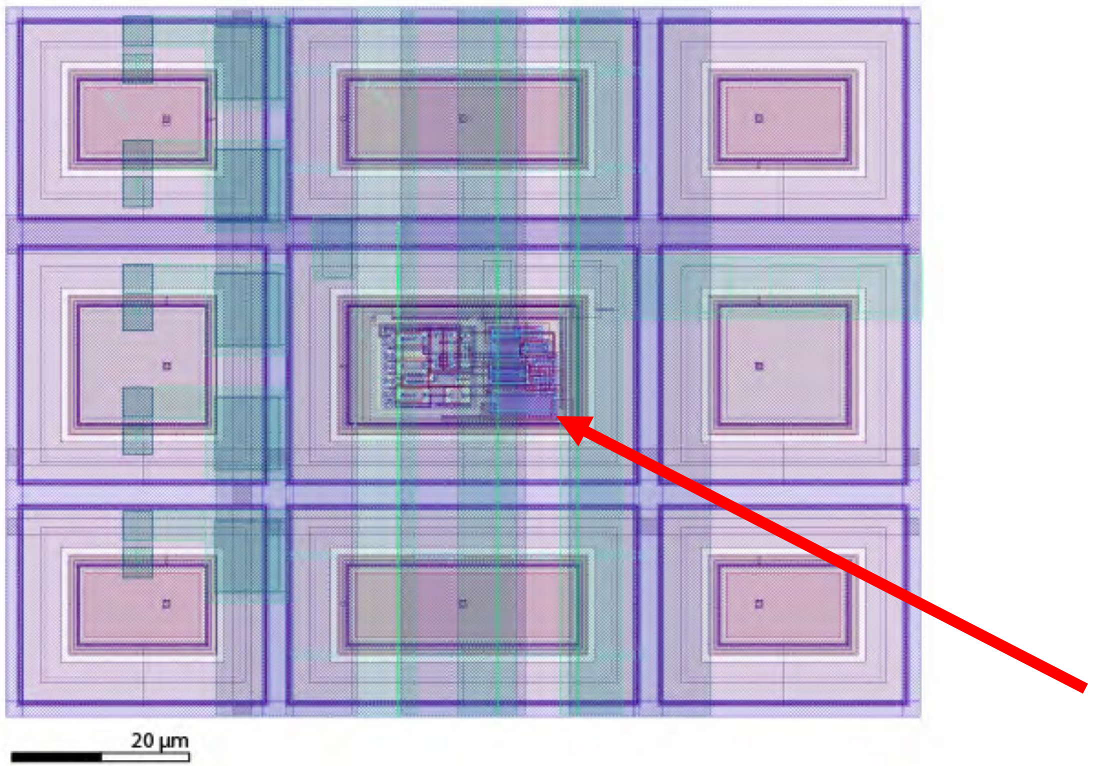



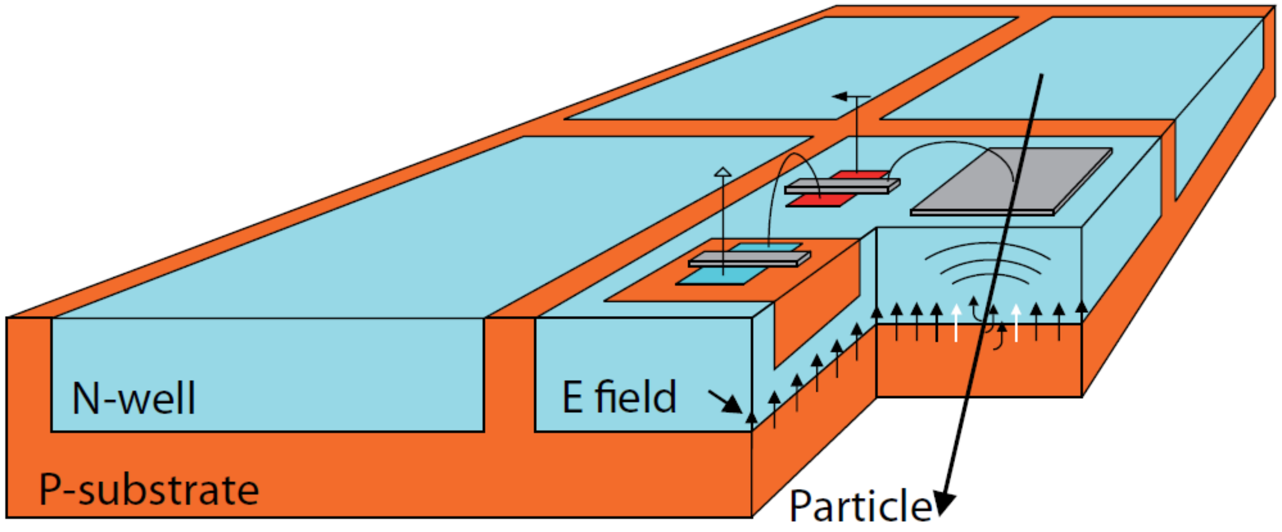


## Pixel Detector Design (by KIT, Heidelberg, Mainz)

High-Voltage Monolithic Active Pixel Sensors (HVMAPS)

- Combines the standard silicone diode with "in-pixel" electronics using the CMOS process
- Put amplification and current line driver into pixel
- Apply HV for each pixel:  ~60 - ~120 V
- Use chip thining down to < 50 µm



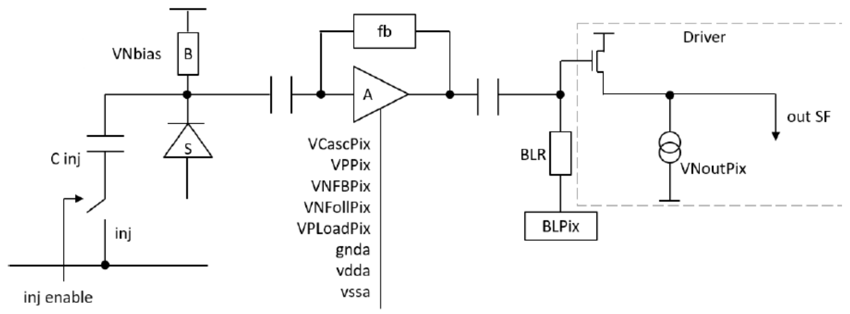




In-Pixel electronics

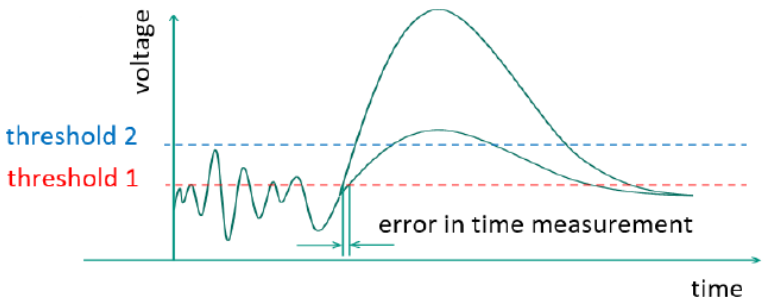
## Pixel Detector Design (Ivan Perić, Alena Weber, KIT)

- Pixel output is a an amplified voltage signal
- Pixel output driver is connected to the hit/readout buffer in the periphery
- Every pixel is connected to its own hit buffer cell
- Periphery circuitry does the following:
    - Timing measurement
    - Amplitude measurement
    - Address signal generation (for each pixel)
    - Storage (arrival time stamp 10 bit and 5 bit ToT)
    - Priority ordered readout
    - Hit bus signal generation
    - Readout logic (serializer etc.)

### In-Pixel Electronics

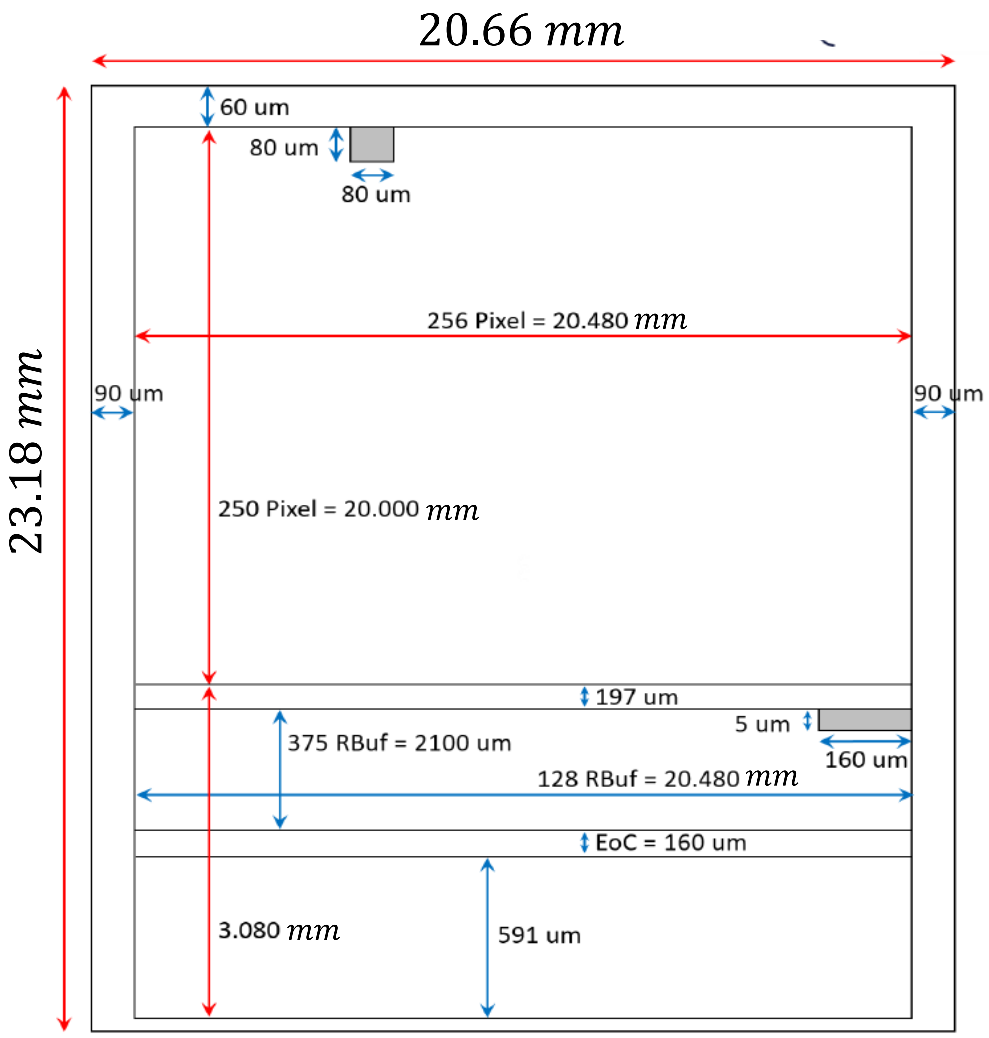


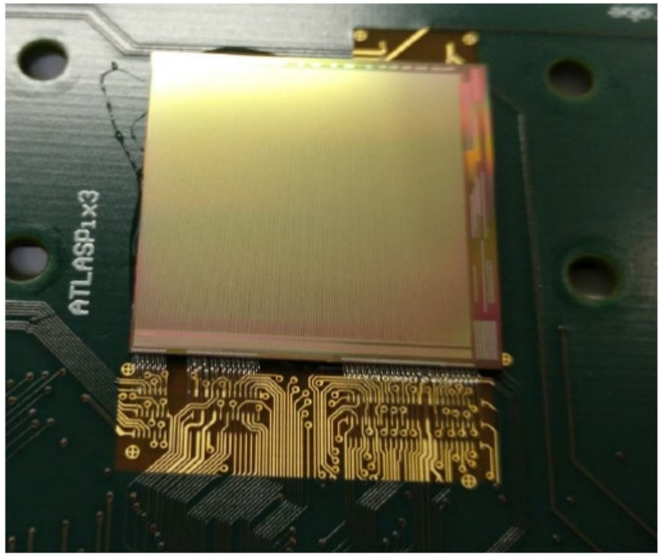

ToT
Arrival time



## Pixel Detector Design (Ivan Perić, Alena Weber, KIT)

- The final size of the individual chips is 2 cm by 2 cm
- Several of them are to be combined to form a plane of whatever size is needed




- Second version of full size chip (ATLASPix3 above was the first version)
- 64000 pixels per chip $(80\ \mu m \times 80\ \mu m)$

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## Main HVMAP Properties

- Pixel Segmentation (rather than just strips) could help with background rejection (pattern)
- Heating: $\sim 300\ mW/cm^2$ (chips work up to $\sim 70°C$)
- Detectors are radiation hard:
  - 862 Mrad X-ray
  - $10^{15}$ n/cm$^2$ (neutrons or protons)
- Detectors can work up to ~90 MHz/cm$^2$ – theoretical up to 1 MHz per pixel, but there are readout limitations and whether there are deadtime losses (or how much) is very much dependent on the image pattern on the detector (have to know the rate distribution to tell).
- From beam tests, the detectors are known to work at 6 MHz in a ~500x500 $\mu m^2$ (~7 × 7 pixels) beam spot with a deadtime loss of $10^{-6}$ .
- Time resolution: $\sim 11\ ns$
- Can be thinned to less than $50\ \mu m$

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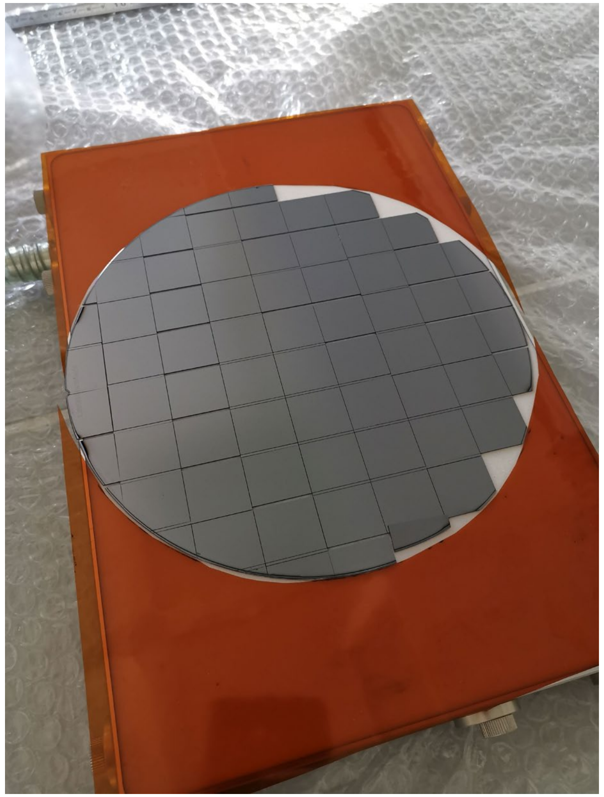
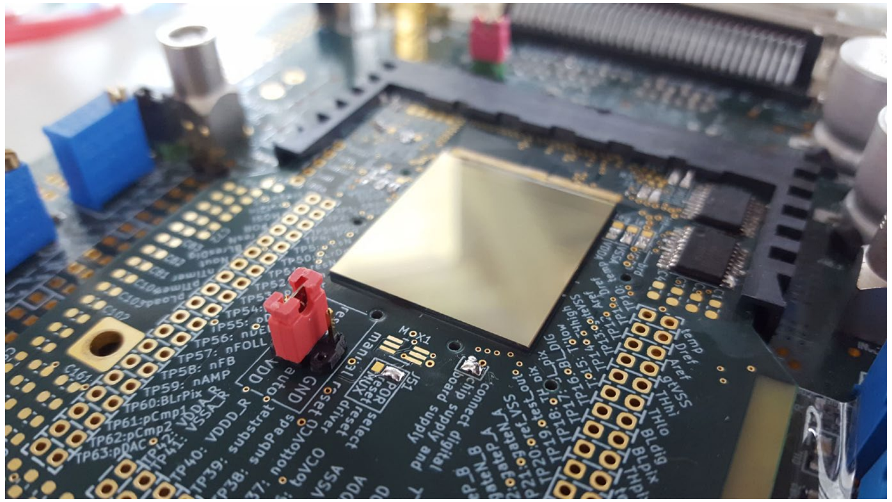
## HVMAP Development and Implementation

- The MuPix HVMAP development was started for Mu3e and ATLAS
- Experiments that will use/implement the chip include Mu3e,  PANDA, P2, and MOLLER
- U. Manitoba group participated in MuPix 10 engineering run with CAD 40k contribution, which provides 2 waver. So we have about 72 chips.
- Plan to use these for prototype development and final implementation for the JLab MOLLER Compton
- Requires In-Vacuum operation
    - Redesign of the carrier board (with removal of most components used on prototype)
    - Extensive testing of cooling methods and noise behavior
    - Mounting and feedthrough design (does the SuperKEKB detector need to retract?)
- Additional funding we have will pay for additional participation in engineering runs and production of full JLab implementation. What we learn should carry over to SuperKEKB.
- Final implementation for SuperKEKB (if this technology is used) would come from a Canadian SuperKEKB grant.

## Work at U. Manitoba

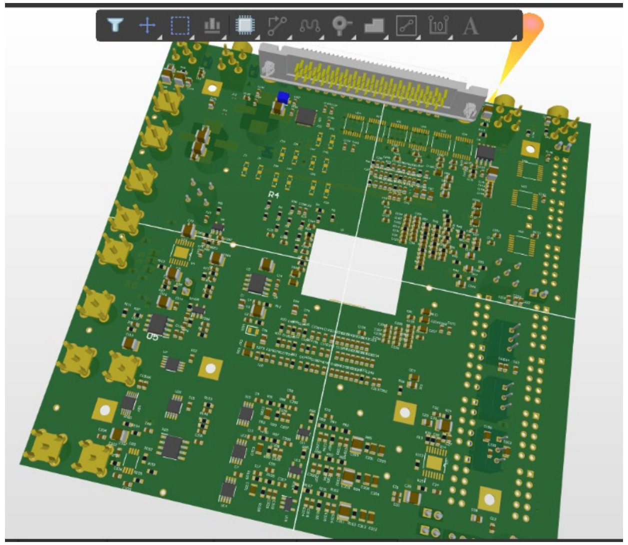
- Version 10 of HVMAP chip on hand (version 11 is in preparation)
- Raw chips from manufacturer shown on upper right; post-processed and thinned chips (50 $\mu m$) shown on lower right
- Functional testing of these is in progress.
- We have a prototype carrier board and are testing it
- Preparing for in-vacuum cooling concept testing
- We will be using off-the shelf FPGA boards (in-hand) for data processing and chip control
- Working FPGA firmware exists – continue to develop
- Planning to have the first full prototype by Fall/Winter 2021
- Beam tests at JLab scheduled for 2022

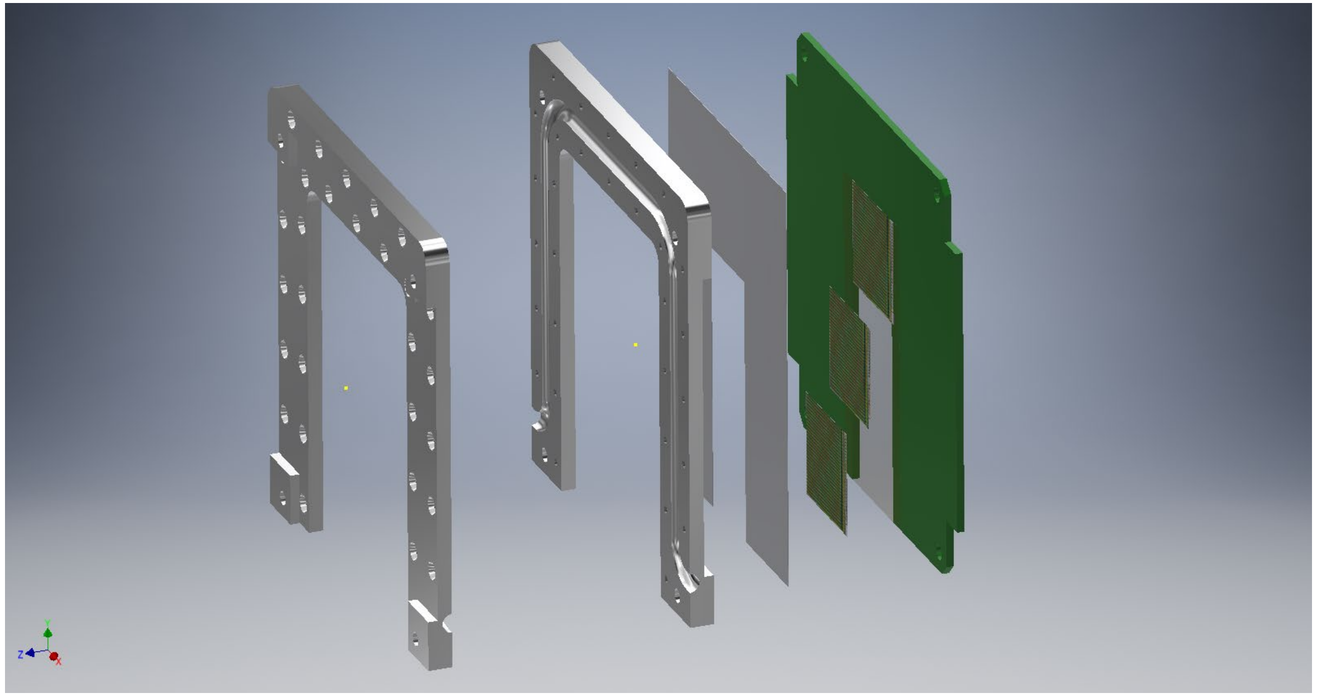


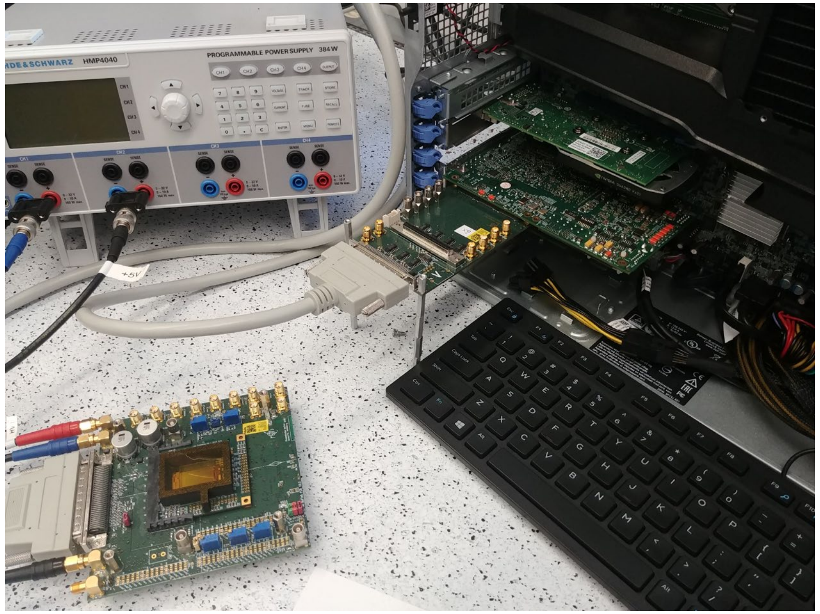


# Work at U. Manitoba

- The detectors need a carrier PCB to interface the chips with
- Currently have a prototype design
- Need to reduce the number of components on the prototype to reduce power consumption
- PCB needs to be attached to a mount that allows in vacuum cooling







## Additional Questions I have:

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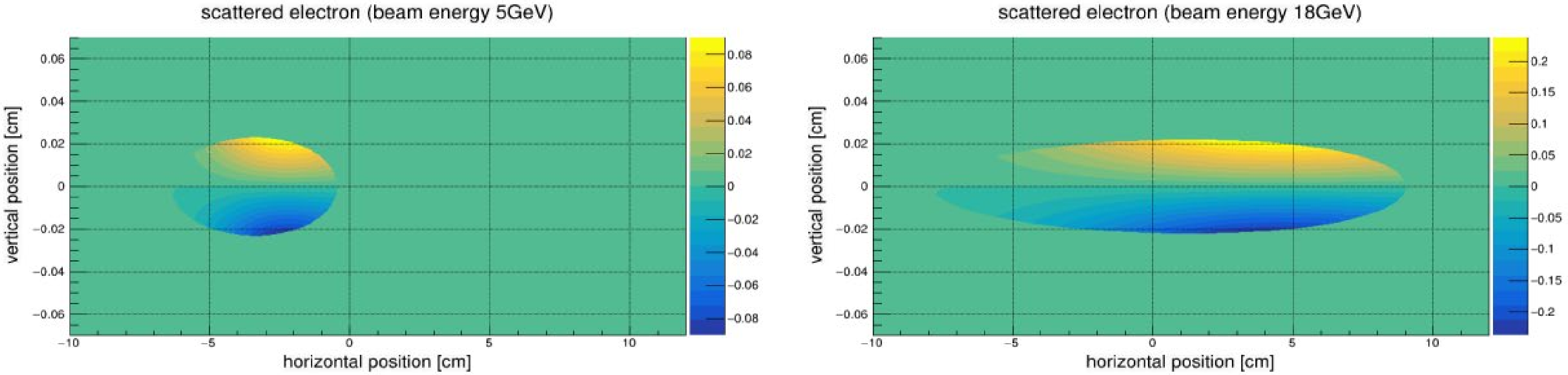


- The above graphs are for transverse polarization. Is this planned for SuperKEKB ?
- Separation is very small. What would this be for SuperKEKB ?
- What is the strip/pixel resolution requirement for SuperKEKB ?
- 4 ns bunch separation is very short – what do we expect for the electron rates ?
- What is the rate distribution for longitudinal measurement ?

**Thank You!**