

# The DIRC Program at Jefferson Lab



Wenliang (Bill) Li (WMU) and Jochen Schwiening (GSI)

on behalf of the GlueX DIRC group

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INSTR'20, Novosibirsk



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Technology

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# Outline

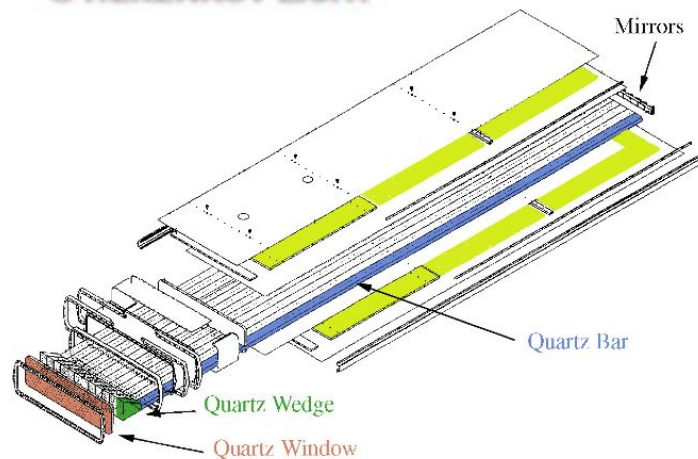


- Introduction
- Installation
- Commissioning
- Initial Experience
- Initial Performance

## DIRC



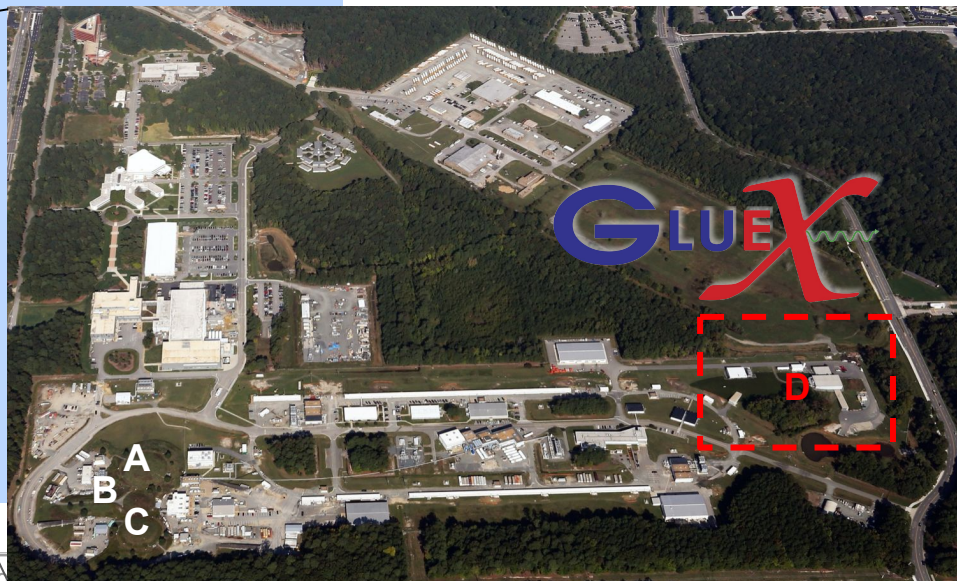
D E T E C T I O N O F  
I N T E R N A L L Y  
R E F L E C T E D  
C H E R E N K O V L I G H T



# Jefferson Lab

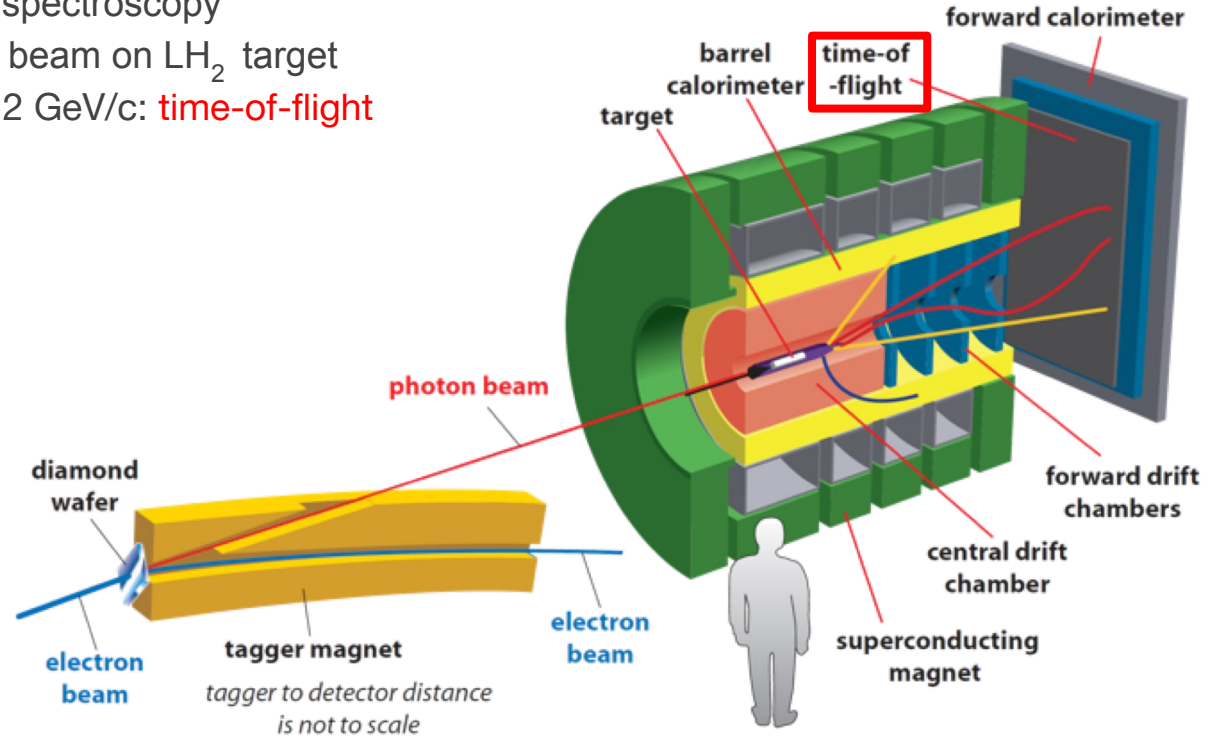
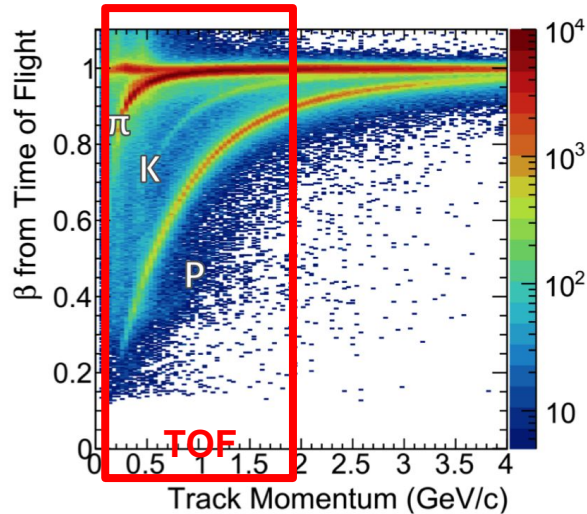


- **Jefferson Lab, Newport New, VA**
  - CEBAF
  - Experimental hall A, B C and **D**
- **Hall D hosts GlueX experiment:** tagged coherent photon beam up 12 GeV (5.5 pass)



# GlueX Experiment at Jefferson Lab: GlueX I

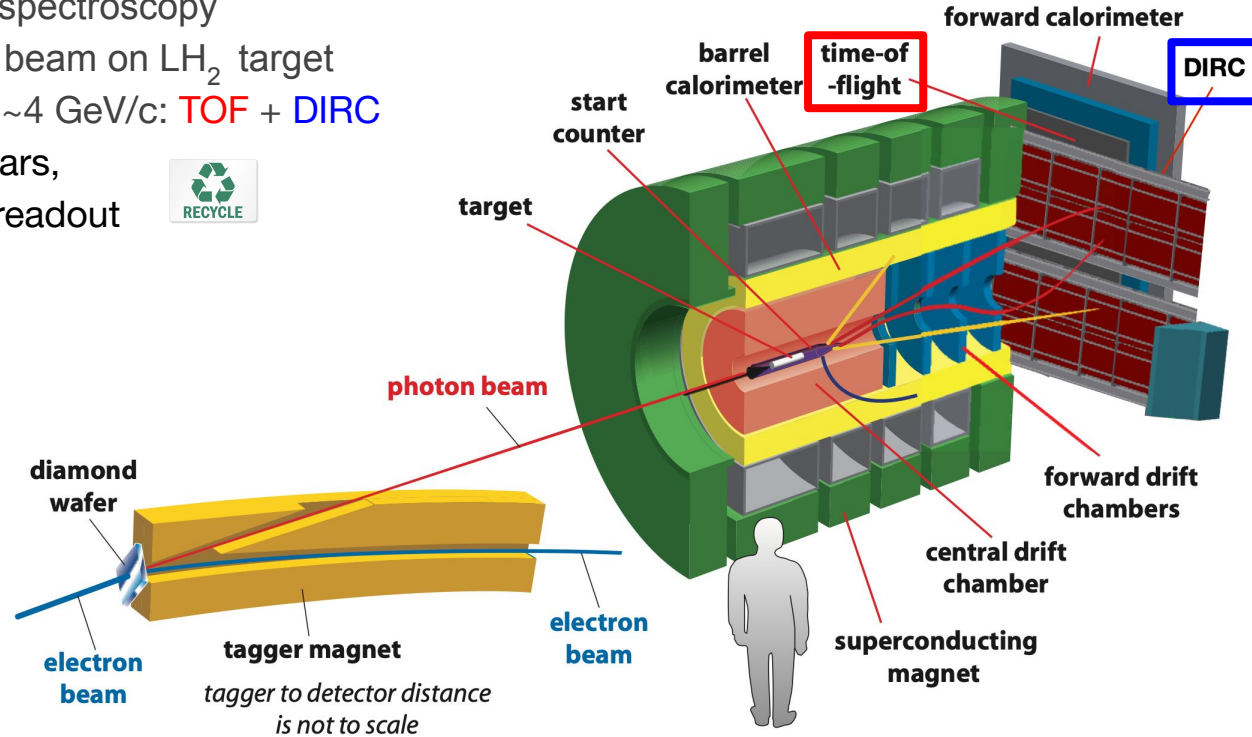
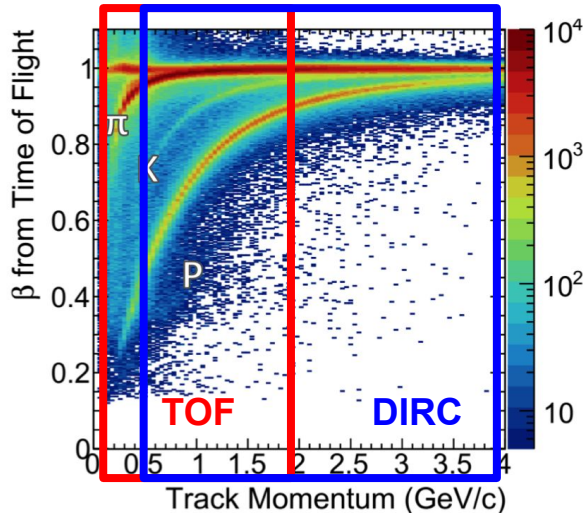
- GlueX I: Sep 2016 - May 2019
- Designed for light quark meson spectroscopy
- 9 GeV linearly-polarized photon beam on LH<sub>2</sub> target
- Baseline  $\pi/K$  separation up to  $\sim 2$  GeV/c: **time-of-flight**





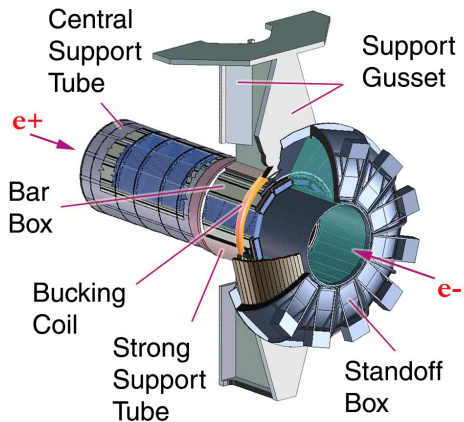
# GlueX Experiment at Jefferson Lab: GlueX II

- GlueX-II is already ongoing right now (Since Jan, 2020 )
- Designed for light quark meson spectroscopy
- 9 GeV linearly-polarized photon beam on LH<sub>2</sub> target
- Upgraded  $\pi/K$  separation up to  $\sim 4$  GeV/c: **TOF** + **DIRC**
- Reusing  $\frac{1}{3}$  of the BaBar DIRC bars, combined with new optics and readout



# DIRC Barbox Transportation (SLAC to JLab)

## BaBar DIRC Detector



## DIRC Bar Box Storage at SLAC



## On the Road in New Mexico



## A long and very, very careful drive



## DIRC Bar Box in Hall D

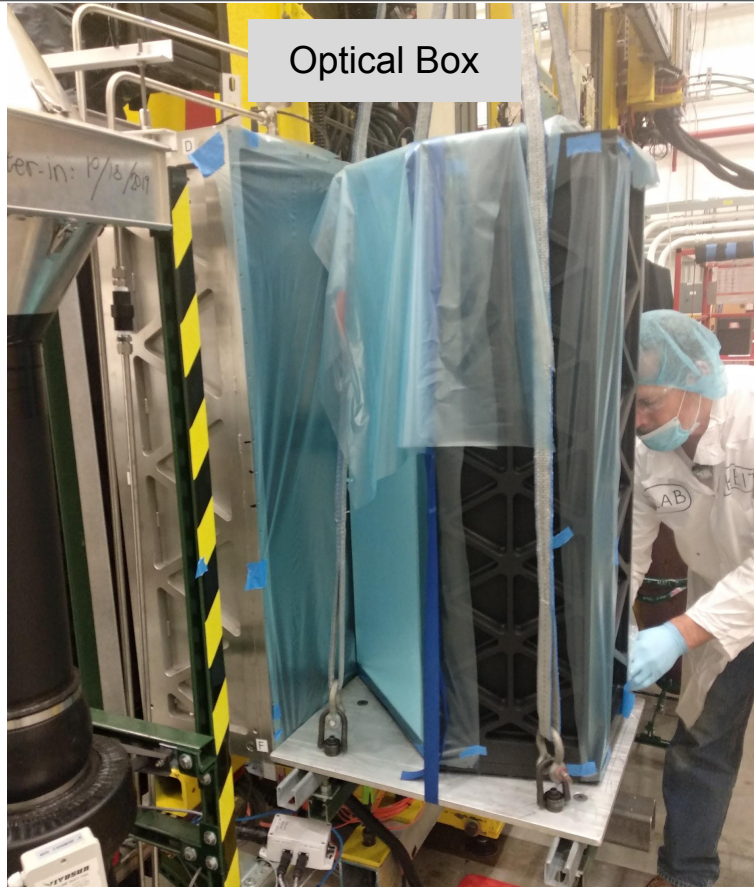


## 3000 miles later at JLab





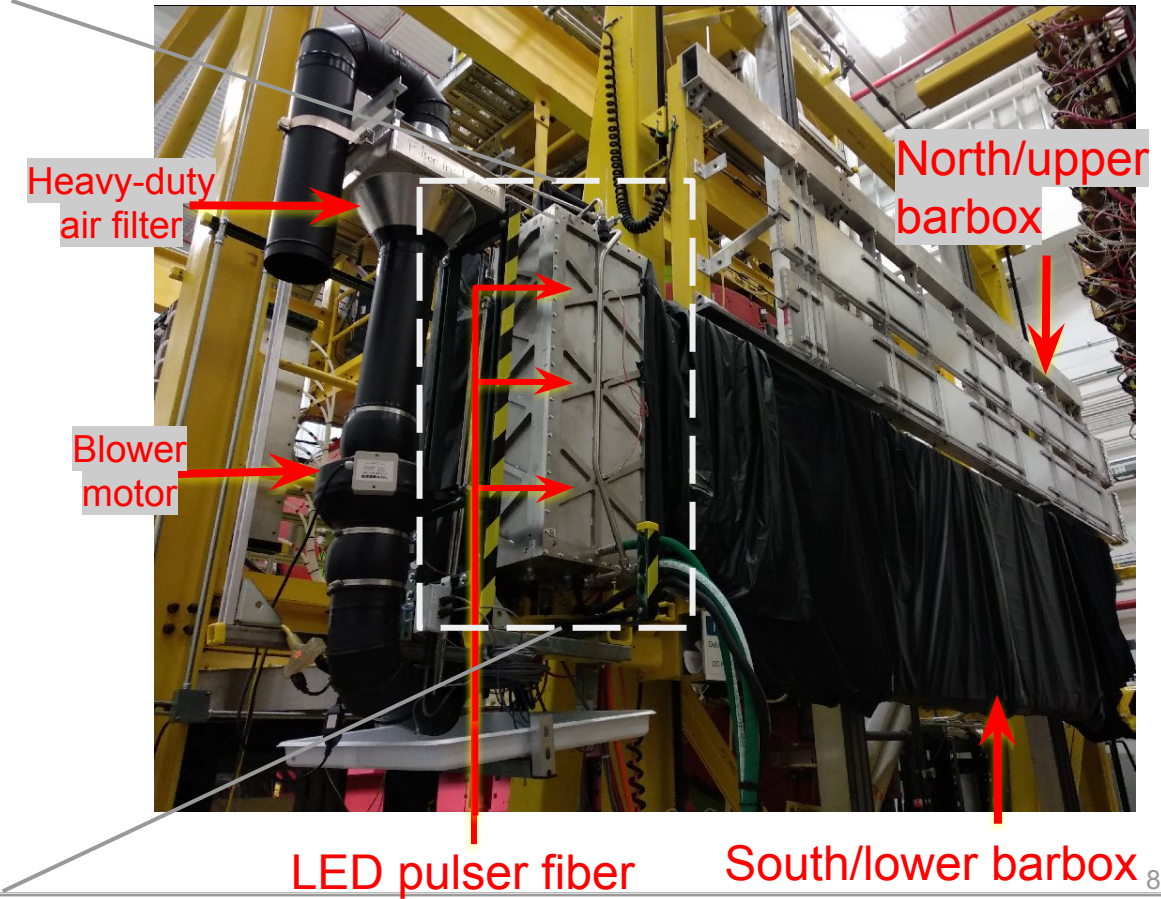
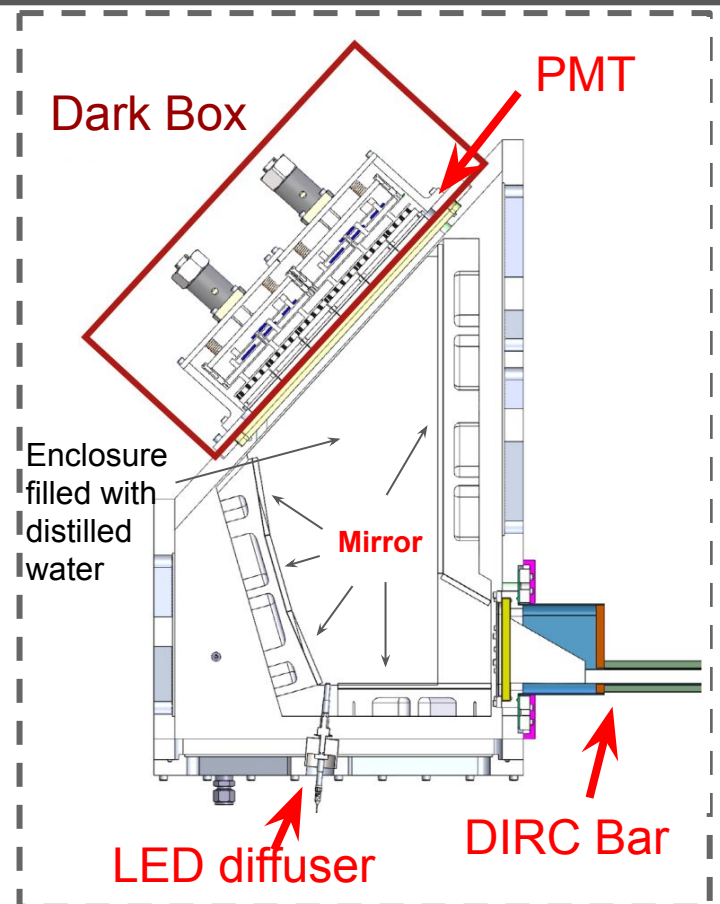
# GlueX DIRC Status



- **Installation timeline**

- First DIRC bar transportation: Nov. 2017
- Remaining DIRC bars transportation: June 2018
- Lower box assembly and installation: Jan./Feb. 2018
- Upper box assembly and installation: Nov. 2018
- DIRC commissioning: Feb. 2019 and Dec. 2019
- GlueX II is taking data with the DIRC right now

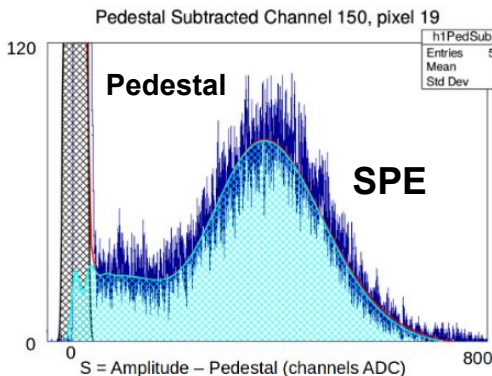
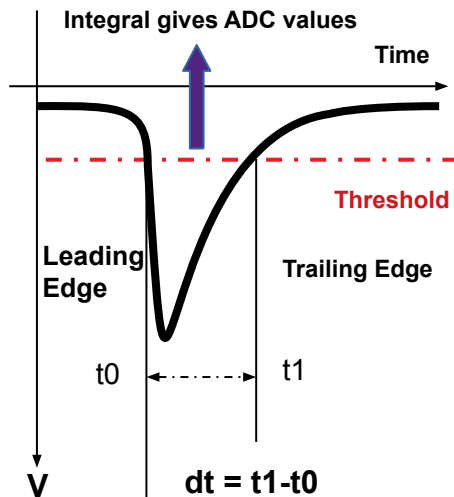
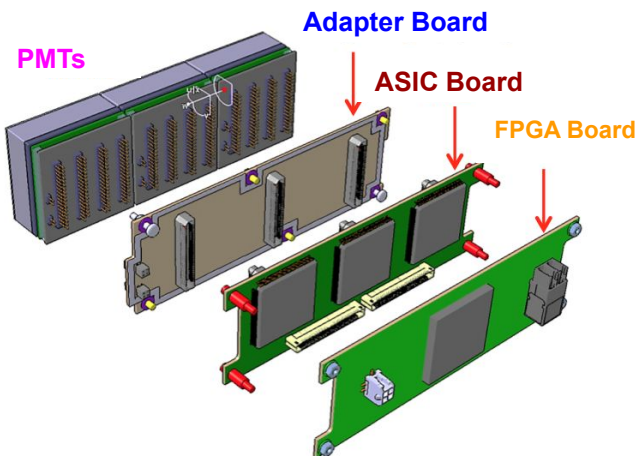
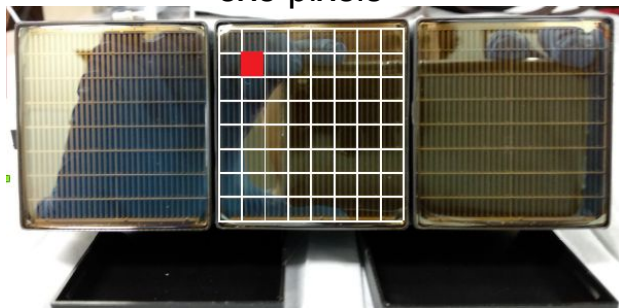
# GlueX DIRC Detector - installed in Hall D





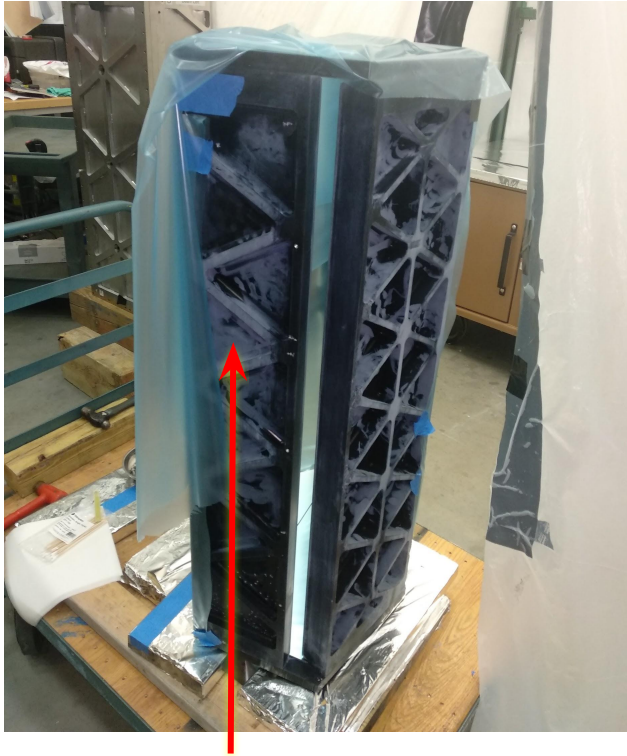
# DIRC Sensors and Readout

Hamamatsu H12700 MaPMT  
8x8 pixels

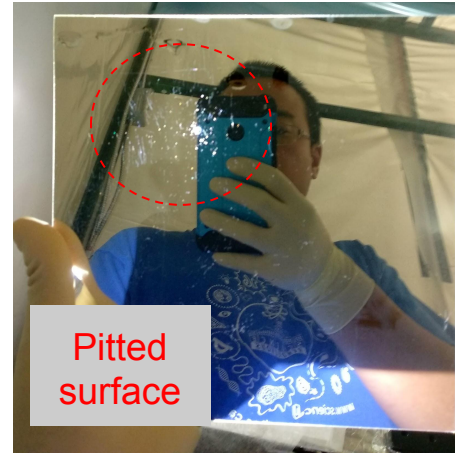


- DIRC PMT Assembly
  - Based on MAROC readout (CLAS 12 RICH)
  - 72 Modules (3 PMTs per module)
  - 11520 channels in total
- Component:
  - **FPGA board**: communication with DAQ, trigger for the laser pulse
  - **ASIC board**: signal processing gives leading and trailing time (ToT), ADC
  - **Adapter board**: PMTs, HV
  - **PMT**: 2 or 3 H12700 PMTs per module
- DAQ:
  - Fiber optics used to transfer data
  - No ADC or TDC modules
  - Leading edge time ( $t_0$ ) and time over threshold (ToT) directly to DAQ

# DIRC Mirror: Reflective Surface Degradation



Type II anodized Al strongback in optical box. Coated with white cloudy residue after few months in water.



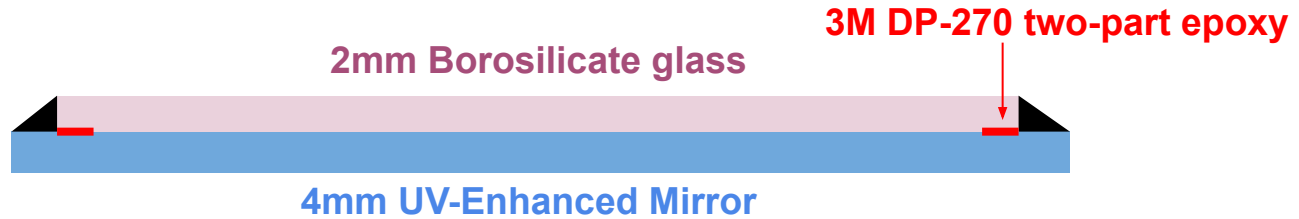
Pitted surface



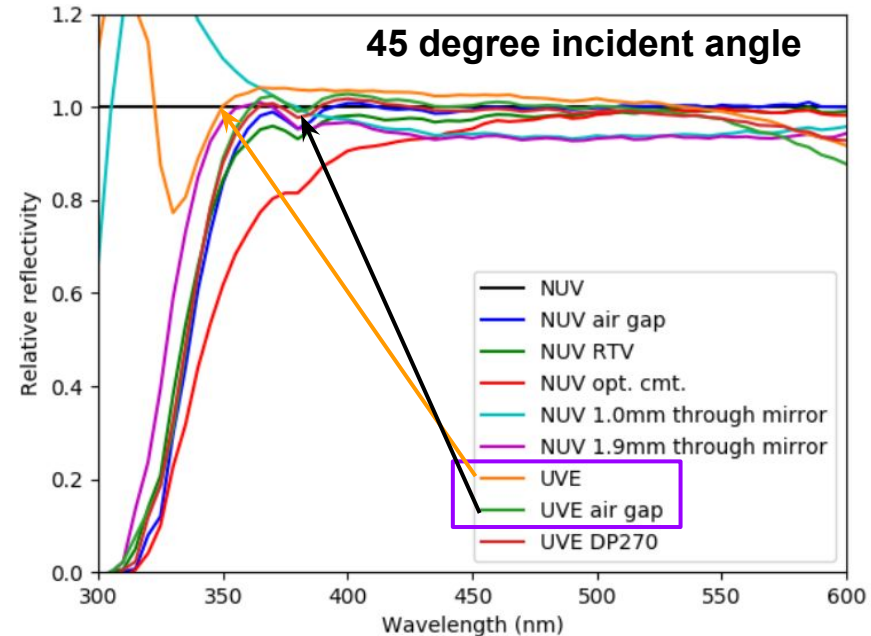
- South/lower box experience:  
Oct 2018 - May 2019, optical box suffered from degradation in water
- Mirror developed non-removable white traces
  - Reflective coating are pitted
  - White residue on the anodized surfaces

# DIRC Mirror: Solution

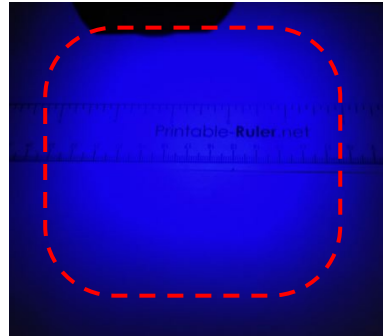
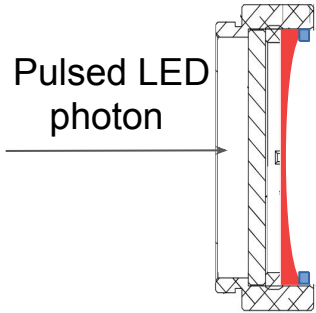
100% silicone sealant



- DIRC mirror configuration
  - Borosilicate glass protect the reflective surface
  - Edges are bonded by DP270 epoxy
  - Additional silicone sealant prevents water coming in via the edges
- Pros: long term stability in mirror surface quality
- Cons:
  - Losing up-to 5% (worst case scenario) reflective surfaces
  - Losing up-to 8% (worst case scenario) photon
- Impact to the geometric reconstruction is being studied



# DIRC LED Diffuser



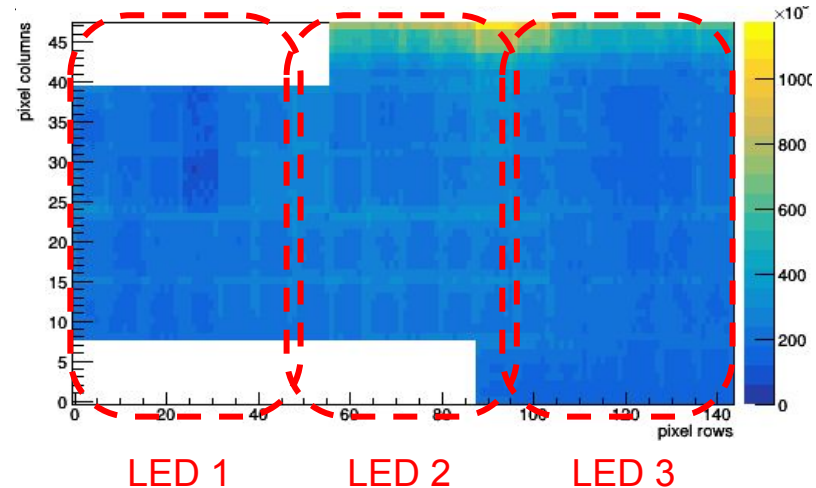
Square pattern

Each optical box: three LED fibers

- 50 Degree square diffuser
- Pulsed at 500 Hz during production
- 10ns delay for each fiber
- Live calibration, timing, monitoring



LED occupancy (three diffuser coverage)

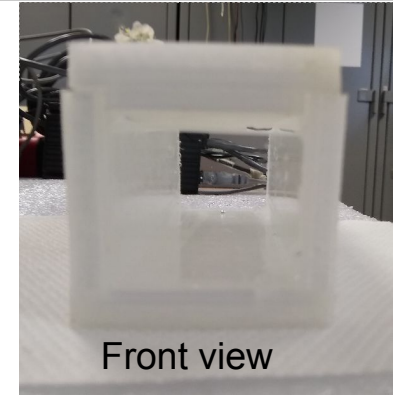
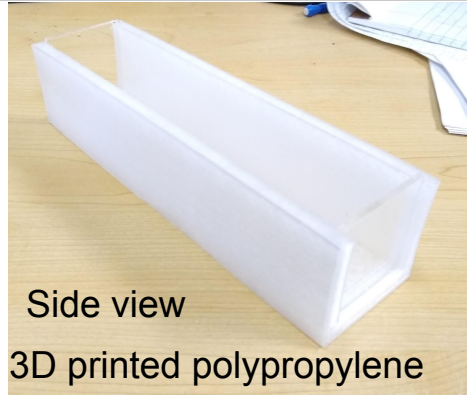
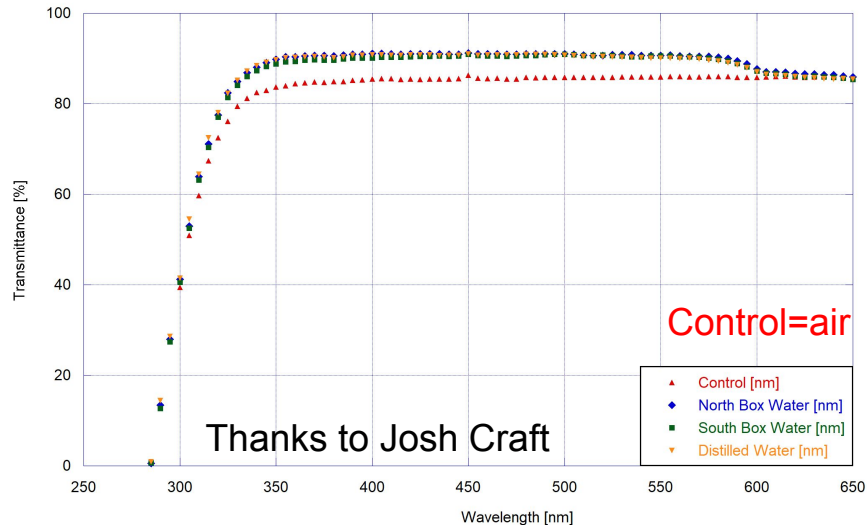




# Water Quality Monitoring throughout the Run

- First water transparency test
  - Sample date: Jan 21, 2020
  - South Lower box: water since Nov 13, 2019
  - North Upper box: water since Jan 2, 2020
  - North Upper box water transparency is fractionally better than the south box

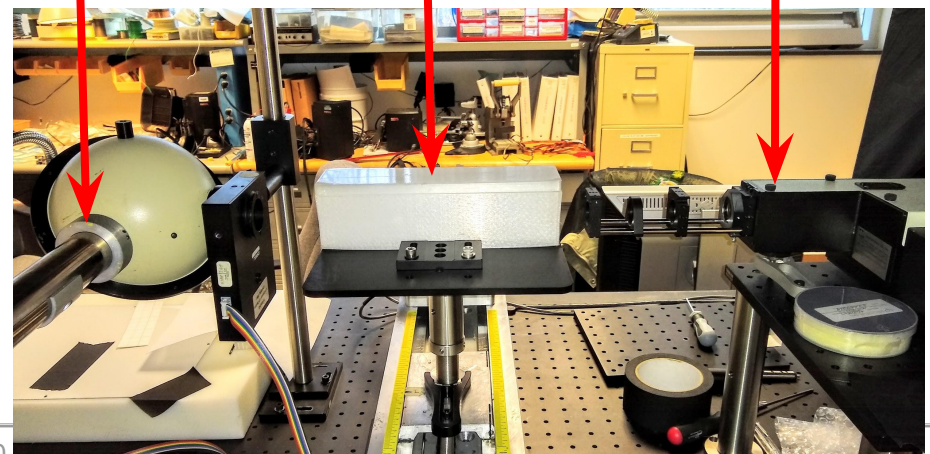
DIRC Water Transmission Comparison



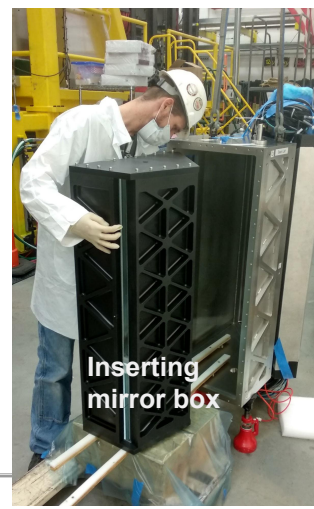
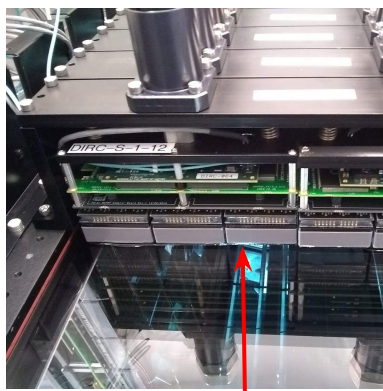
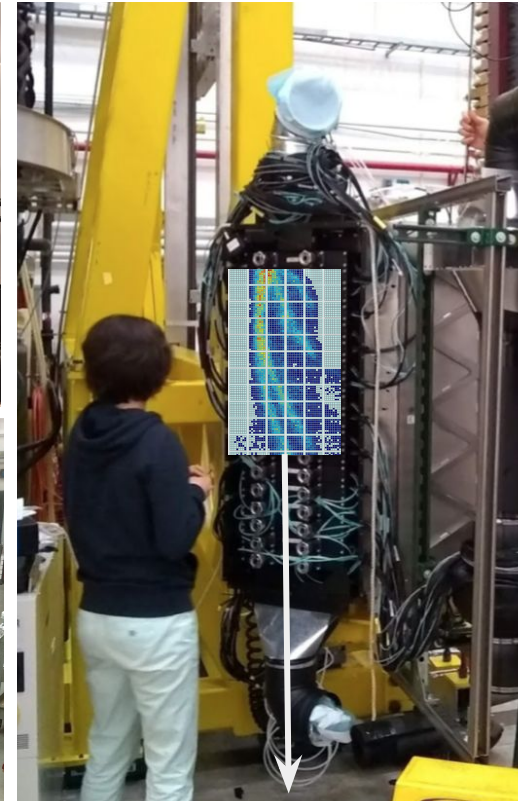
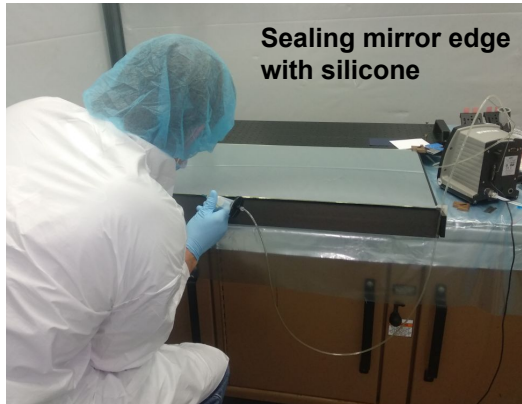
Detector

Water cartridge

Light Source



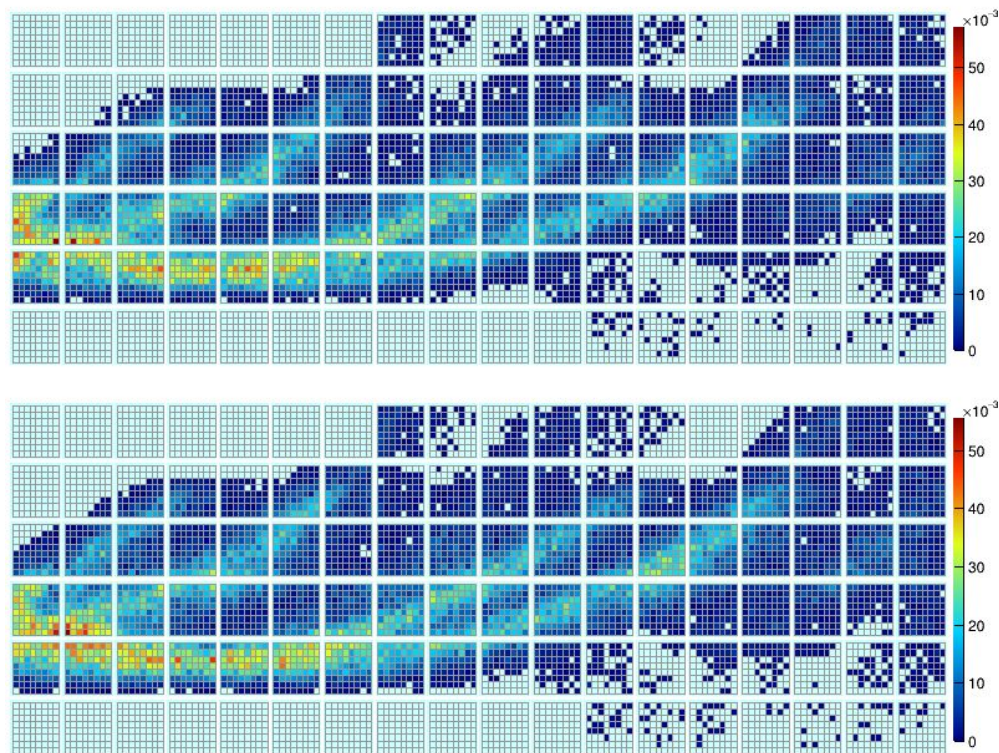
# Mirror and PMT Installation



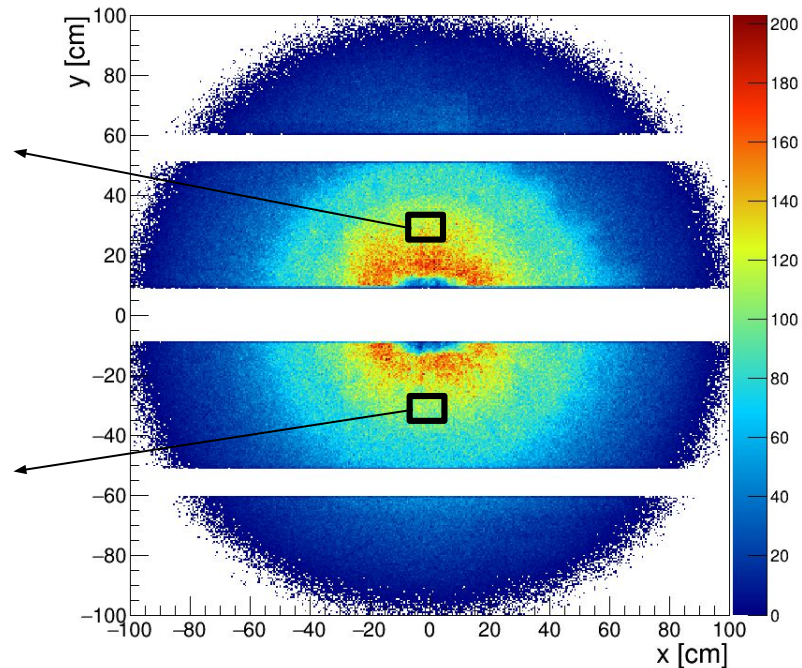


# Hit Pattern

pions, momentum  $>4$  GeV/c

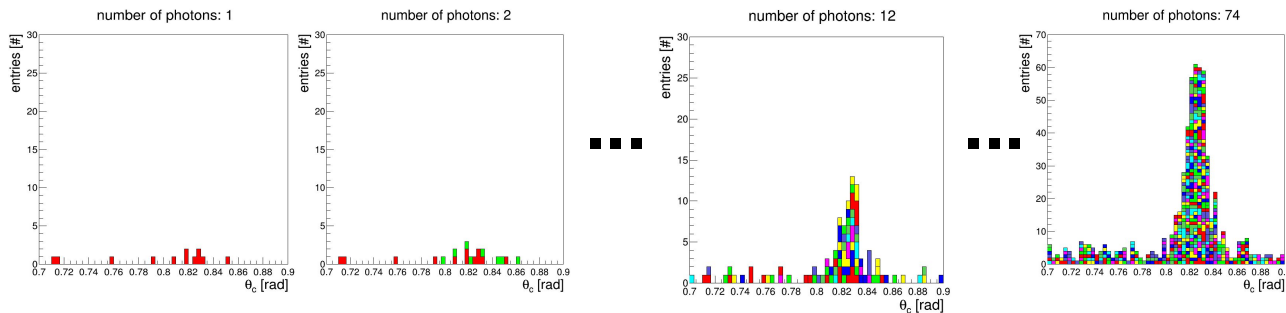


Hit position of the charged tracks on the radiator wall:

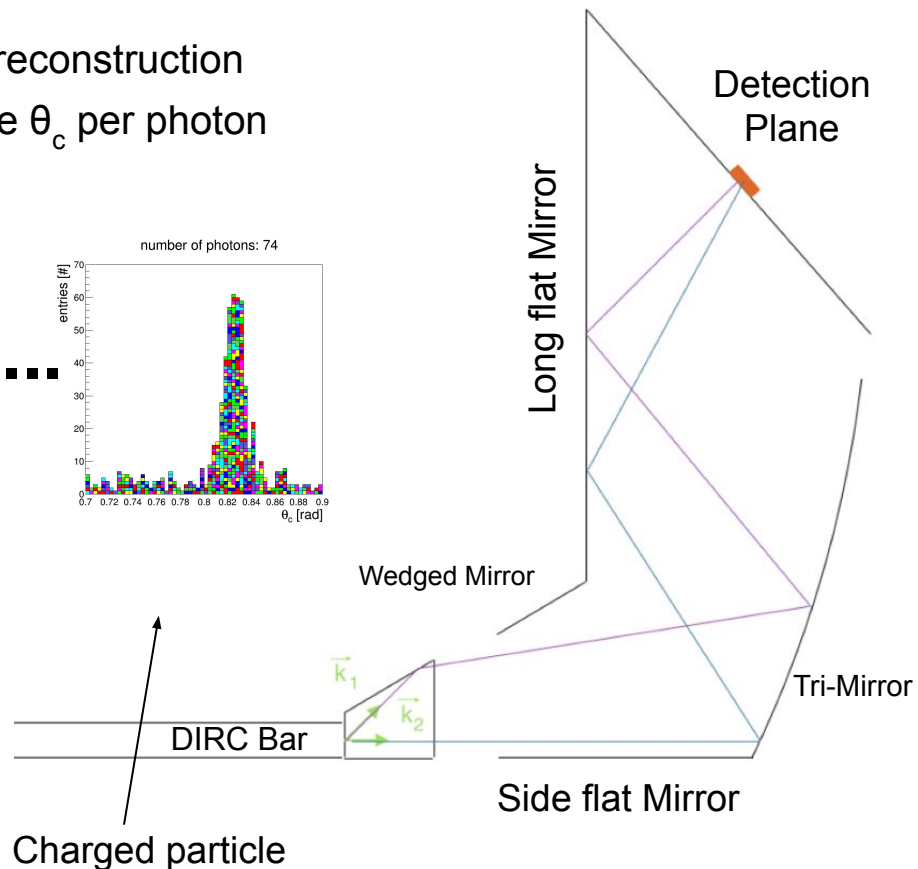


# Geometrical Reconstruction (LUT Method)

- Adapted from the BaBar and PANDA Barrel DIRC reconstruction
- Geometrical algorithm determines Cherenkov angle  $\theta_c$  per photon using Look Up Tables (LUT) from Geant simulation

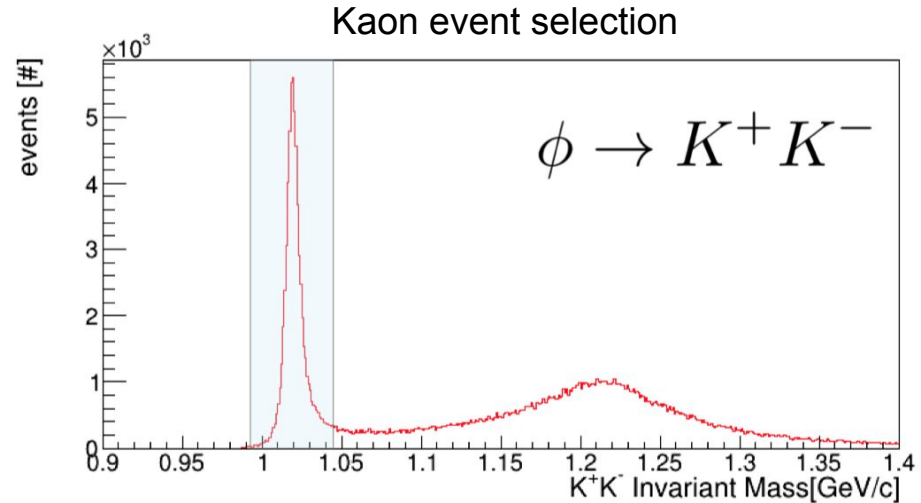
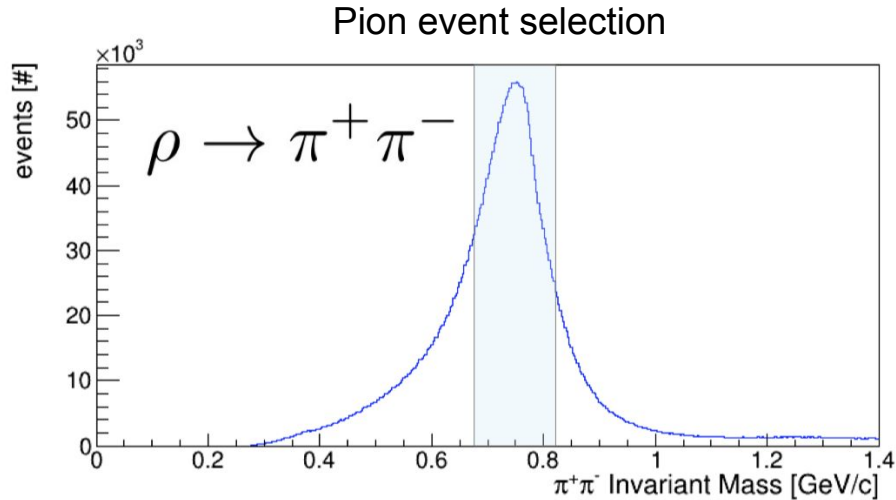


- PID performed by unbinned likelihood fit of the determined  $\theta_c$  using different mass hypothesis





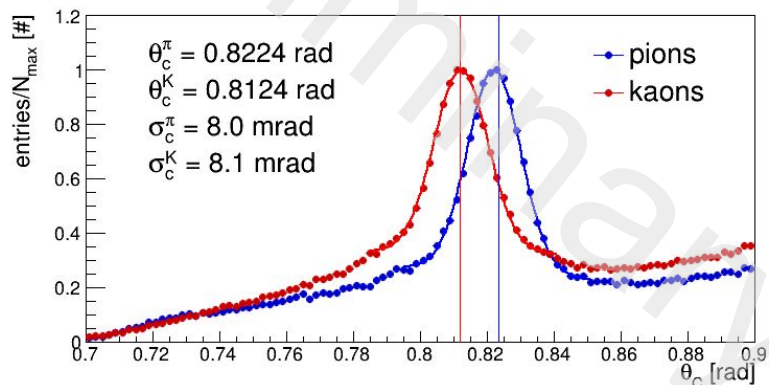
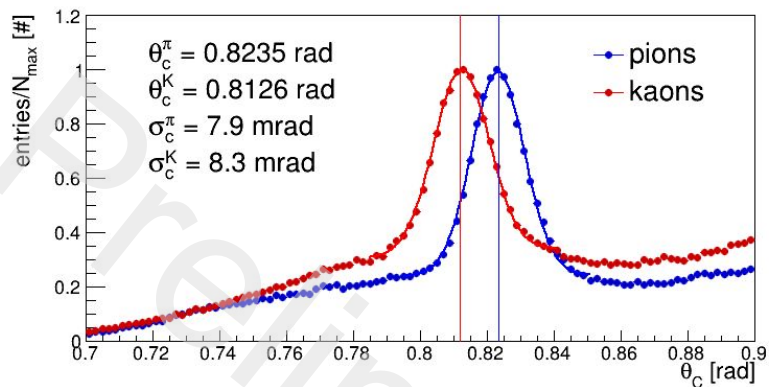
# DIRC Commissioning: Event Selection



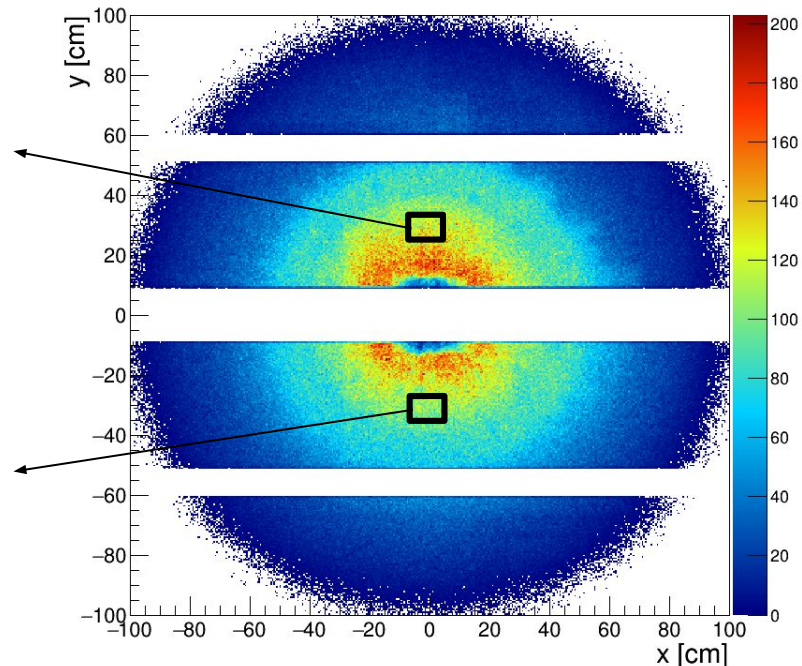
- February 2019: 10 days of GlueX beamtime with first (lower) half of DIRC installed
- December 2019: 16 days of GlueX beamtime with complete DIRC installed
- Samples of exclusive  $\rho$  and  $\phi$  production provide pure samples of  $\pi$  and  $K$  tracks for PID studies

# Single Photon Resolution (LUT Method)

pions / kaons @ 3 GeV/c momentum



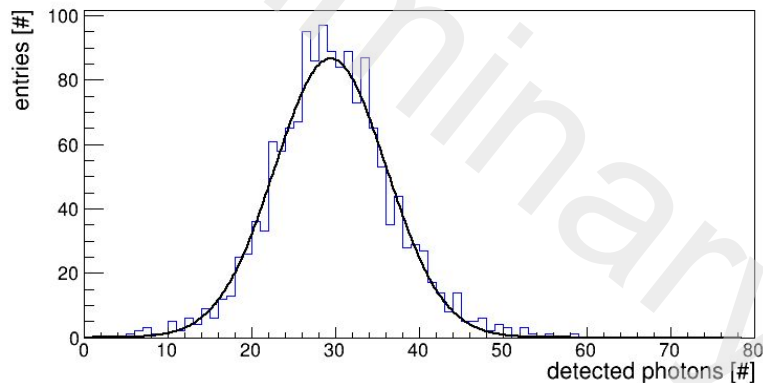
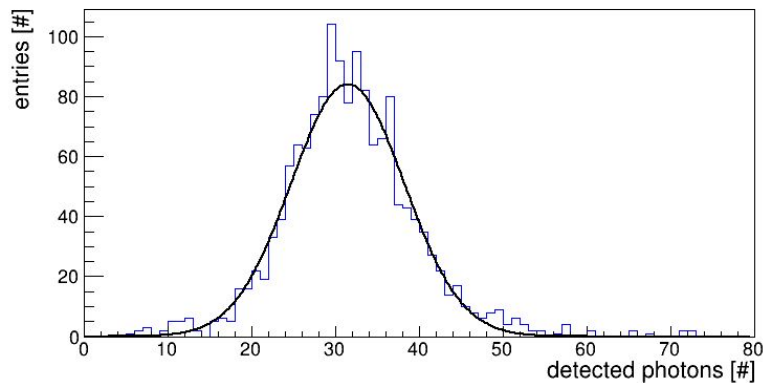
Hit position of the charged tracks on the radiator wall:



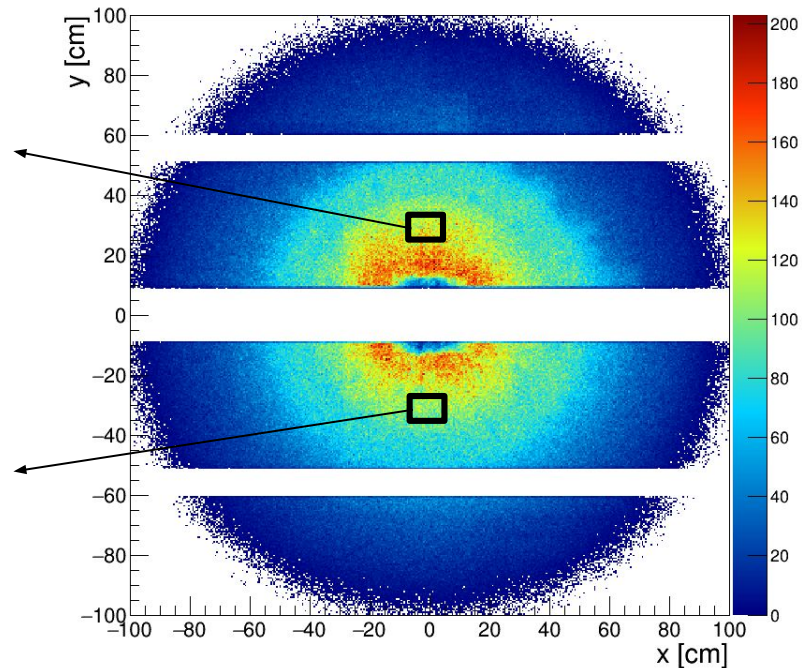
(BaBar DIRC: 9.6 mrad resolution per photon)

# Photon Yield (LUT Method)

photons @ 3 GeV/c momentum



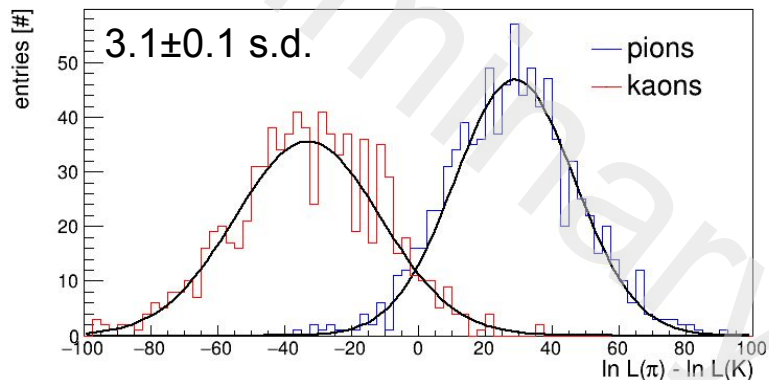
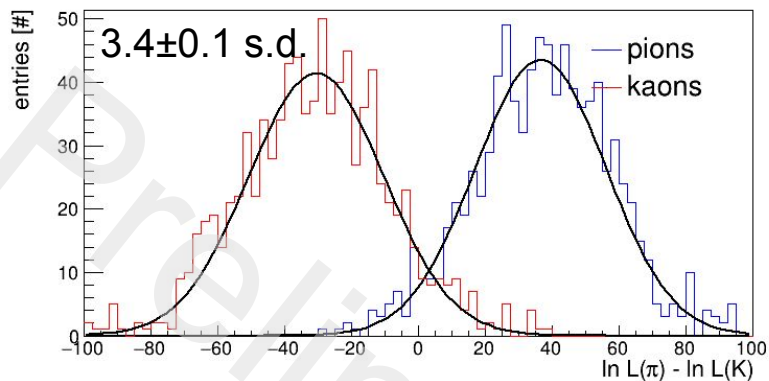
Hit position of the charged tracks on the radiator wall:



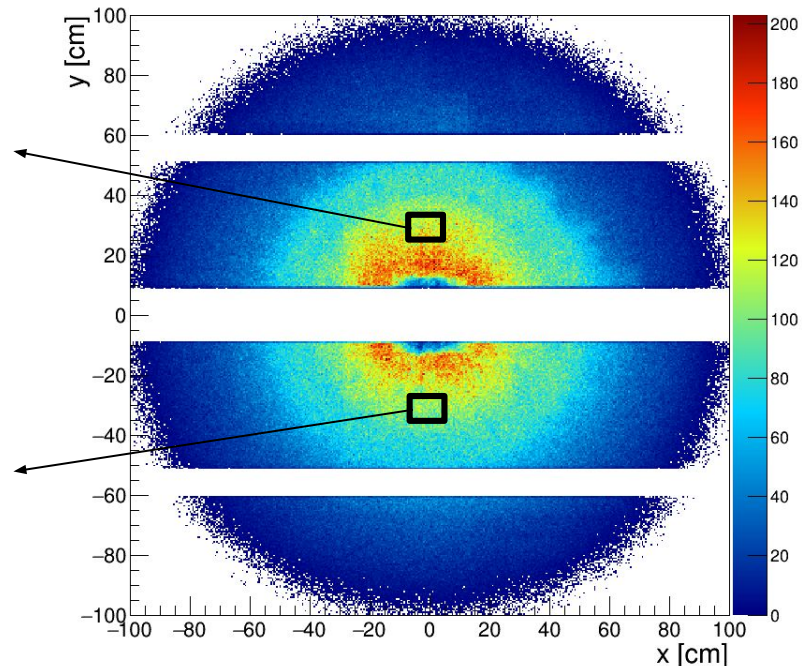
(BaBar DIRC: ~25 photons/particle at 90 deg)

# Separation Power (LUT Method)

pions / kaons @ 3 GeV/c momentum



Hit position of the charged tracks on the radiator wall:

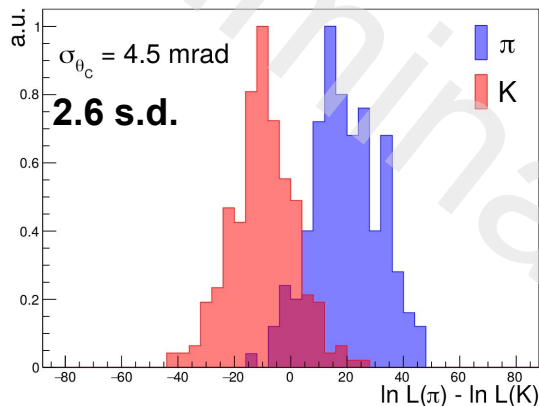
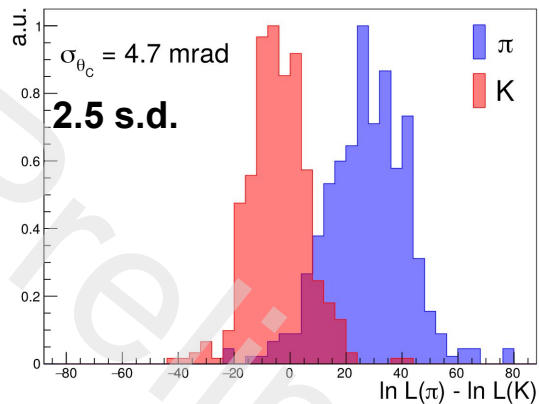


(BaBar DIRC: 4 s.d.  $\pi/K$  separation at 3 GeV/c)

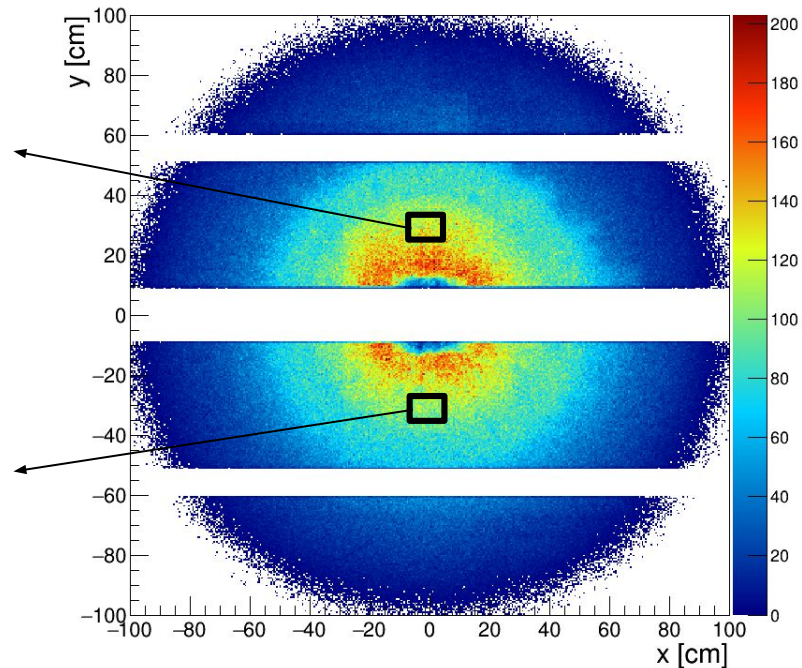


# Performance (FastDIRC Method)

pions / kaons @ 3 GeV/c momentum



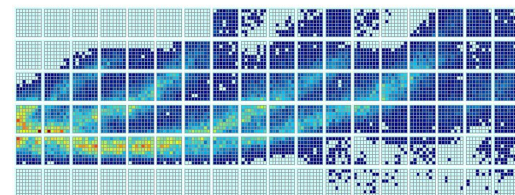
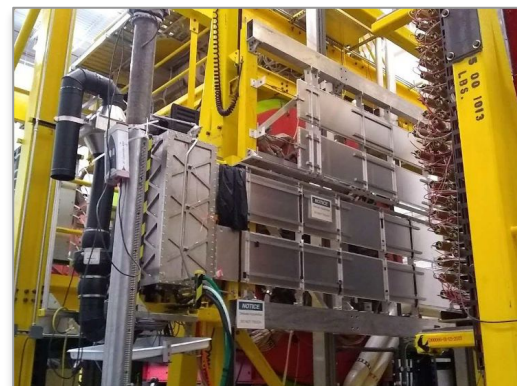
Hit position of the charged tracks on the radiator wall:



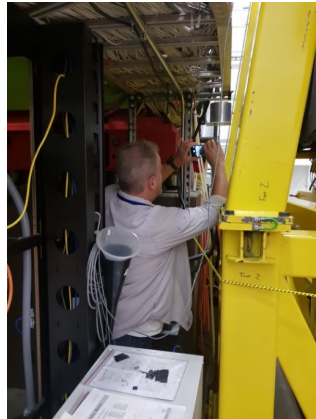
(BaBar DIRC: 4 s.d.  $\pi/K$  separation at 3 GeV/c)

# Conclusion

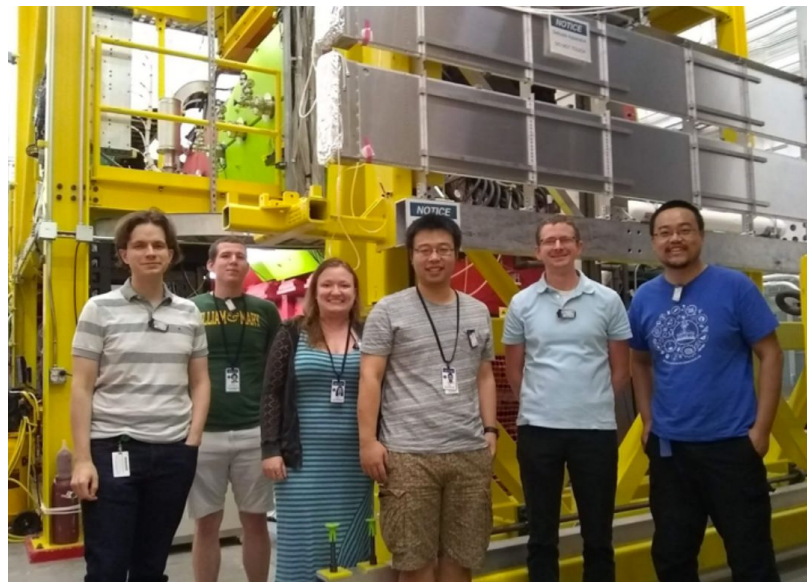
- Four BaBar DIRC bar boxes transported safely from SLAC to JLab, combined with new optics and readout, installed in GlueX as forward PID wall
- Successful commissioning runs (Feb. 2019, Dec 2019)
- GlueX DIRC worked right from the start, bar boxes fully functional, hit patterns as expected
- Measured Cherenkov angle resolution per photon agrees with design and simulation
- Initial  $\pi/K$  separation: 3 s.d. at 3 GeV/c (very preliminary)
- Analysis well underway, performance expected to improve significantly with better calibration and alignment



# The core GlueX DIRC team



Thank you for your attention



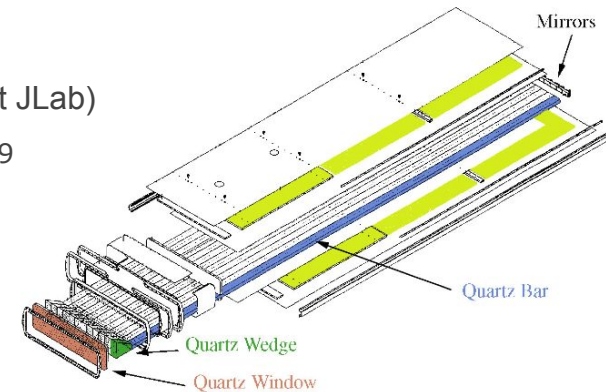


# Backup Slides

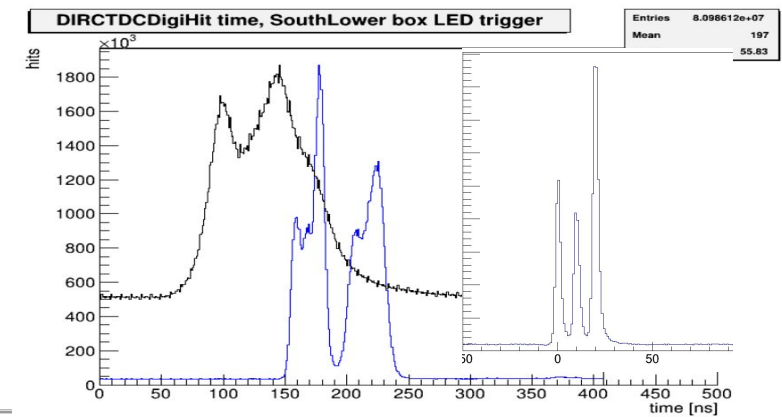
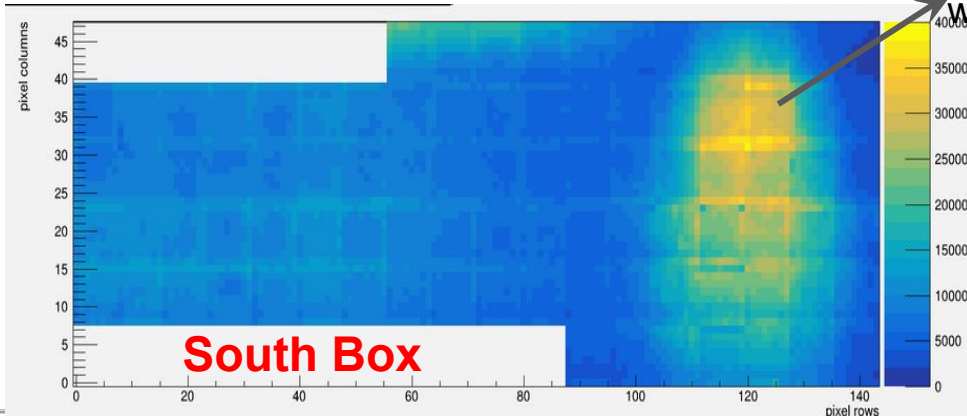
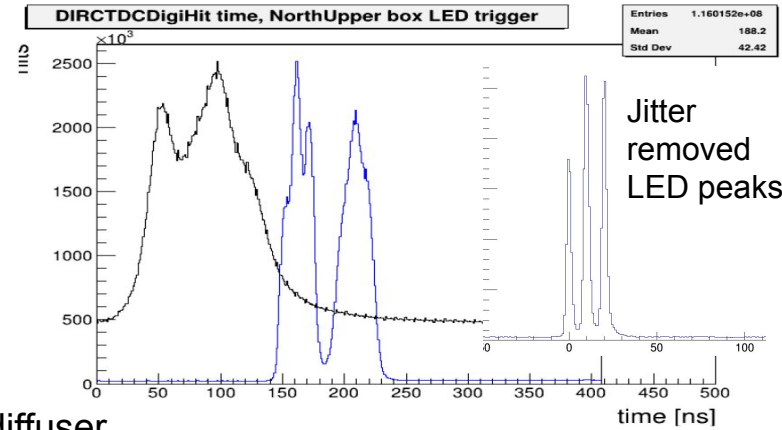
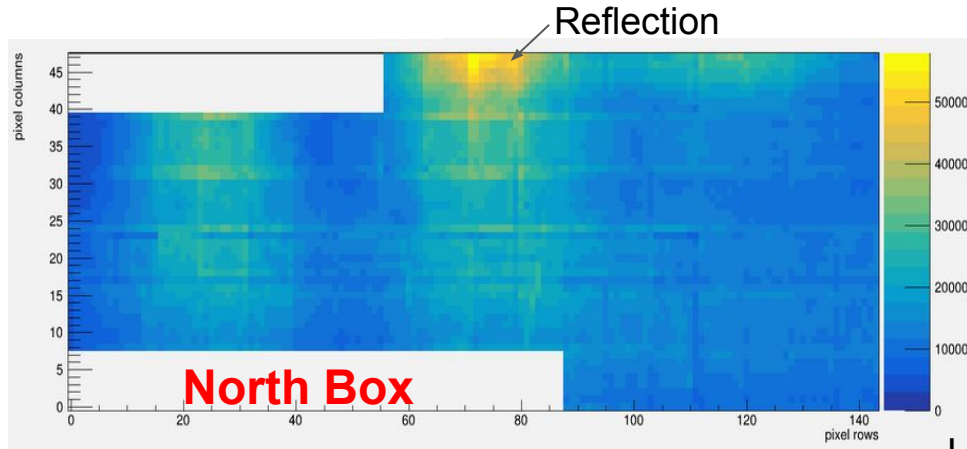
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# GlueX DIRC timeline

- 2004: First suggestion to upgrade GlueX PID capabilities with a DIRC
- 2013: SLAC & DOE issue call for proposals for decommissioned BaBar DIRC bar boxes
- 2014: 4 bar boxes ( $\frac{1}{3}$  of the bars) awarded to GlueX, condition: keep bar boxes intact
- Plan: move bar boxes to JLab, install as forward DIRC wall, design new optics to replace large water tank used in BaBar, replace PMTs and electronics
- New optics based on SLAC fDIRC design with simplifications:  
Segmented flat mirrors instead of cylindrical mirror,  
distilled water instead of fused silica
- H12700 MaPMTs as sensors, MAROC readout (same as CLAS12 RICH at JLab)
- 2015: TDR <https://halldweb.jlab.org/doc-public/DocDB/ShowDocument?docid=2809>
- 2017: first bar box transported from SLAC to JLab  
- very, very carefully and successfully
- 2018: use same approach to transport three more bar boxes, install all boxes in Hall D
- 2019: two commissioning runs (10 days + 16 days) for GlueX DIRC



# LED Monitoring Occupancy & Timing

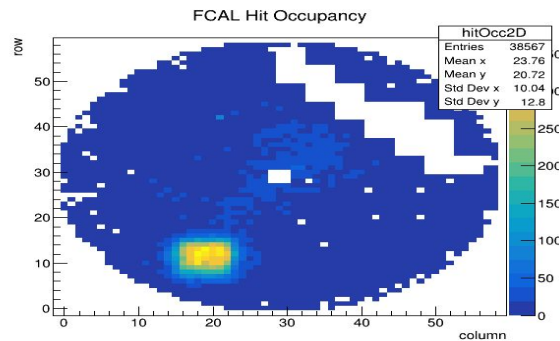
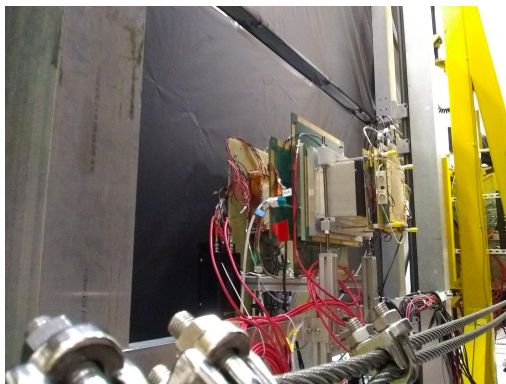
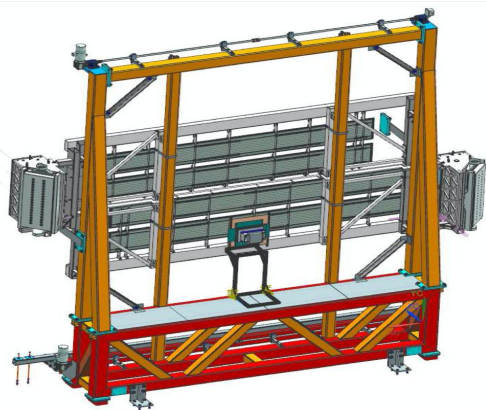


LED diffuser  
water



# Commissioning with GEM/TRD

- GEM/TRD installed directly upstream of the DIRC
  - Provides ~2 planes of tracking near DIRC: ~200  $\mu\text{m}$  GEM and wire TRD with ~400  $\mu\text{m}$  resolution in x-direction
  - 3 x-positions along DIRC with focused FCAL trigger to readout slow GEM electronics
- Collected significant data with solenoid field on and off



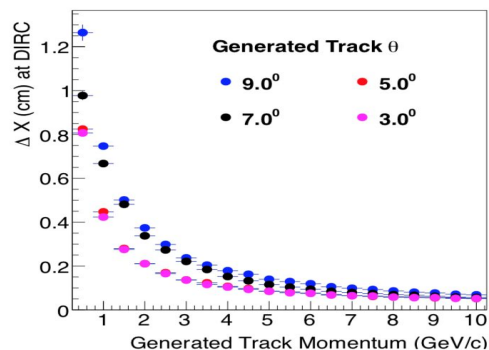
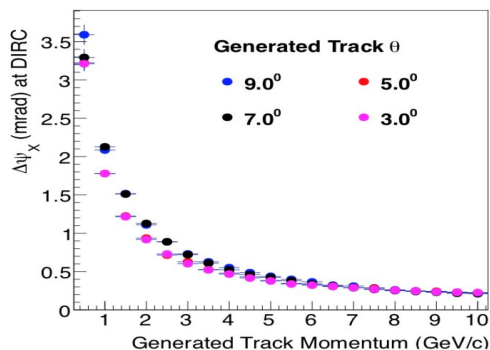
<https://logbooks.jlab.org/entry/3747075>

# Analysis of GEM/TRD data

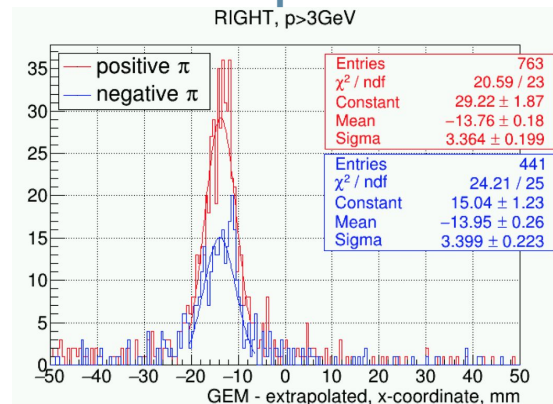
- Alignment of package position with straight track data (Lubomir), code in place to include GEM/TRD hits (Simon)
- Broader residuals on extrapolated position than expected from simulation, need to determine impact on  $\sigma_{\theta_c}$
- Solution required before REST production

$$\sigma_{\theta_c}^{\text{track}} = \sqrt{\left(\frac{\sigma_{\theta_c}^{\text{photon}}}{\sqrt{N_{\text{photons}}}}\right)^2 + (\sigma_{\text{correlated}})^2}$$

## Simulated tracking resolutions (from TDR)



## Measured x-position residual

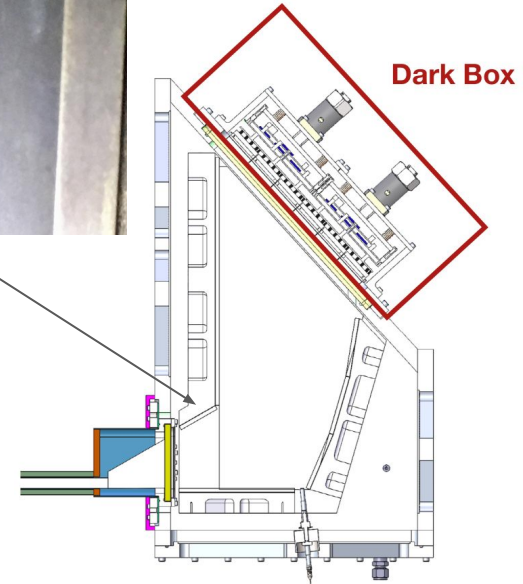


Lubomir:

[https://www.jlab.org/Hall-D/detector/trd/tracking\\_Jan23\\_2020.pdf](https://www.jlab.org/Hall-D/detector/trd/tracking_Jan23_2020.pdf)

# January 2020 Inspection

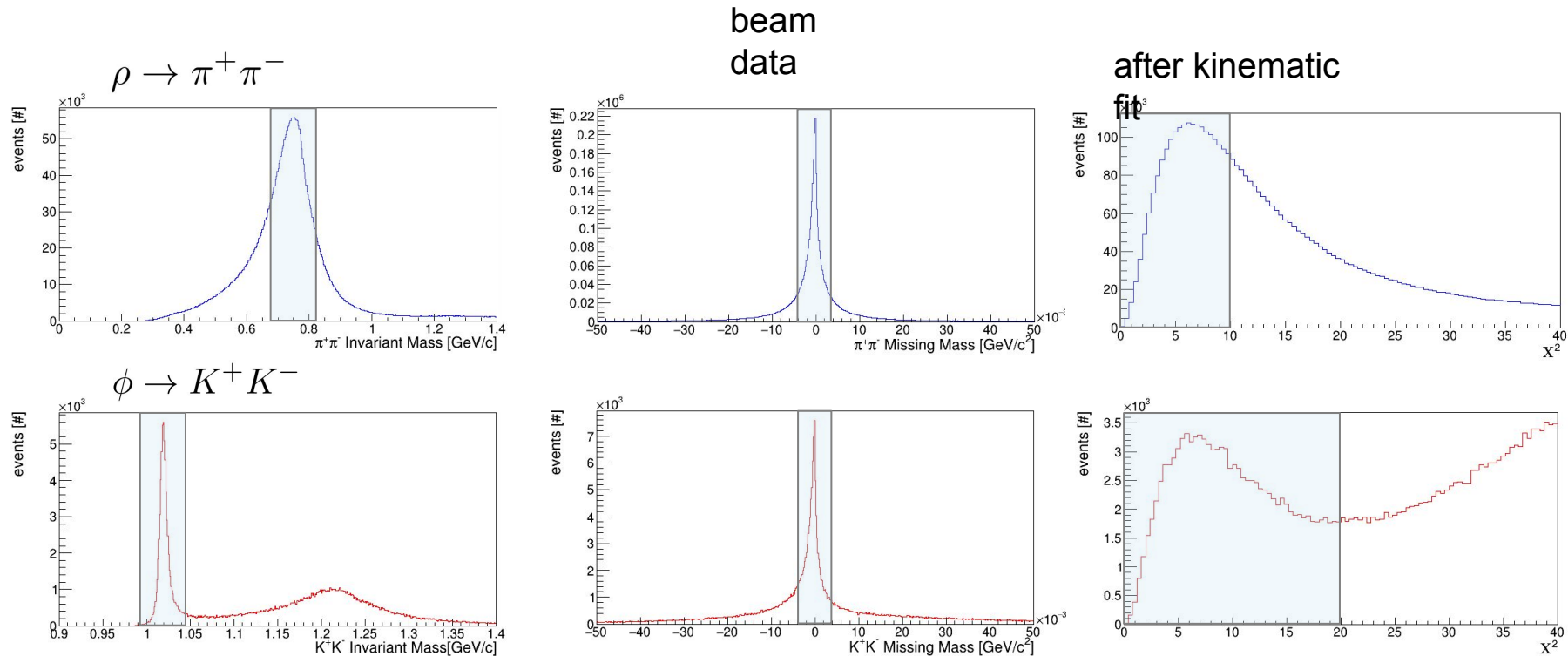
- Most mirror have pristine quality!
  - No white trace marks
  - No rainbow colored marks
  - Only removable small dusts observed
- Water came in between the wedged mirror!
- LED diffuser leaked water!



**Water**

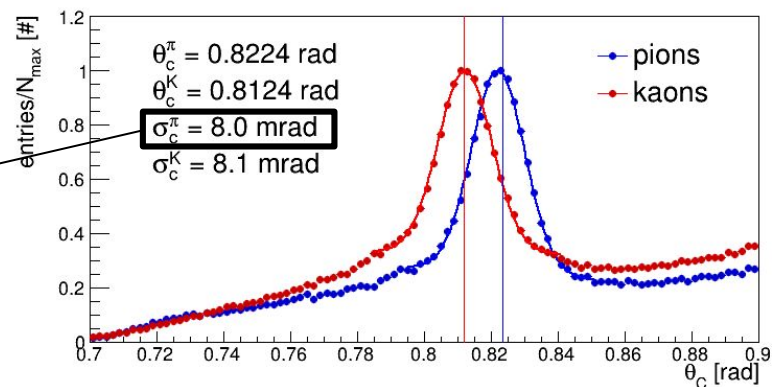
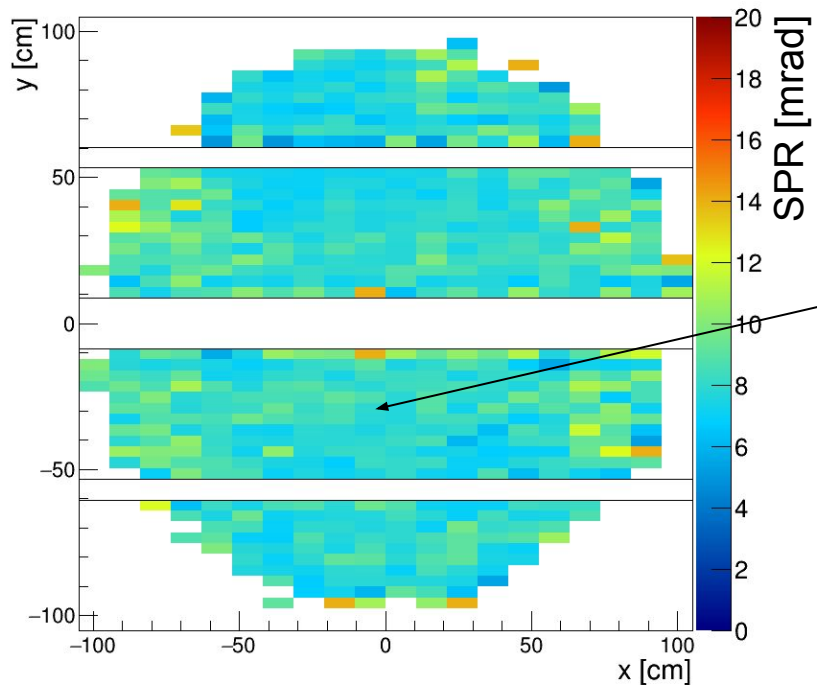


# Event Selection



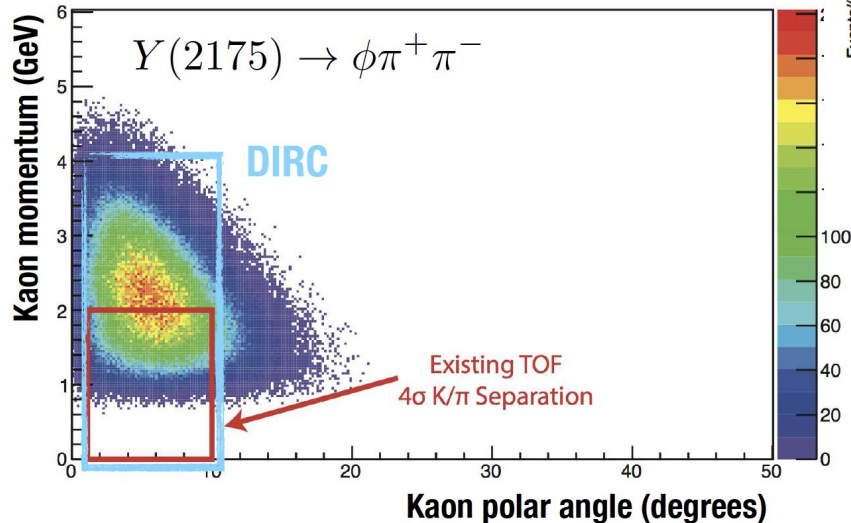
# Single Photon Resolution (LUT Method)

SPR for pions @ 3 GeV/c beam momentum:

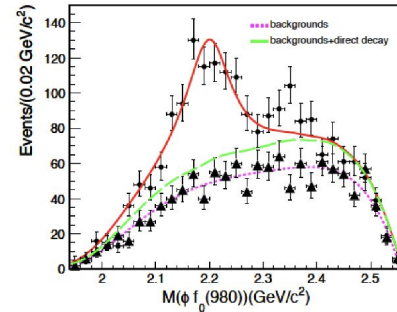


# Expected DIRC performance

GLUEX Simulation



BES III:  $J/\psi \rightarrow \eta \phi \pi^+ \pi^-$



PRD 91, 052017 (2015)

- \* Significantly extends reach in search for exotic hadrons (hybrid, multi-quark, etc.) containing strange quarks