

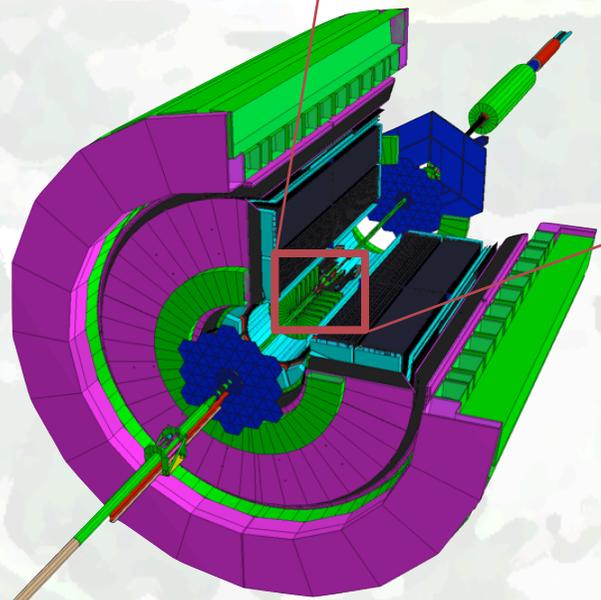
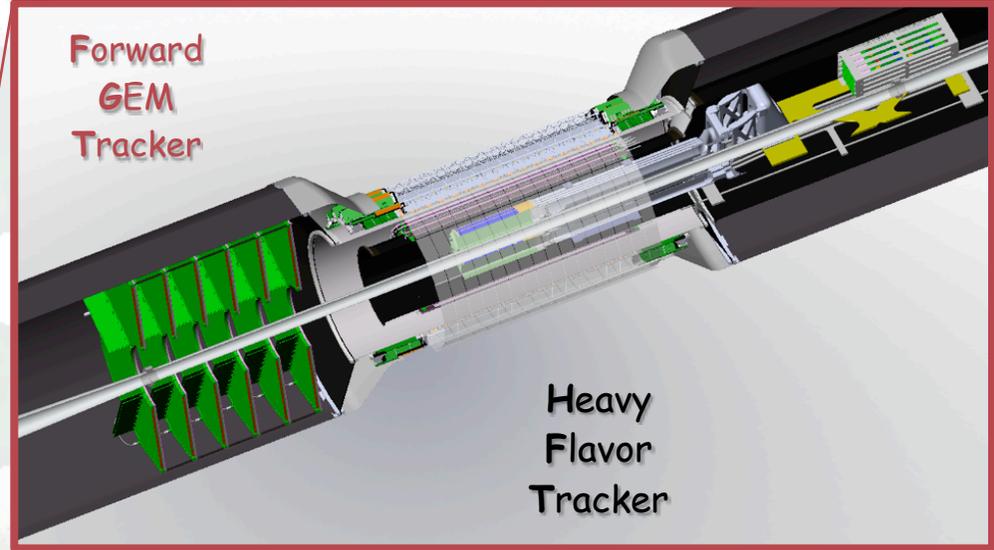
# The STAR Forward GEM Tracker at RHIC at BNL

Xuan Li & Bernd Surrow  
(On behalf of the STAR Collaboration)



# Outline

- **FGT** Overview
  
- **FGT** Technical Realization
  - Triple-GEM Assembly
  - Front-End Electronics
  - DAQ
  - Integration
  
- Summary

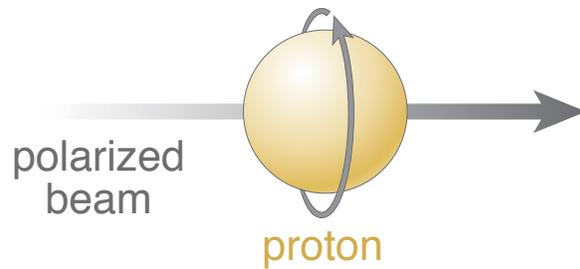


# FGT Overview

- Probing the quark flavor structure using  $W$  boson production: Unique new probe

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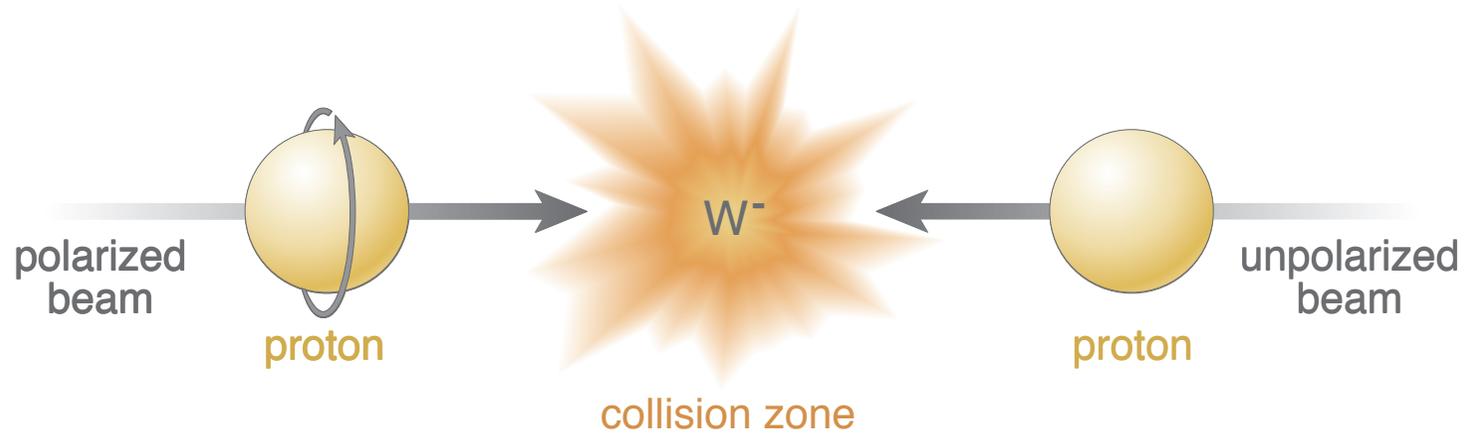
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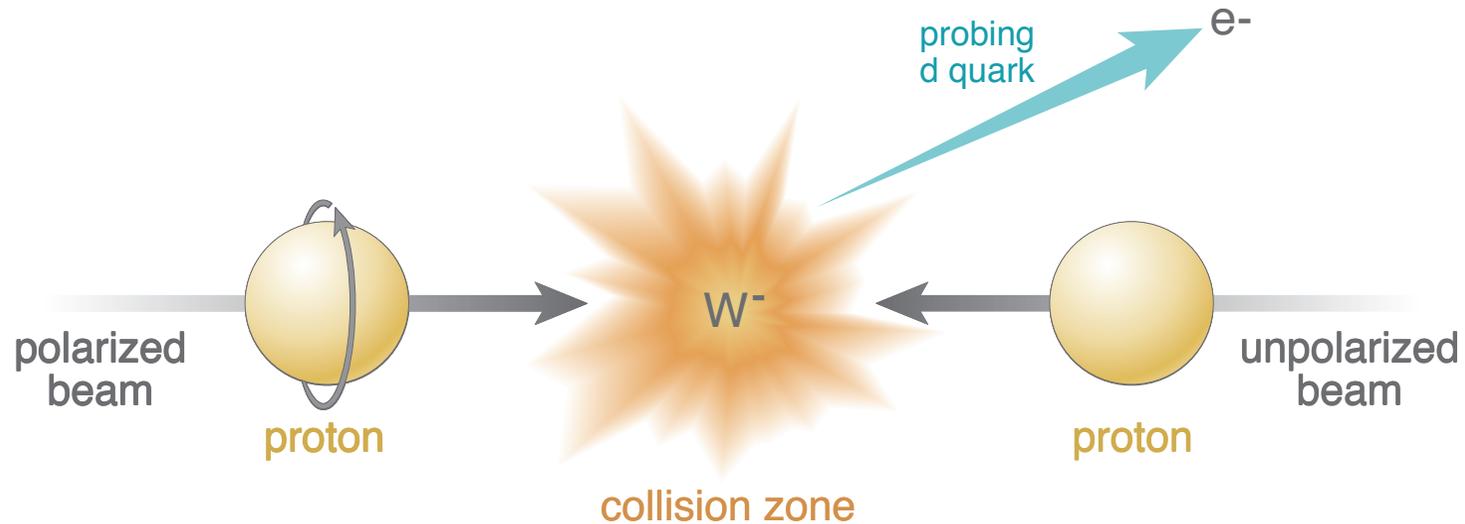
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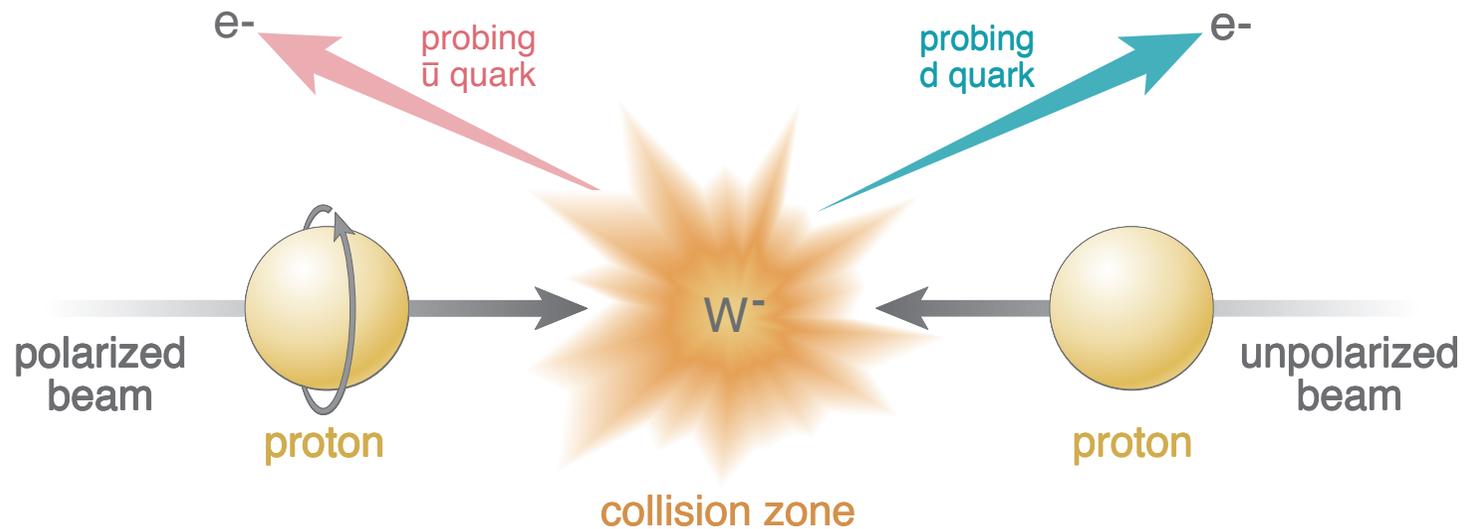
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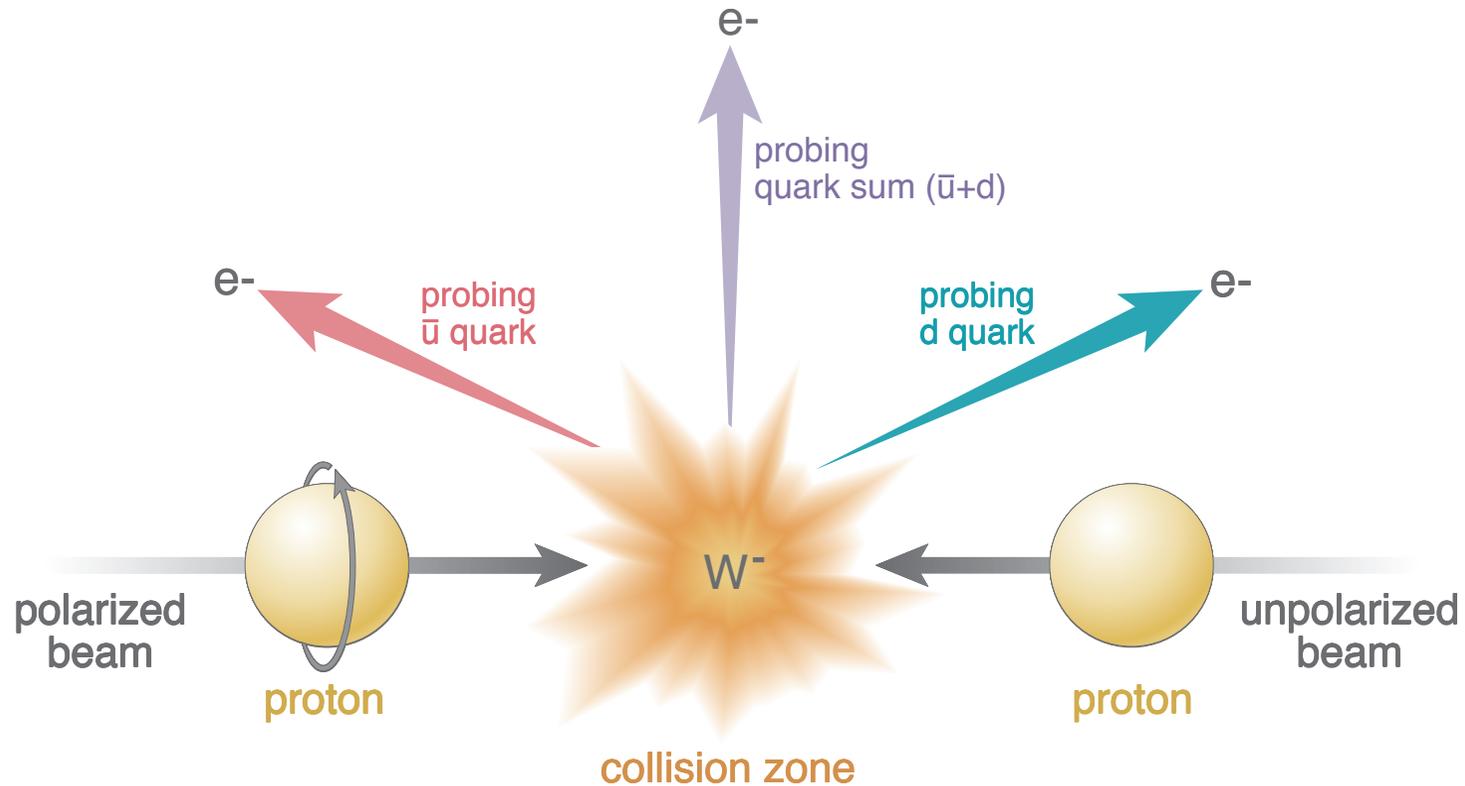
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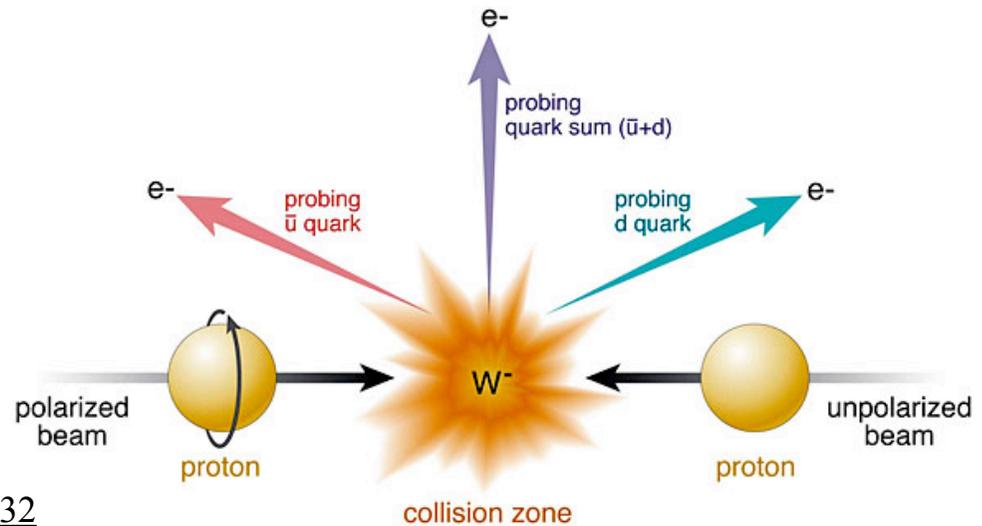
- Probing the quark flavor structure using  $W$  boson production: Unique new probe

## Unique New Probe of Proton Spin Structure at RHIC

Direct measurements allow detailed look at how quarks of different flavors contribute to spin

February 15, 2011

UPTON, NY — Scientists hoping to unravel the mystery of proton spin at the [Relativistic Heavy Ion Collider](#) (RHIC), a 2.4-mile-circumference particle accelerator at the U.S. Department of Energy's (DOE) Brookhaven National Laboratory, have a new tool at their disposal — the first to *directly* explore how quarks of different types, or “flavors,” contribute to the overall spin of the proton. The technique, described in papers just published by RHIC's STAR and PHENIX collaborations in *Physical Review Letters*, relies on the measurement of particles called  $W$  bosons, the mediators of the weak force responsible for the decay of radioactive nuclei.



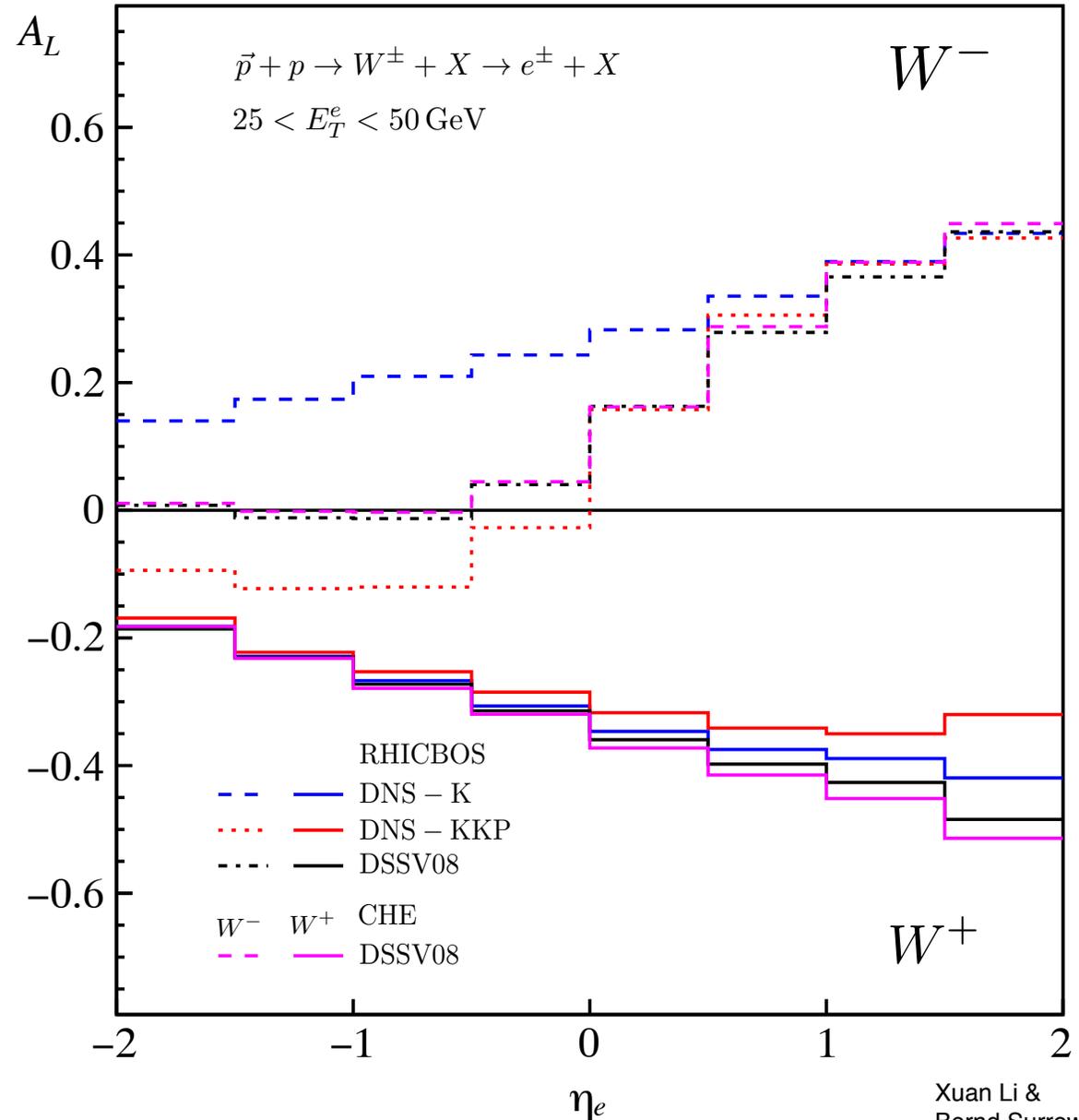
News Release:

[http://www.bnl.gov/bnlweb/pubaf/pr/PR\\_display.asp?prID=1232](http://www.bnl.gov/bnlweb/pubaf/pr/PR_display.asp?prID=1232)

Illustration of a new measurement using  $W$  boson production in polarized proton collisions at RHIC. Collisions of polarized protons (beam entering from left) and unpolarized protons (right) result in the production of  $W$  bosons (in this case,  $W^-$ ). RHIC's detectors identify the particles emitted as the  $W$  bosons decay (in this case, electrons,  $e^-$ ) and the angles at which they emerge. The colored arrows represent different possible directions, which probe how different quark flavors (e.g., “anti-up,”  $\bar{u}$ ; and “down,”  $d$ ) contribute to the proton spin. [+ ENLARGE](#)

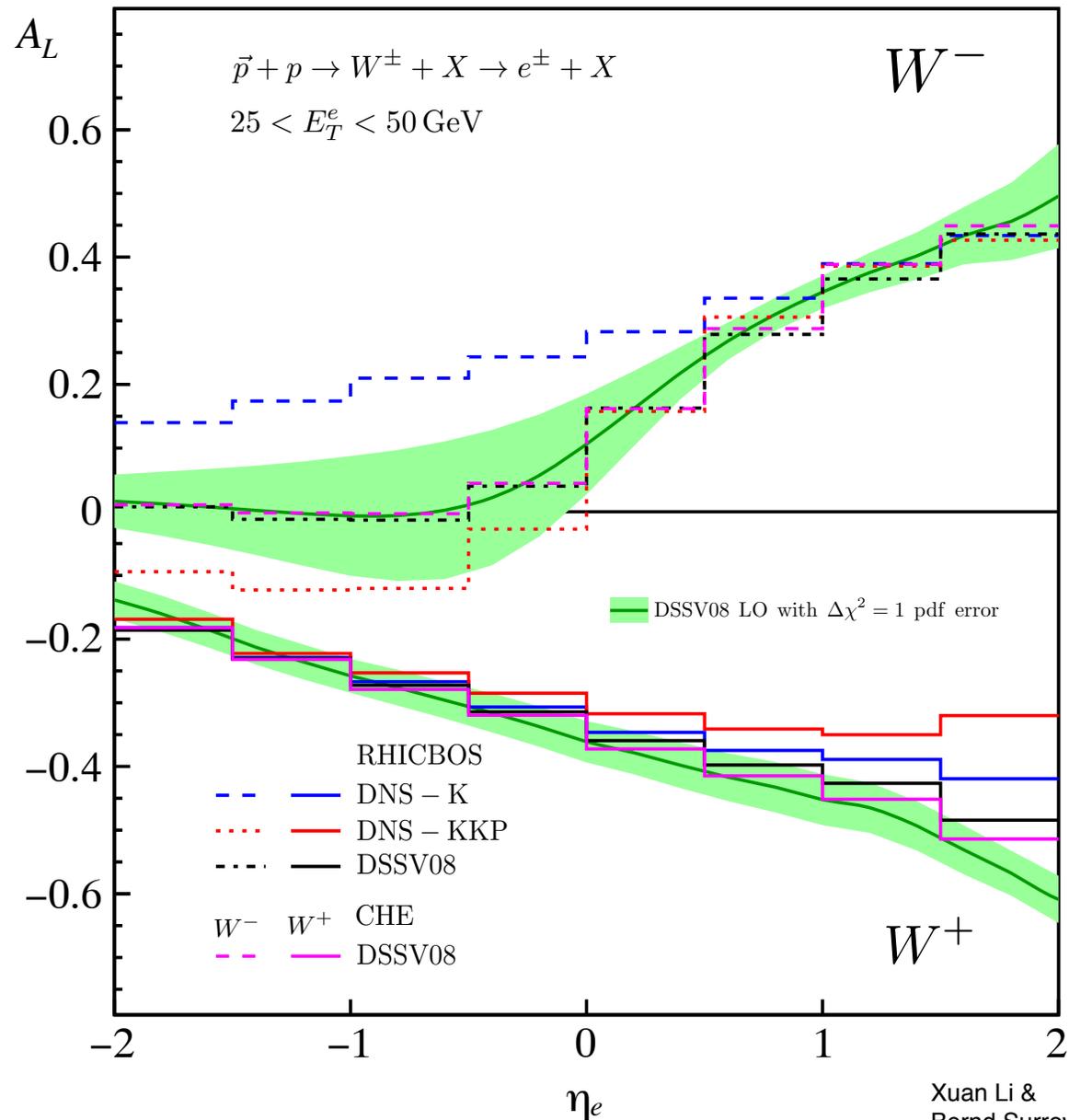
# FGT Overview

## □ STAR $A_L$ results / projections



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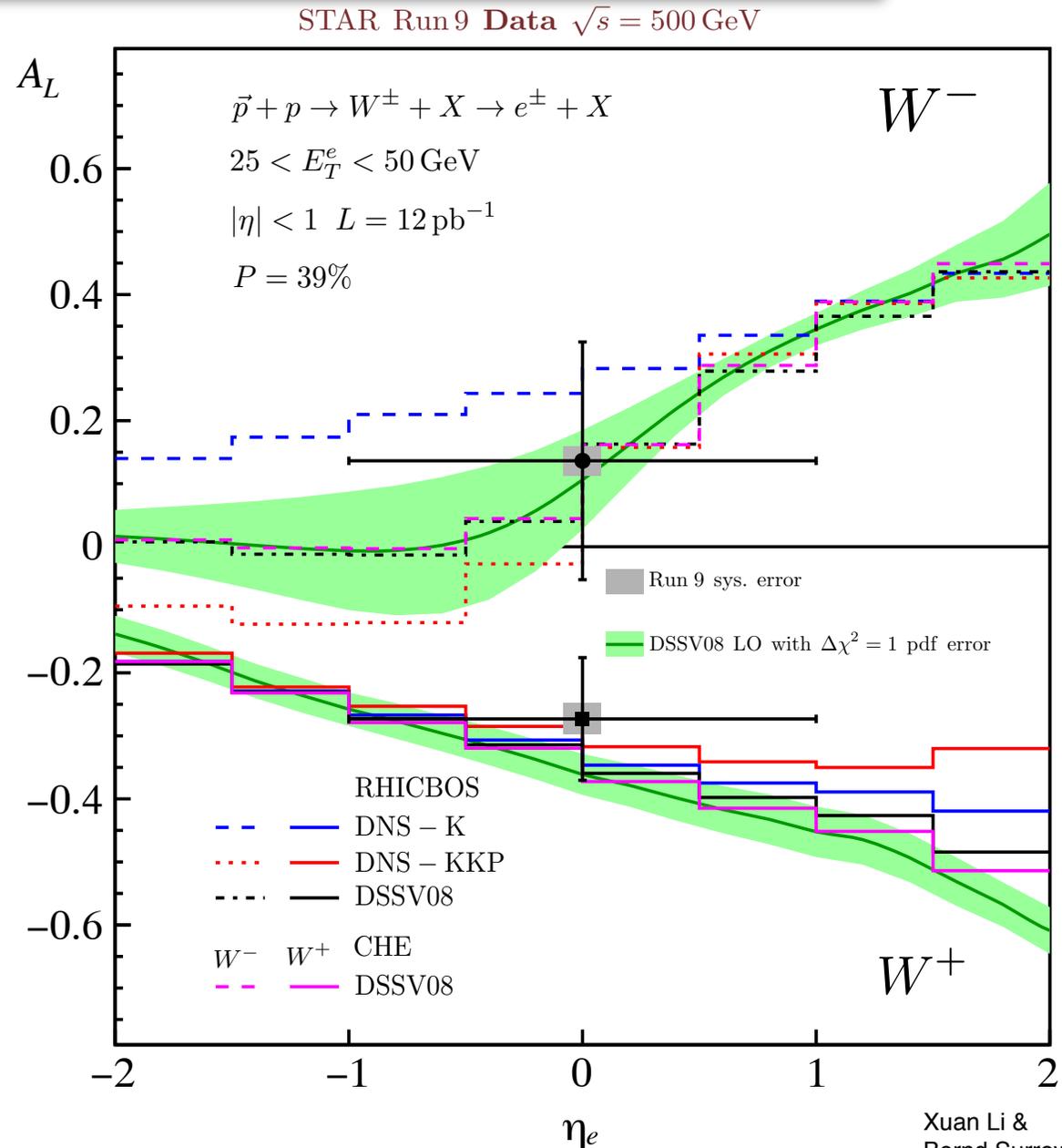
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## □ STAR $A_L$ results / projections

Measured asymmetries (Run 9) are in agreement with theory evaluations using polarized pdf's (DSSV) constrained by polarized DIS data  
 $\Rightarrow$  Universality of helicity distr. functions!



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## □ STAR $A_L$ results / projections

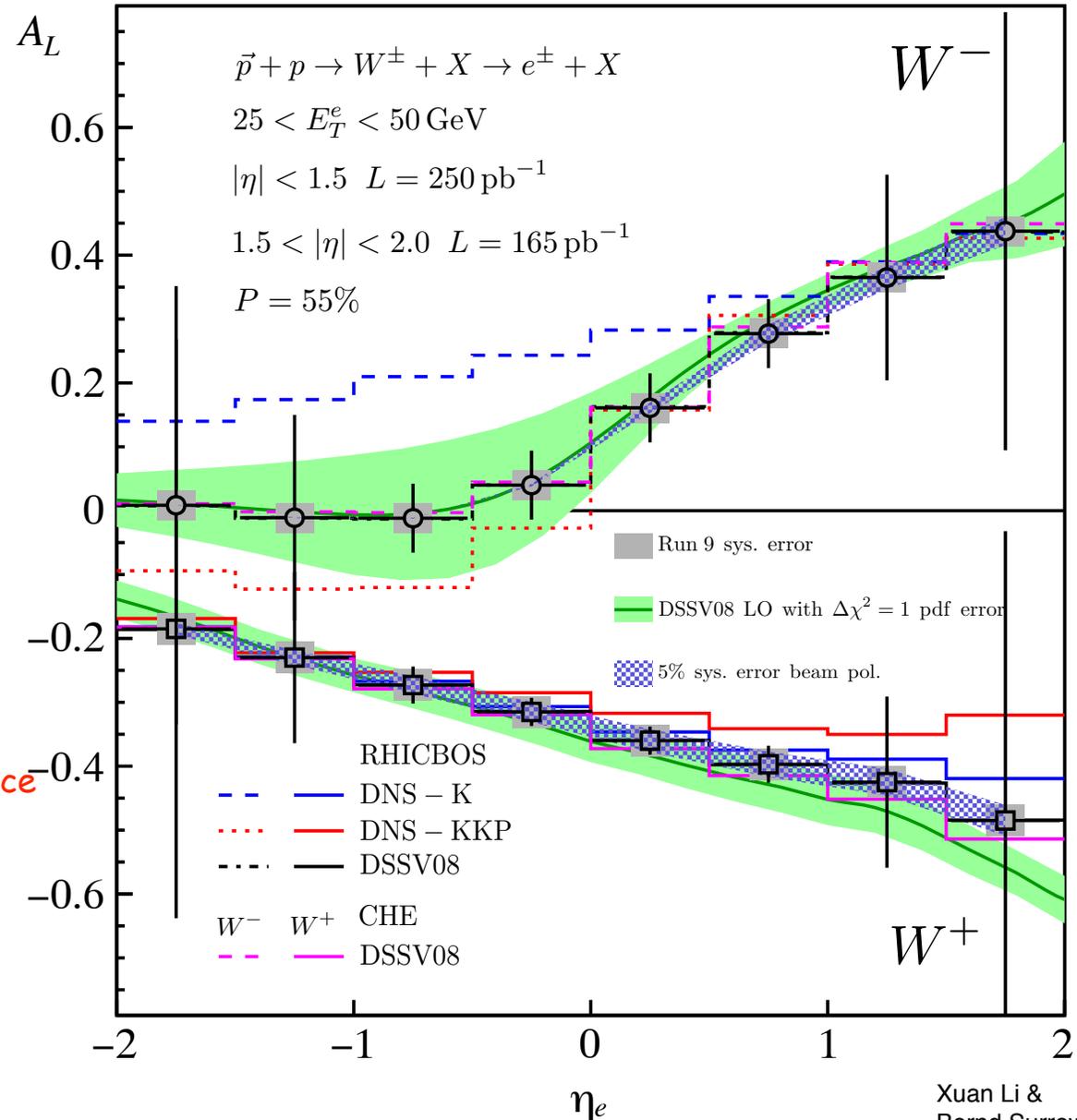
Measured asymmetries (Run 9) are in agreement with theory evaluations using polarized pdf's (DSSV) constrained by polarized DIS data  
 $\Rightarrow$  Universality of helicity distr. functions!

Critical: Measurement of  $W^+$  and  $W^-$  asymmetries as a function  $\eta_e$

Extension of backward / forward  $\eta_e$  acceptance enhances sensitivity to anti-u / anti-d quark polarization

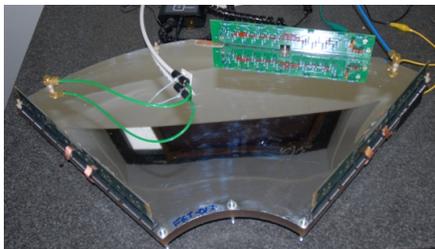
$\Rightarrow$  STAR Forward GEM Tracker ( $1 < |\eta_e| < 2$ )

STAR Run 12 + Run 13 Projections  $\sqrt{s} = 500$  GeV

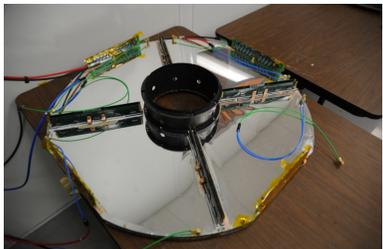


# FGT Overview

## Forward GEM Tracker - Layout



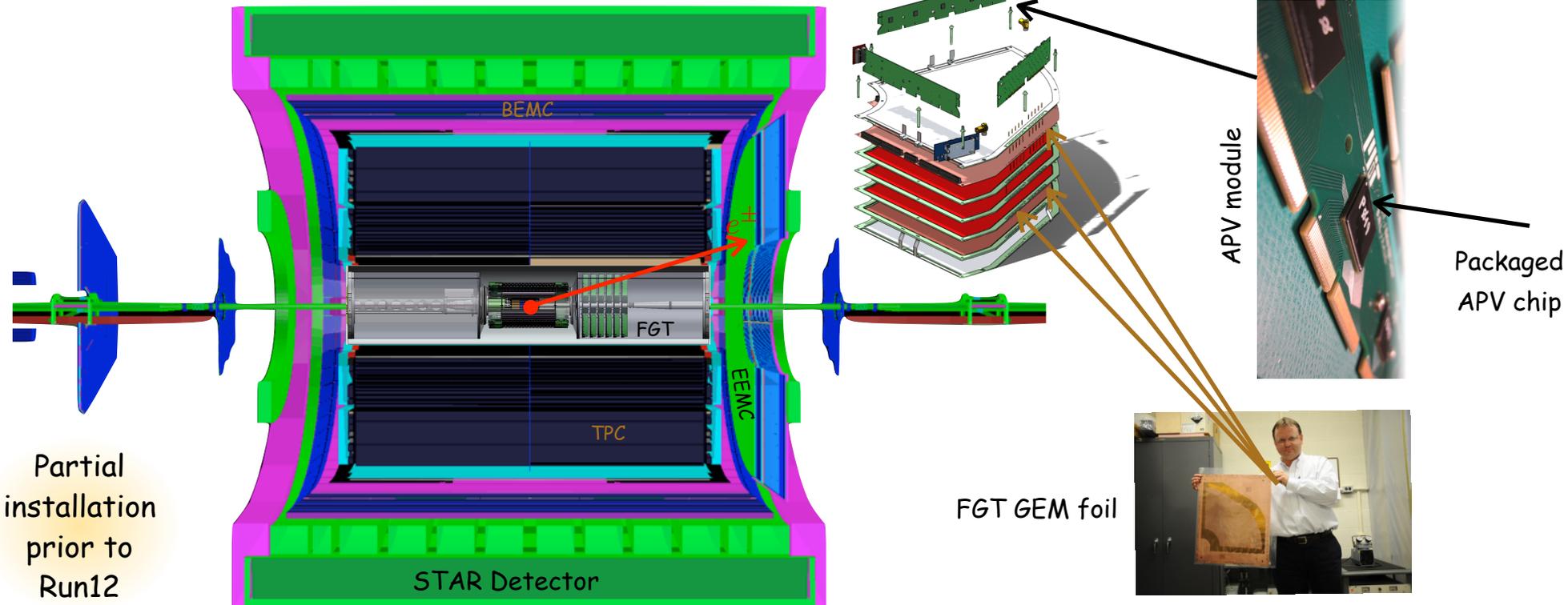
Quarter section



Disk



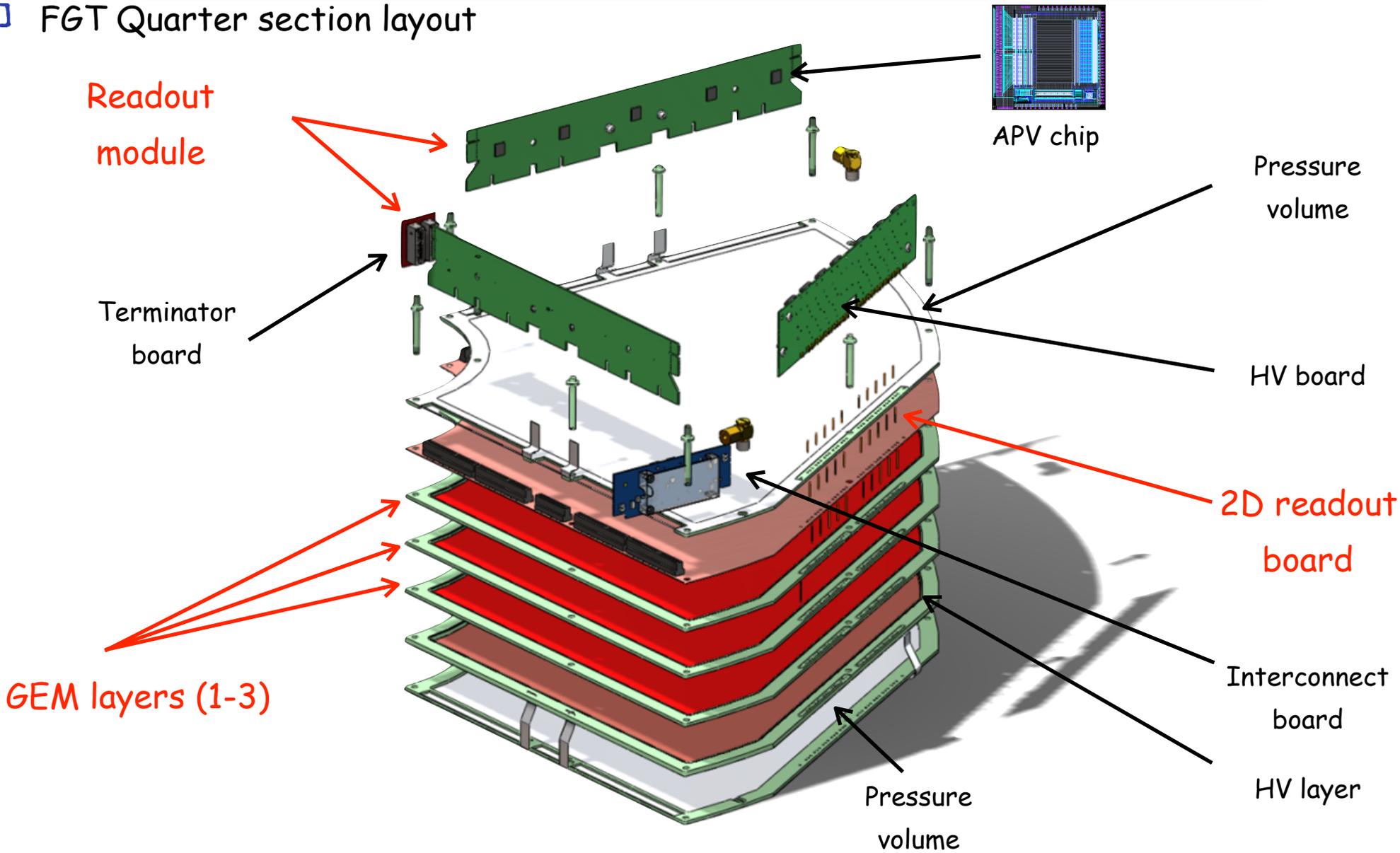
Quarter section



Partial installation prior to Run12

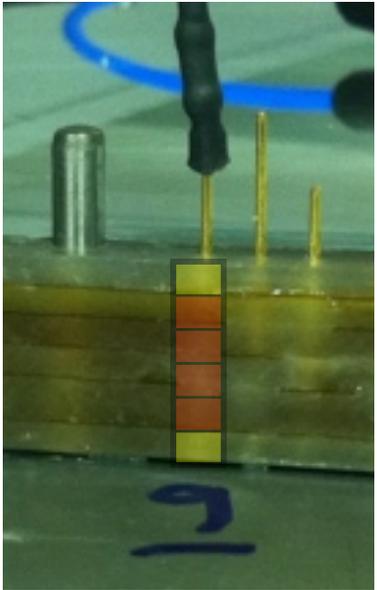
# FGT Technical Realization / Triple-GEM design

## FGT Quarter section layout



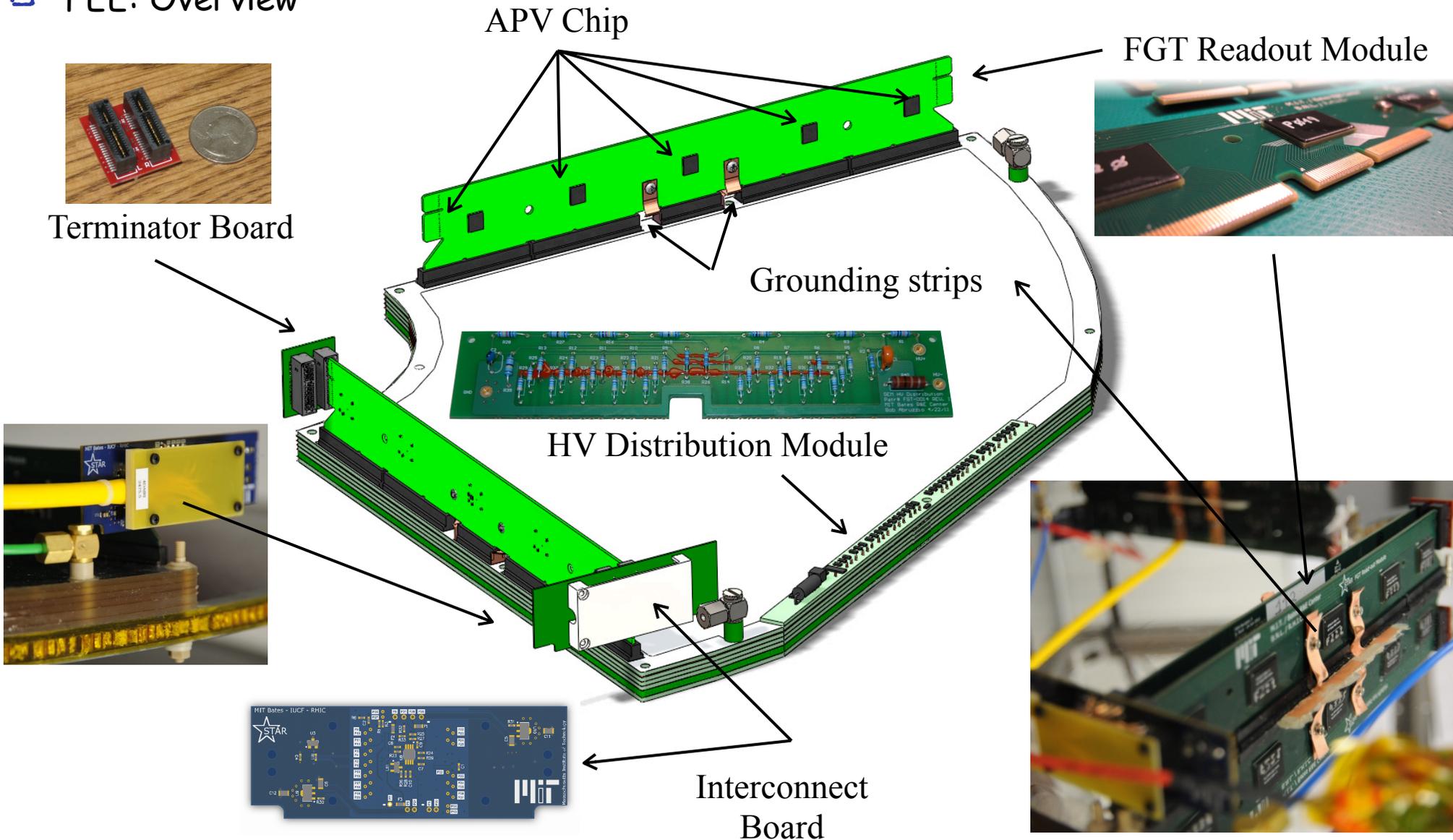
# FGT Technical Realization / Triple-GEM design

## FGT Quarter section layout



# FGT Technical Realization / FEE overview

## □ FEE: Overview

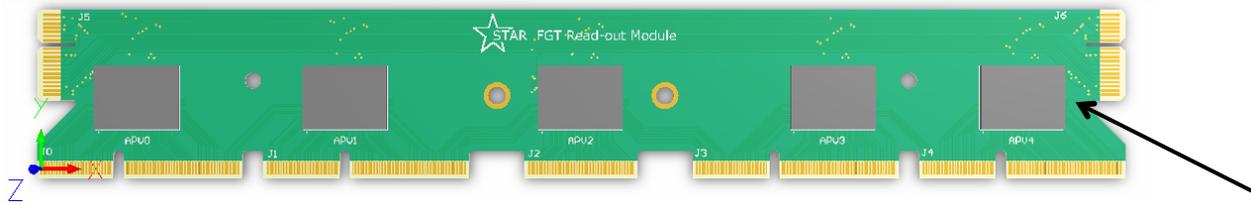


# FGT Technical Realization / FEE design

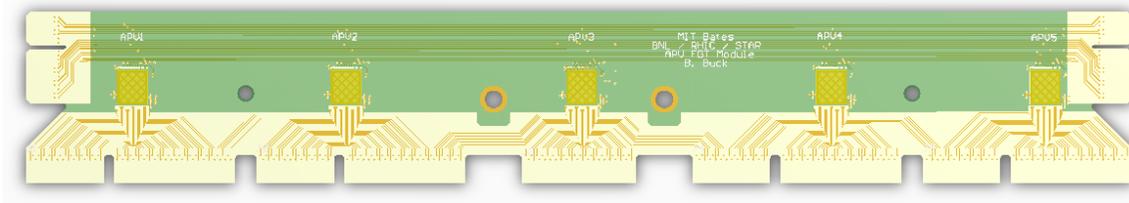
## □ FEE: Design and prototype options

### ○ Two concepts for readout module:

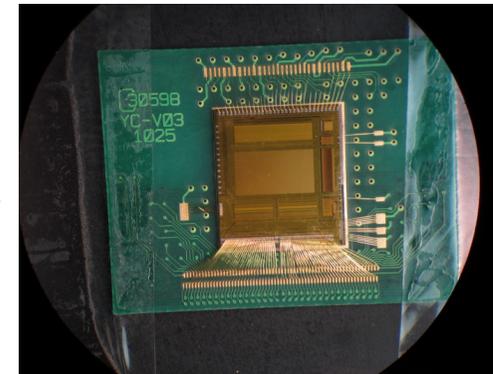
- Final design version: **Packaged chip option**  
(Cheaper / More flexible)



- Earlier design: **Chip on board option**  
(More expensive / Difficult production)



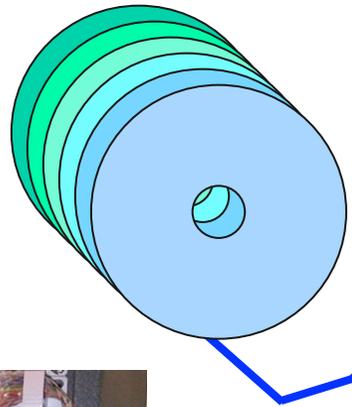
- Chip carrier design completed by Compunetics
- Assembly and bonding performed by **Corwil (Successful APV packaging for NASA)**



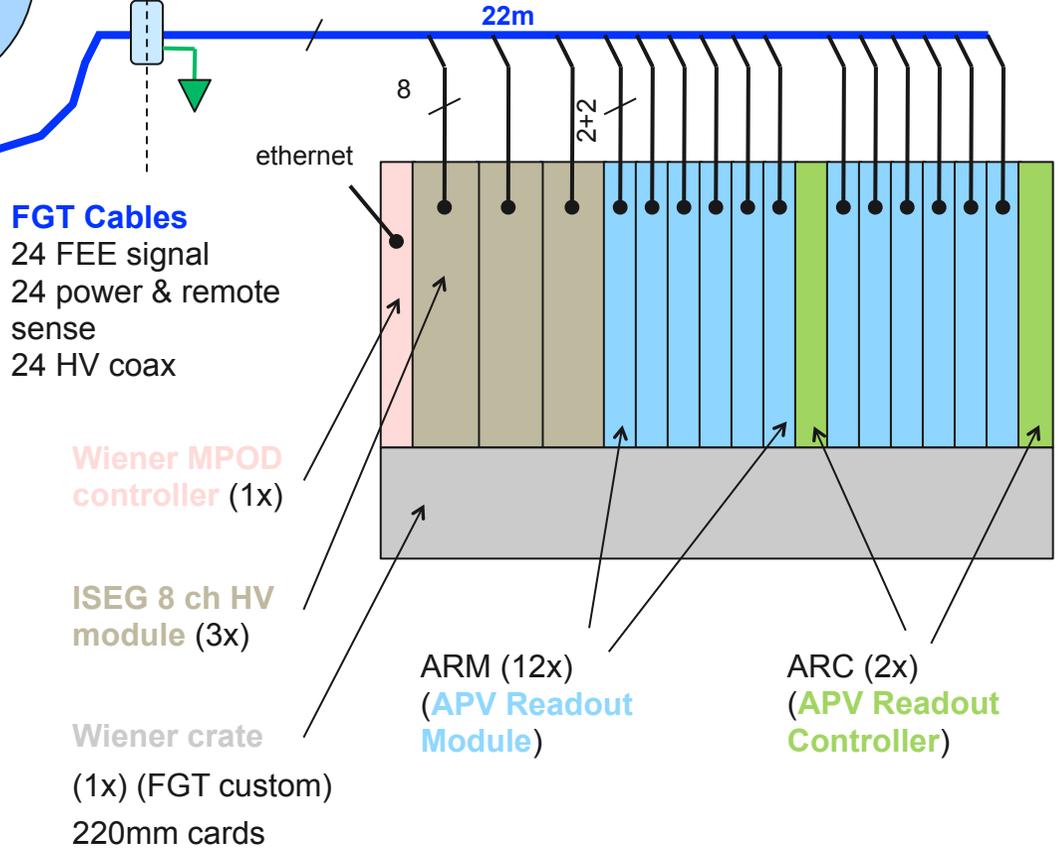
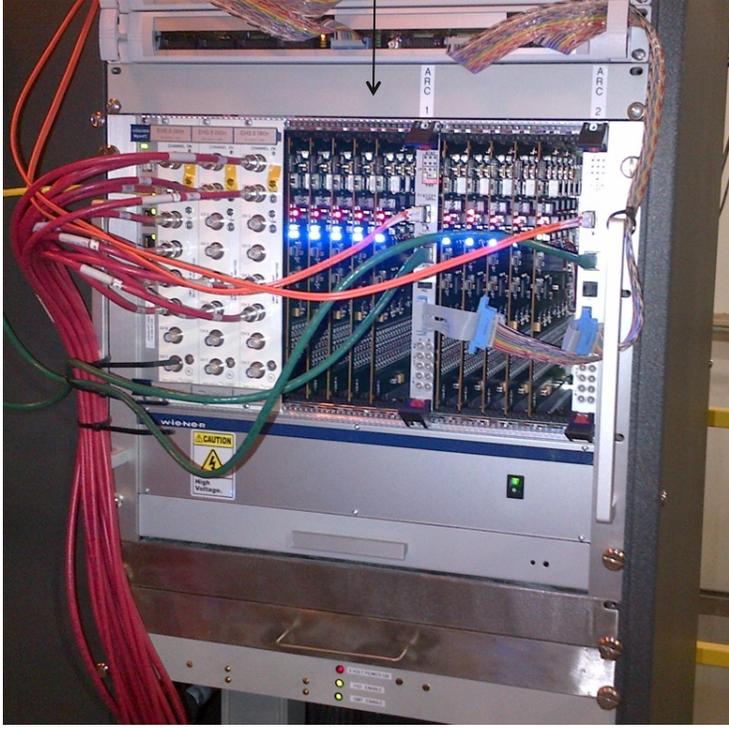
- First prototype produced in late 2008 and tested / Second prototype delivered beginning of June 2009

# FGT Technical Realization / DAQ

## □ DAQ: Overview

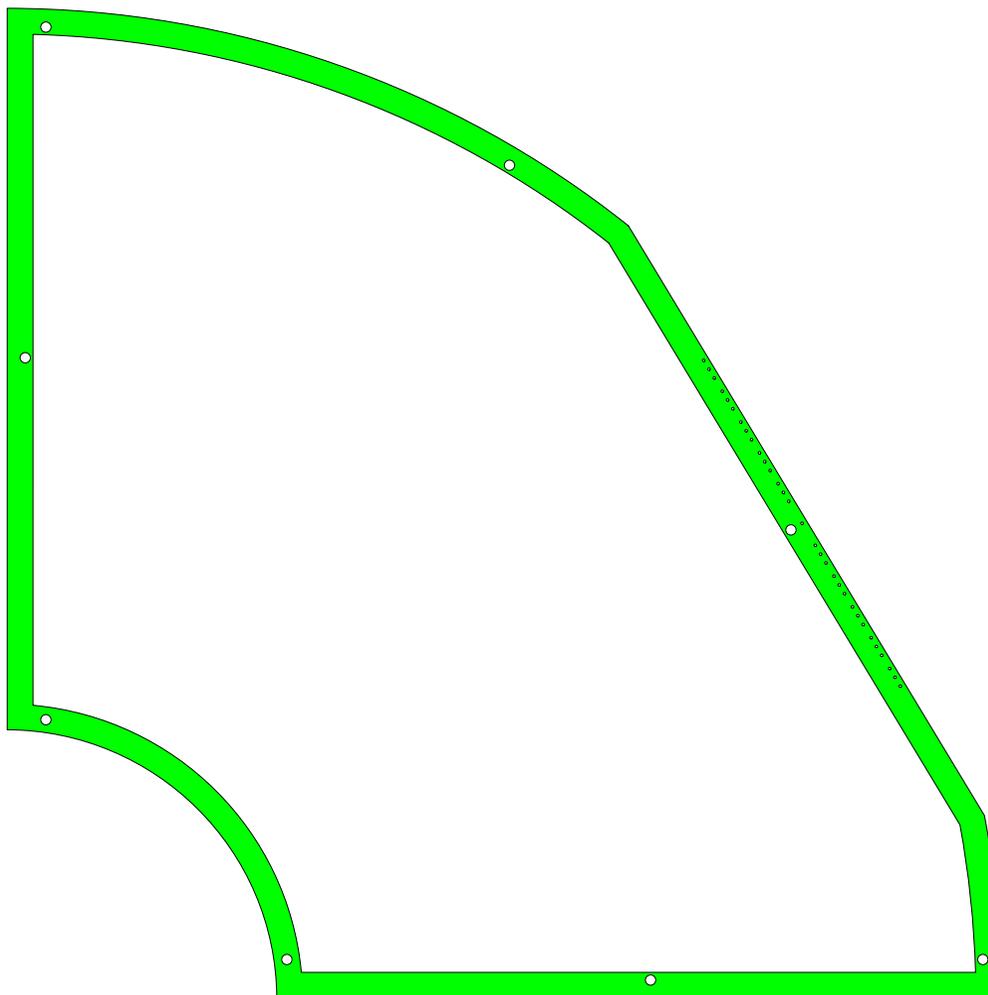


FGT DAQ system provides a fast, reliable and efficient APV chip readout system - adapted also to other STAR system



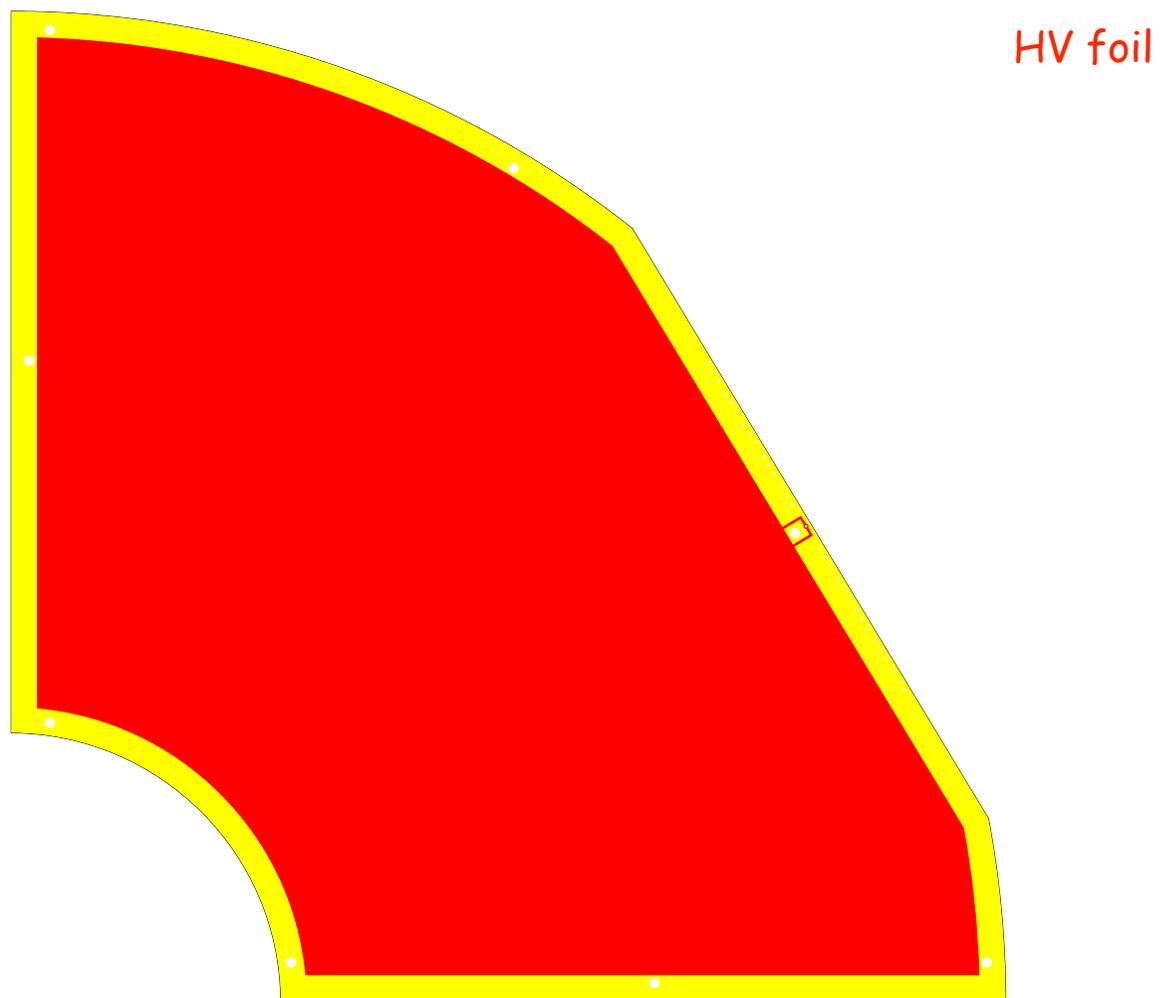
# FGT Technical realization / Layout

- Triple-GEM: Quarter section design



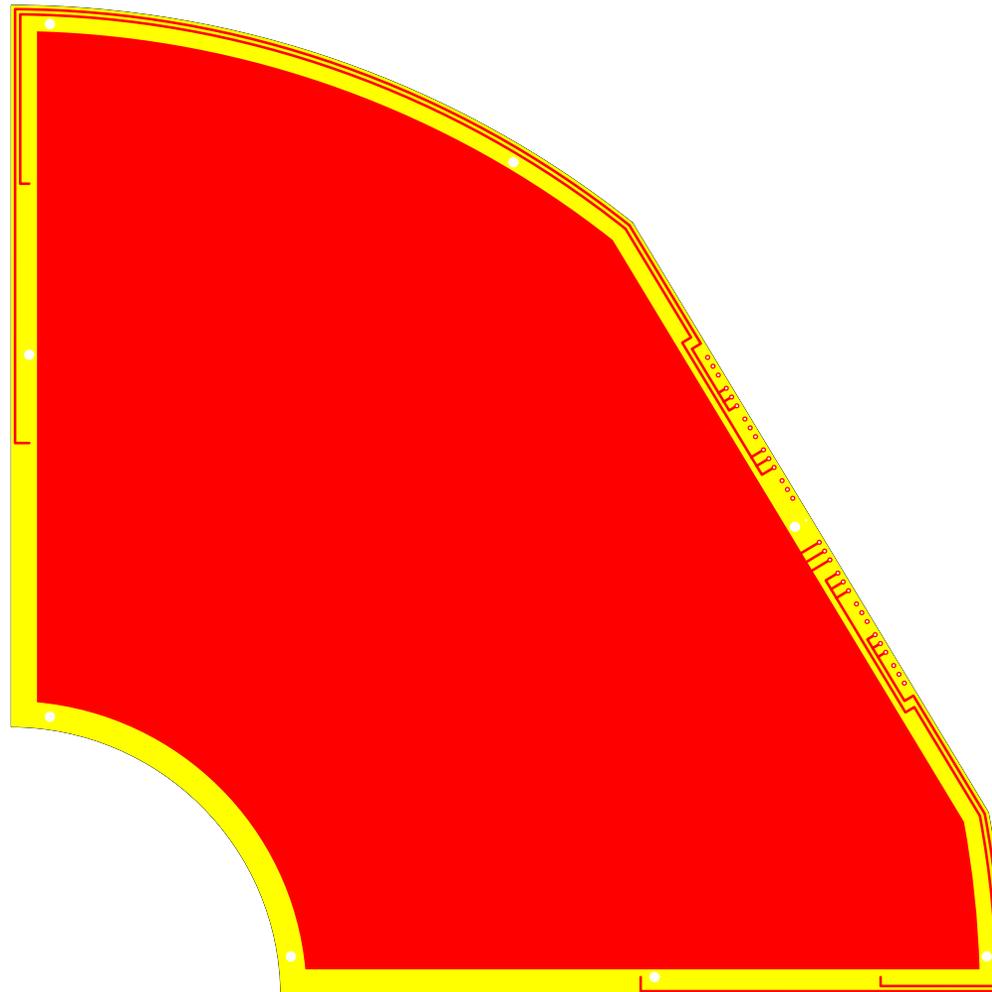
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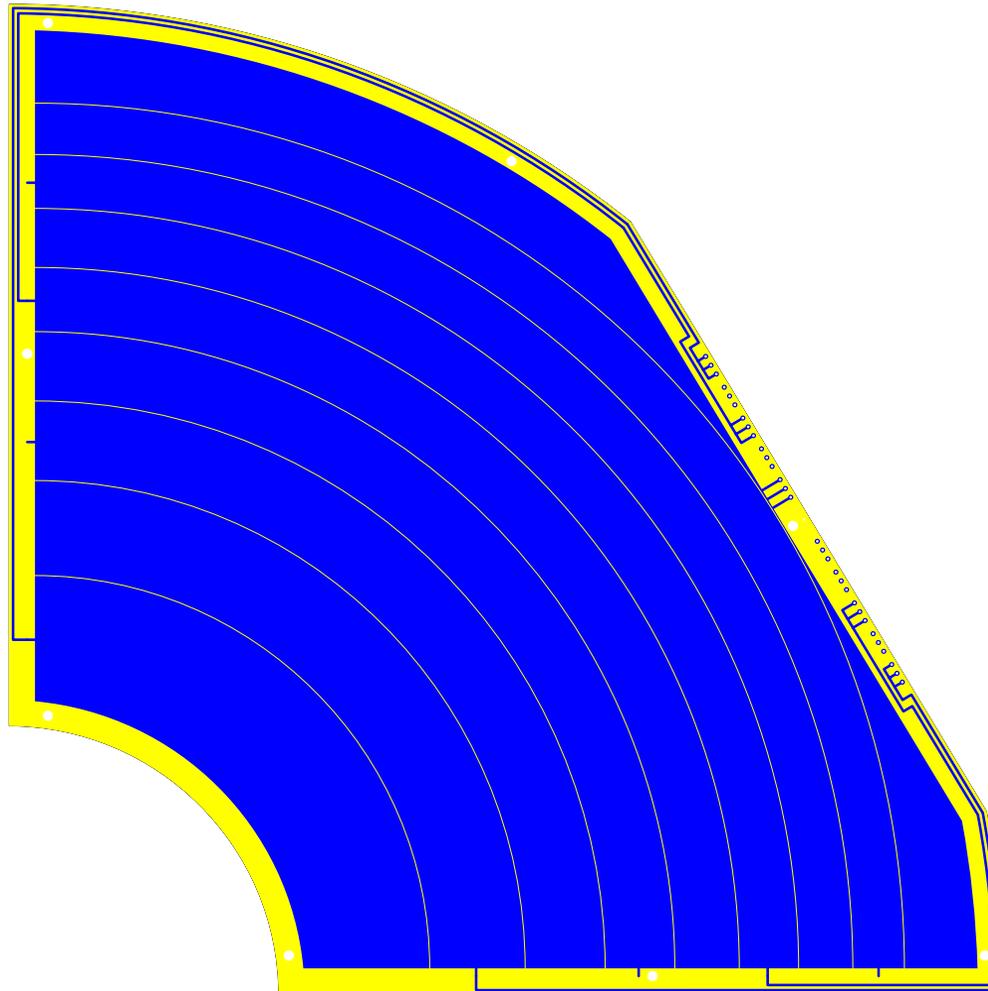


HV foil

FGT GEM foil  
(unsegmented side)

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- Triple-GEM: Quarter section design



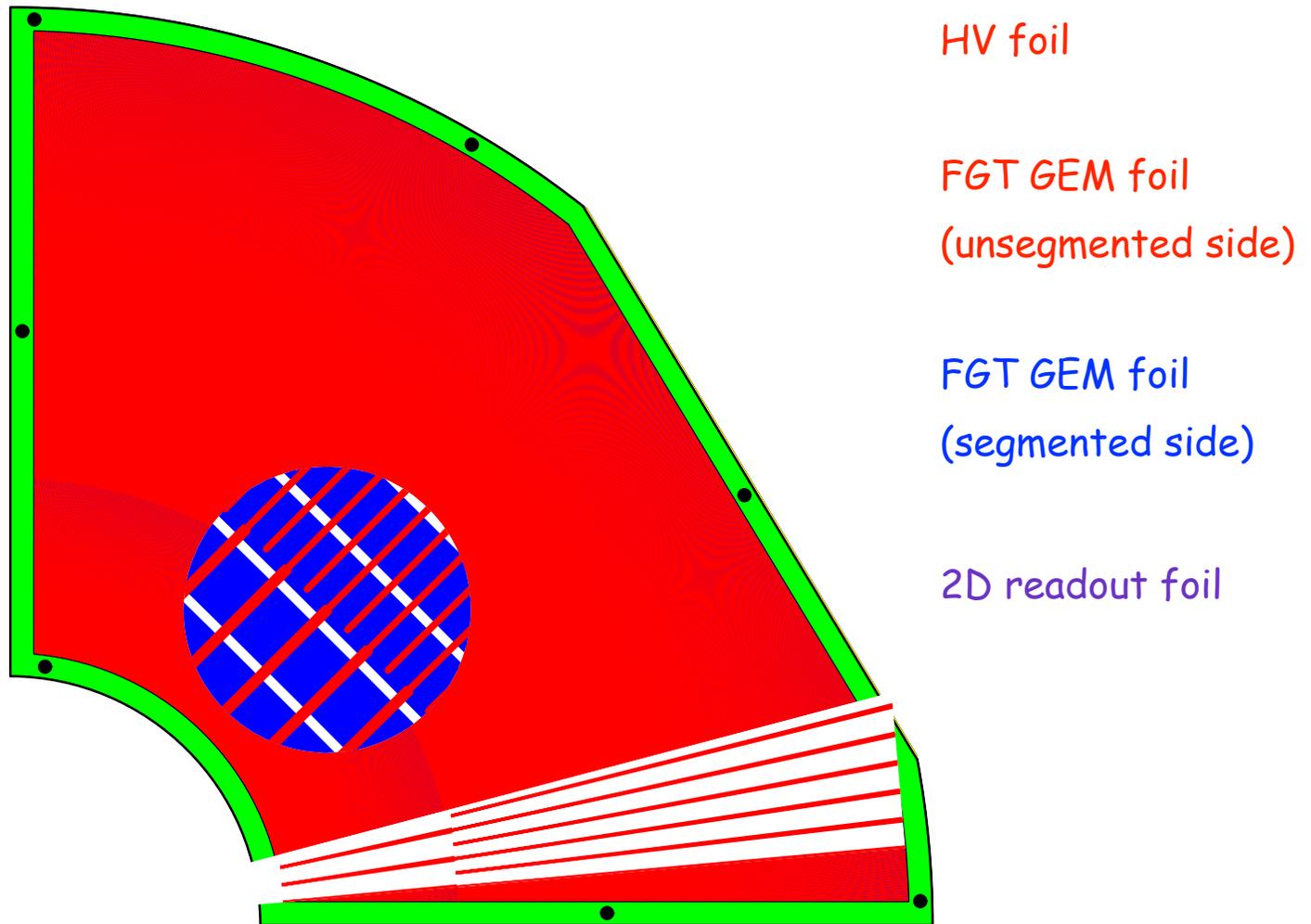
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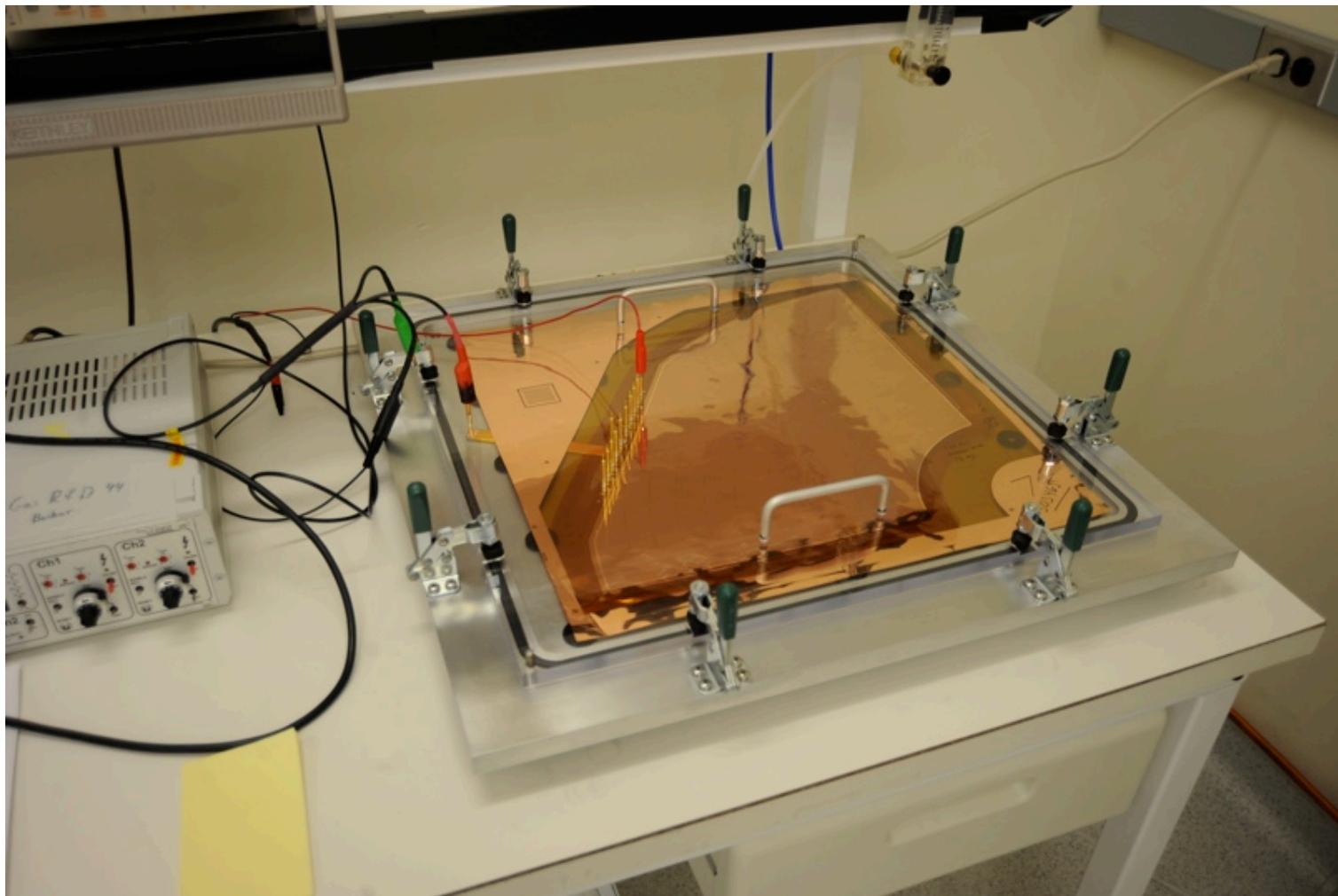
# FGT Technical realization / Layout

- Triple-GEM: Quarter section design



# FGT Technical realization / GEM foils

- Triple-GEM: GEM foil - Leakage current tests

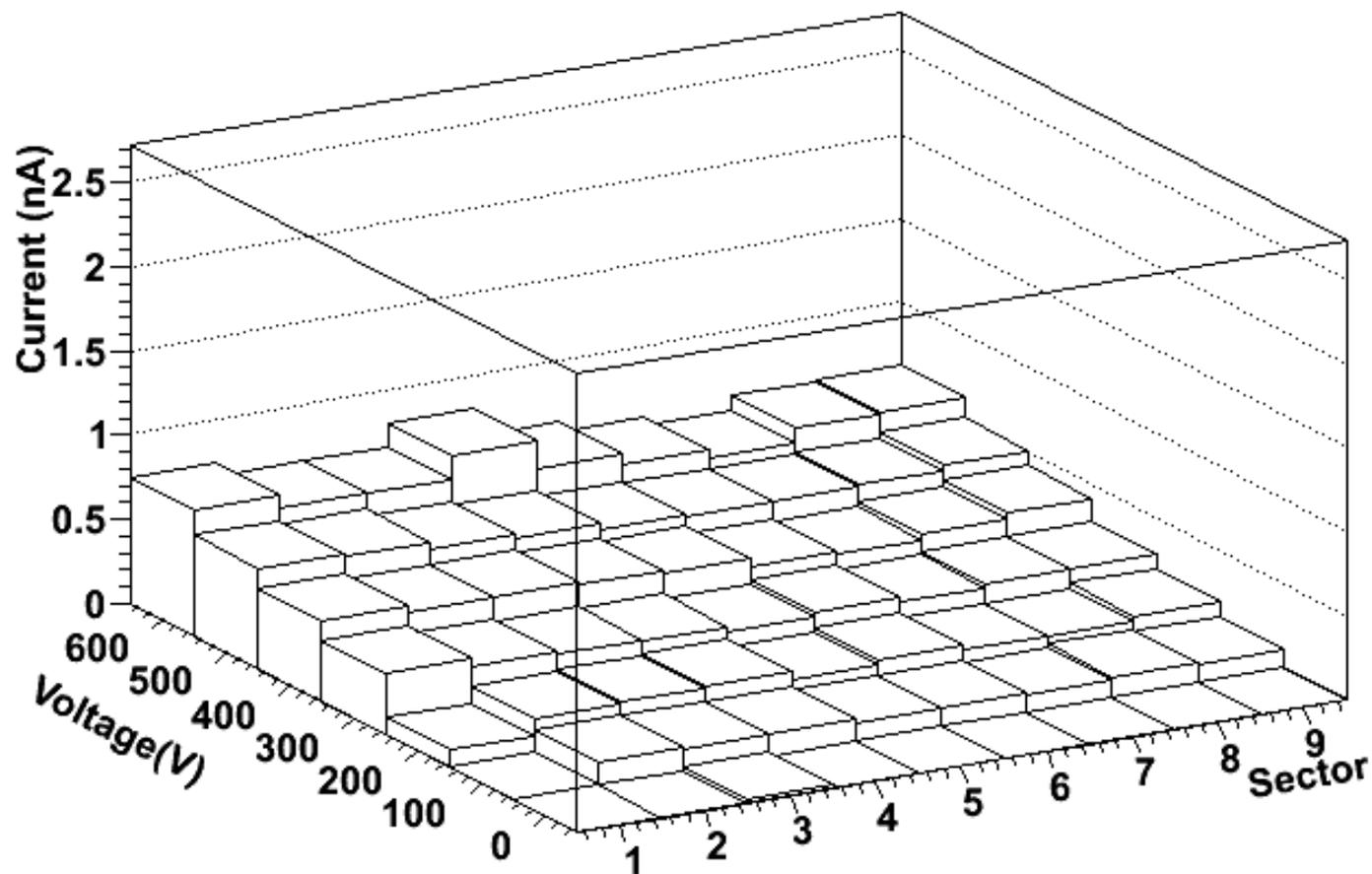


HV box for GEM foil leakage current tests

# FGT Technical realization / GEM foils

- Triple-GEM: GEM foil testing: Tech-Etch production foil results

Leakage Currents in Tech-Etch Foil #1 (Oct2010)



# FGT Technical realization / GEM foils

## □ Triple-GEM: GEM foil testing - CCD Scans



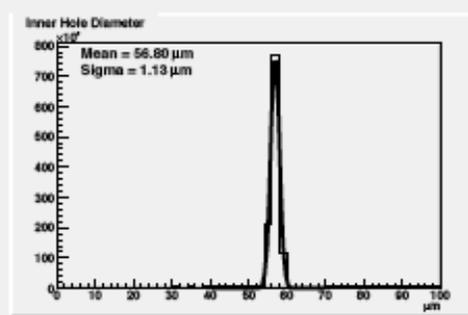
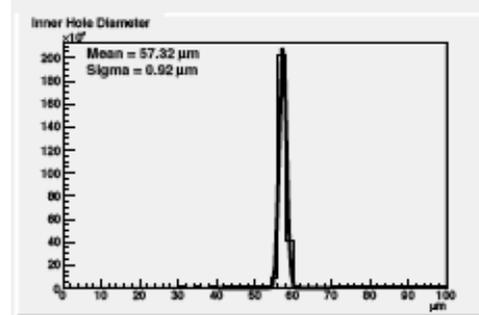
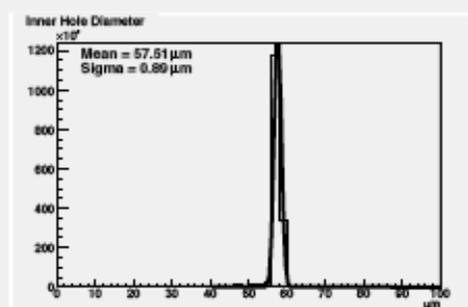
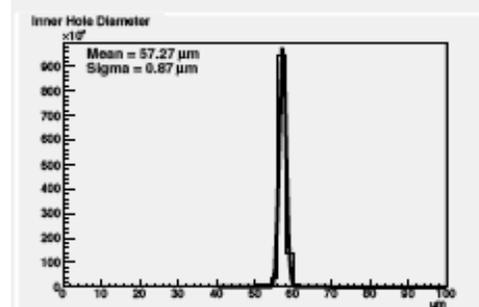
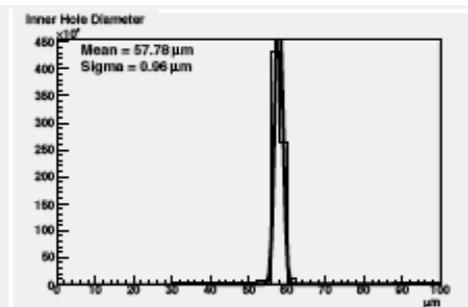
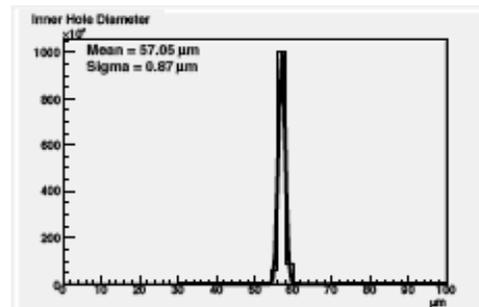
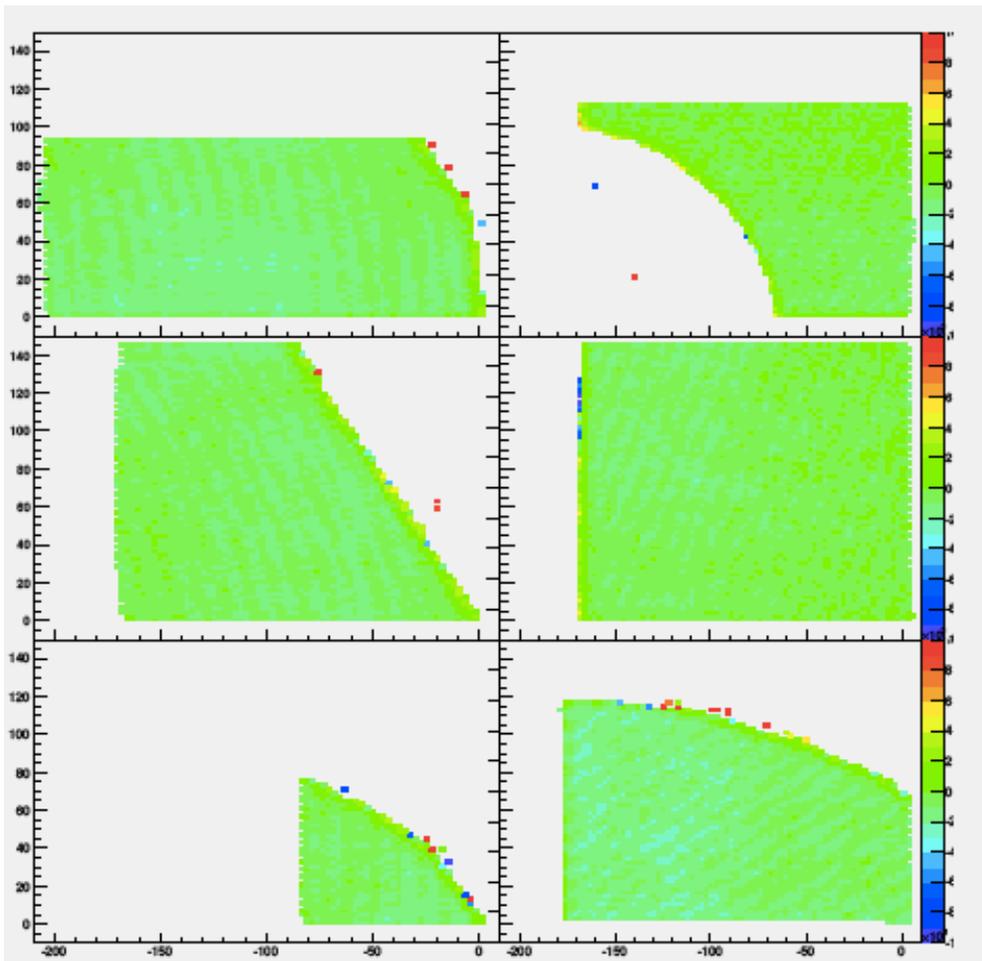
CCD camera setup for optical GEM foil scans

### Optical scans:

- Measure inner and outer hole diameter / Uniformity across full surface (Important for gain uniformity) - Ongoing
- Systematic Tech-Etch and CERN comparison

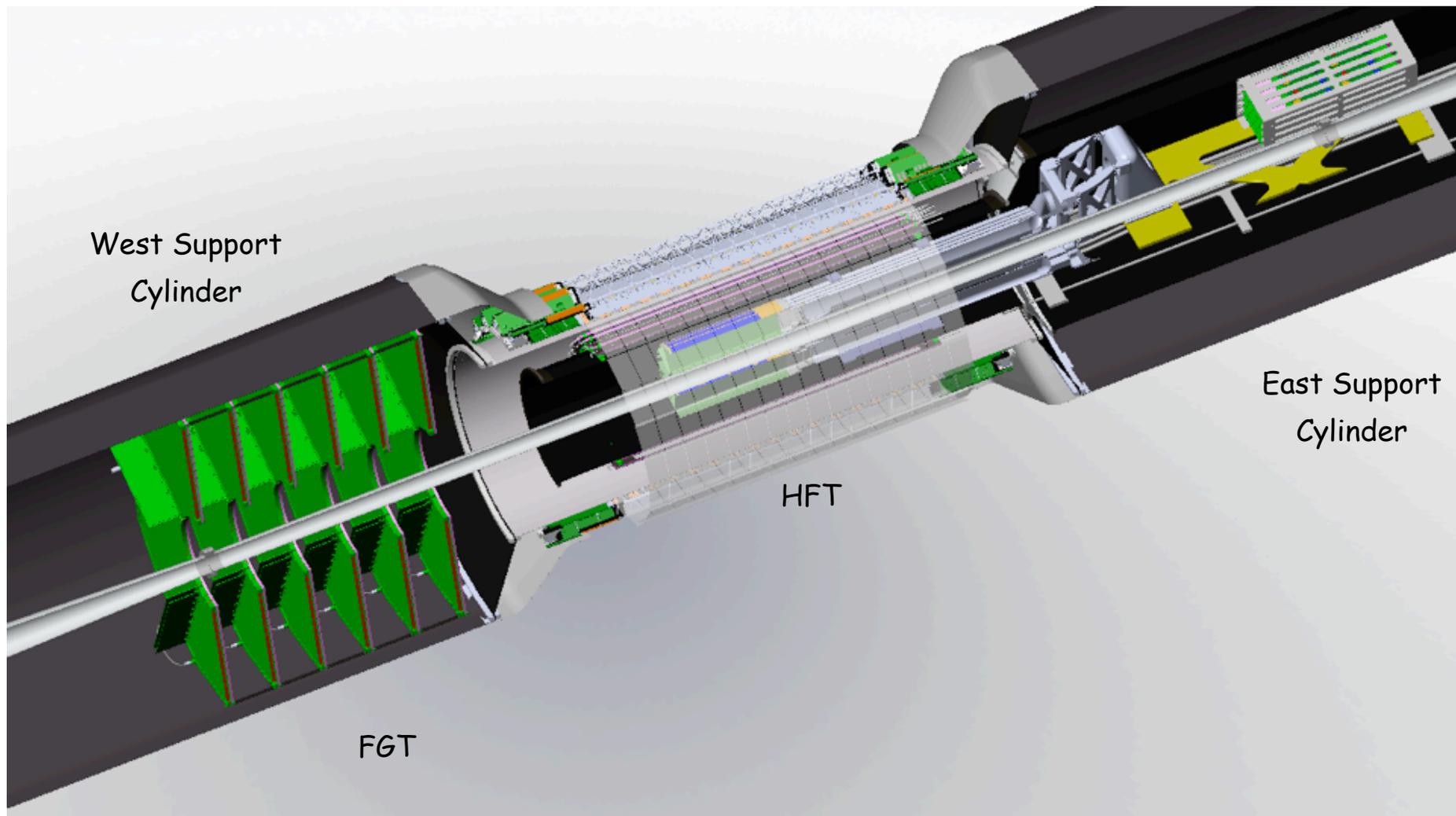
# FGT Technical realization / GEM foils

- Triple-GEM: GEM foil testing - Tech-Etch / Inner hole distr. - Production foil



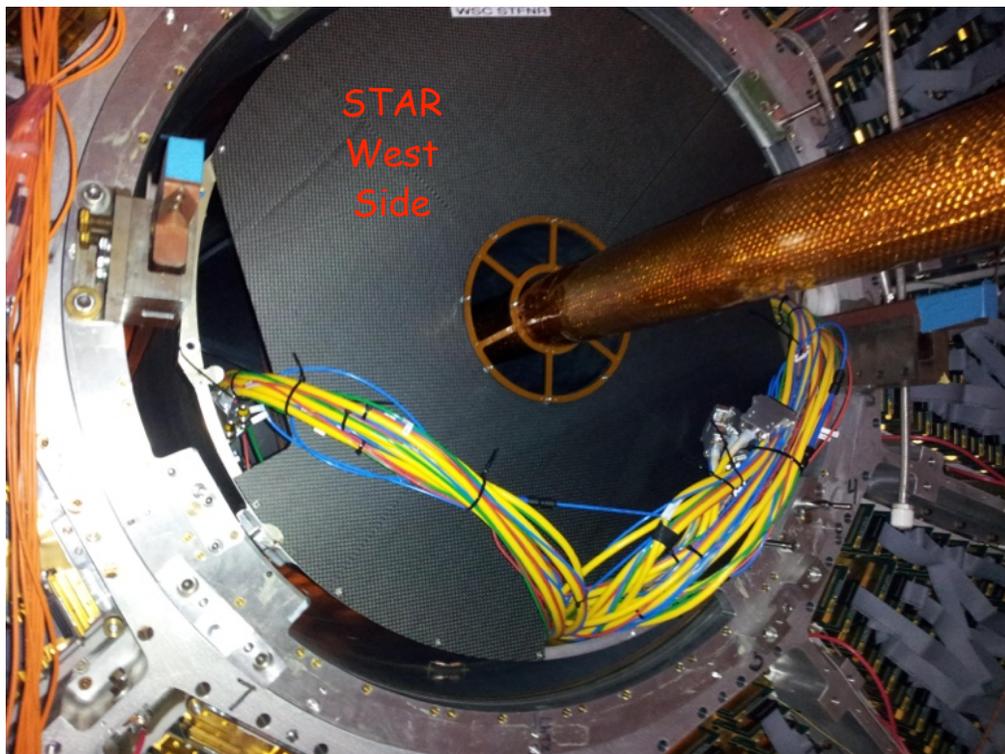
# FGT Technical realization / Integration

## □ Integration



# FGT Technical realization / Integration

## □ Photo album - Integration (3)



# Summary / Outlook

## □ Summary

- Extensive R&D period:
  - Commercial GEM foil production by Tech-Etch Inc. (SBIR funding)
  - Optical CCD scan
  - 2D readout board (Layout and foil) / Commercial production by Tech-Etch Inc. (SBIR funding)
  - FEE design (BGA concept / Multi-pin connector)
- Strong interest to use FGT technology for future applications at BNL / JLab / LHC
- Partial installation in summer 2011 (14/24 quarter sections)

## □ Outlook

- Completion of assembly and installation (24/24 quarter sections) in summer/fall 2012
- Future: Expect and need several long 500GeV production runs beyond Run 12 (e.g. Run 13)