

# Hadron Blind Detector: Detector Talk

Jason Kamin

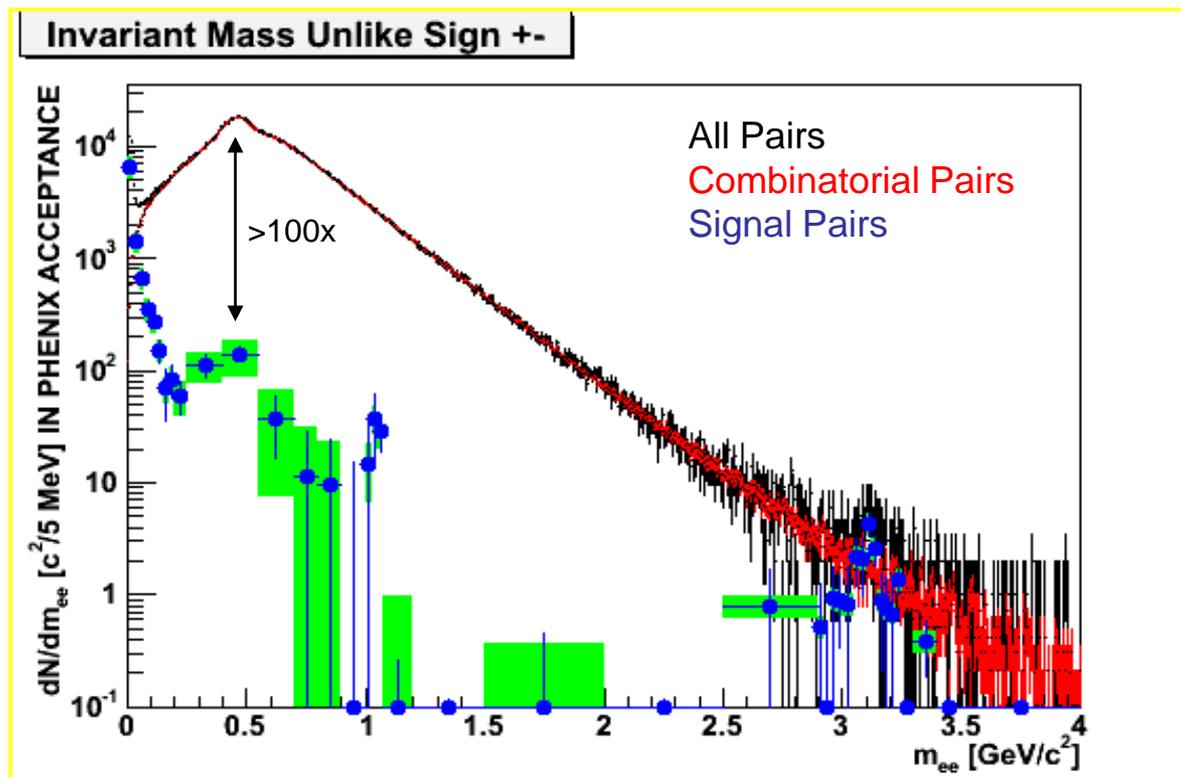
PHENIX Focus Seminar

23 Jan 2007

# Outline

1. Principles of HBD operation
  1. Electric Fields
  2. Electron Avalanche
  3. Cherenkov Radiation
2. How GEMs work
3. CsI Evaporation Techniques
4. Current Status

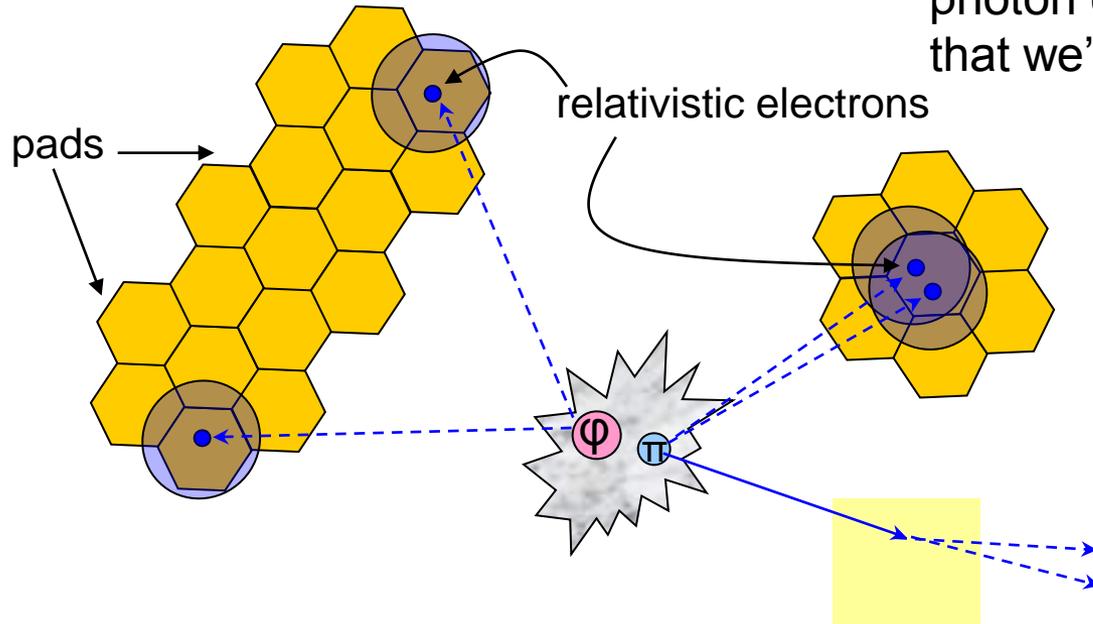
# Invariant Mass Spectrum from $e^+e^-$



- **Major problem:** Huge combinatorial background mostly due to:
  - $\gamma$ -conversions &  $\pi^0$  Dalitz decays.
- We need a new detector to identify the above by supplying:
  - eID
  - momentum directionthus reducing background by a factor of 10-100.

# Is it a $\pi$ or a $\phi$ ?

Back to the basics (briefly)...



A lot of particles have  $e^+e^-$  decay channels. How can we tell the Dalitz decays and photon conversions apart from the decays that we're interested in??

Dalitz decay electrons have apparent mass from  $2m_e \rightarrow m_\pi$  with highest probability near  $2m_e$

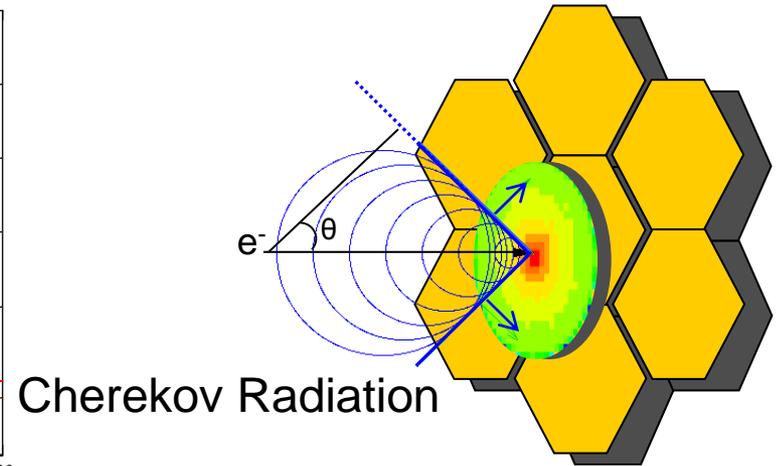
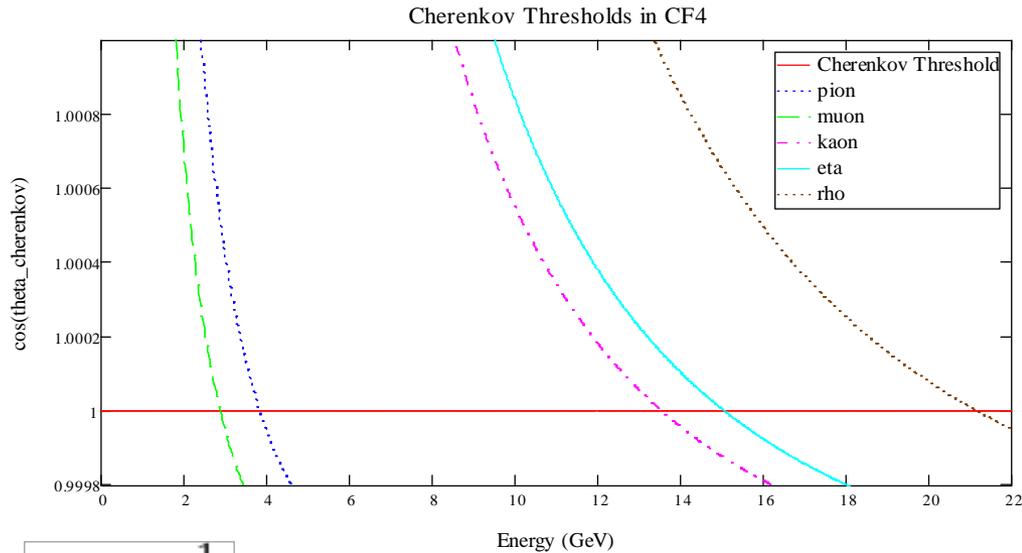
Photon conversions  
EVEN MORE tightly peaked around  $2m_e$

**Dalitz and Photon conversions have smaller opening angles!!**

**How about a Cherenkov Detector???**

- ID electrons
- give directional information.

# Cherenkov Radiation

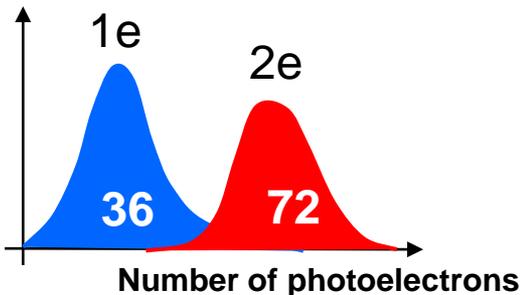


Cherenkov Radiation

$$\cos \theta = \frac{1}{n\beta}$$

$\theta$ : Cherenkov angle  
 $\beta$ : velocity of particle  
 $n$ : refractive index of medium

When a particle moves faster than the speed of light in a medium, light is emitted!

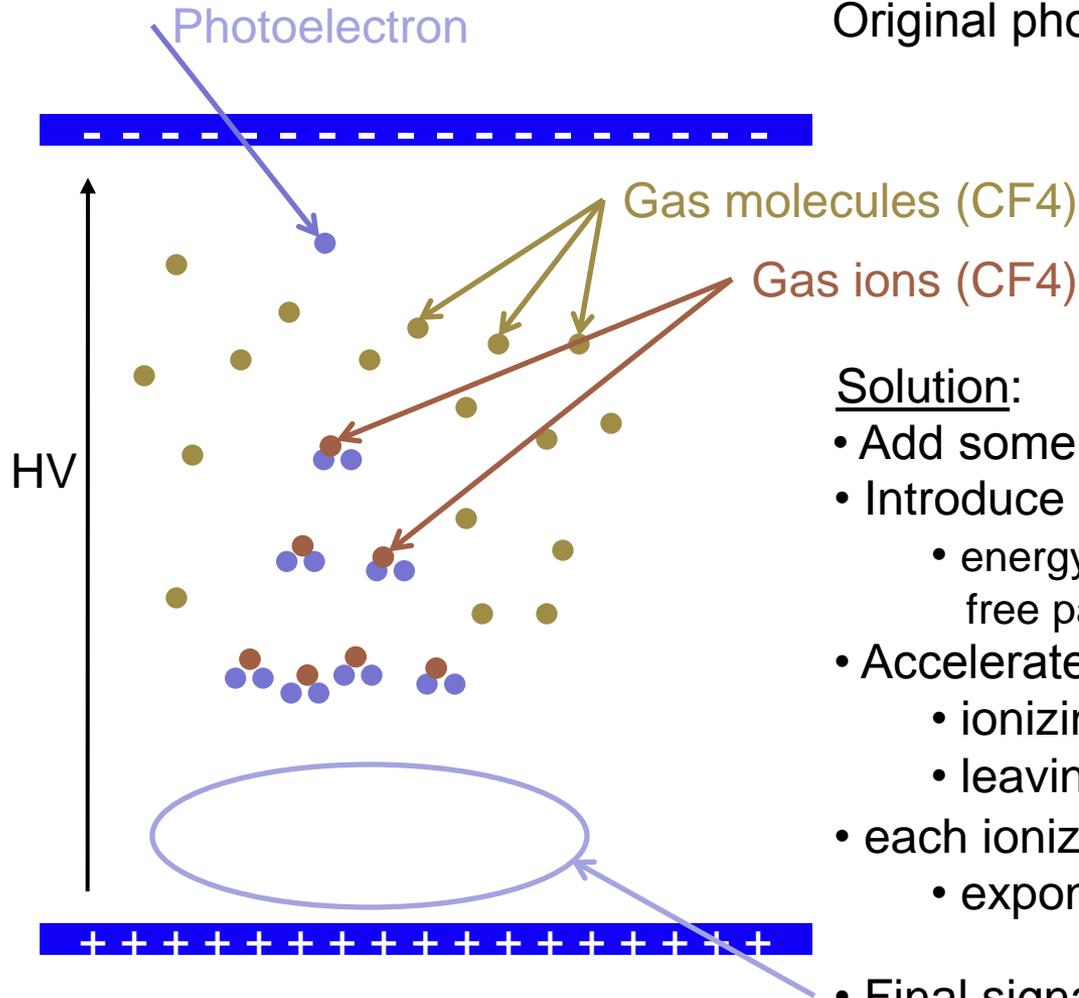


- analogous to a sonic boom.
- typically only electrons are light enough to be traveling fast enough to radiate.
- in CF4:  $\pi < 4\text{GeV}$  do not radiate.

# Avalanche Process

## Problem:

Original photoelectron isn't measurable



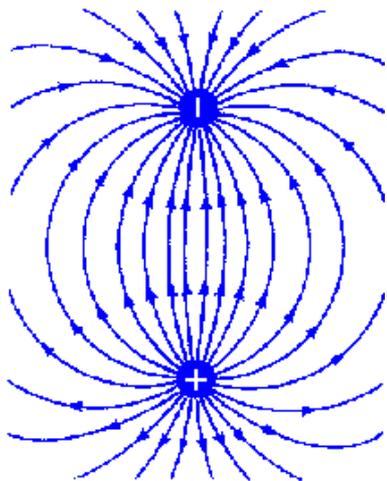
## Solution:

- Add some gas (CF<sub>4</sub>)...
- Introduce **strong** electric field...
  - energy gained per photoelectron per mean free path > energy to ionize a gas molecule.
- Accelerate electron through gas...
  - ionizing molecules along the way,
  - leaving an ionization trail behind.
- each ionized electron gets accelerated too!
  - exponentially increasing the signal
- Final signal IS measurable!! 😊

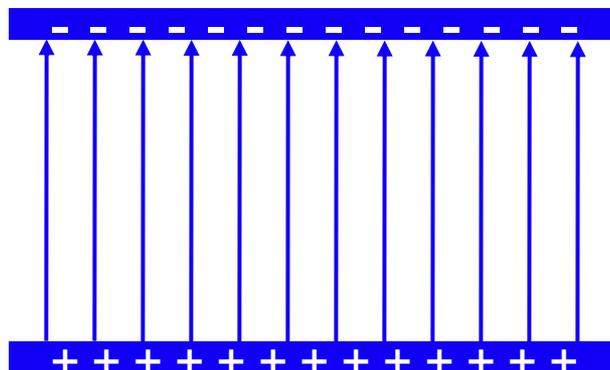
# Electric Fields 101

As always class, let's ignore fringe effects!

Dipole

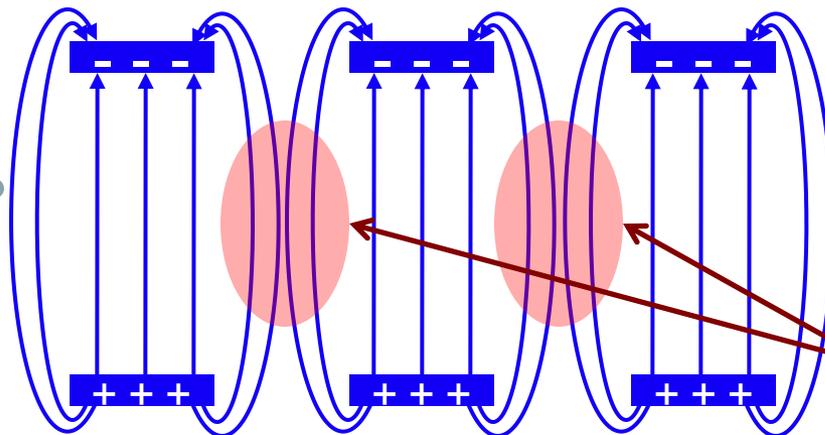


Parallel Plate



On second thought, let's *not*!

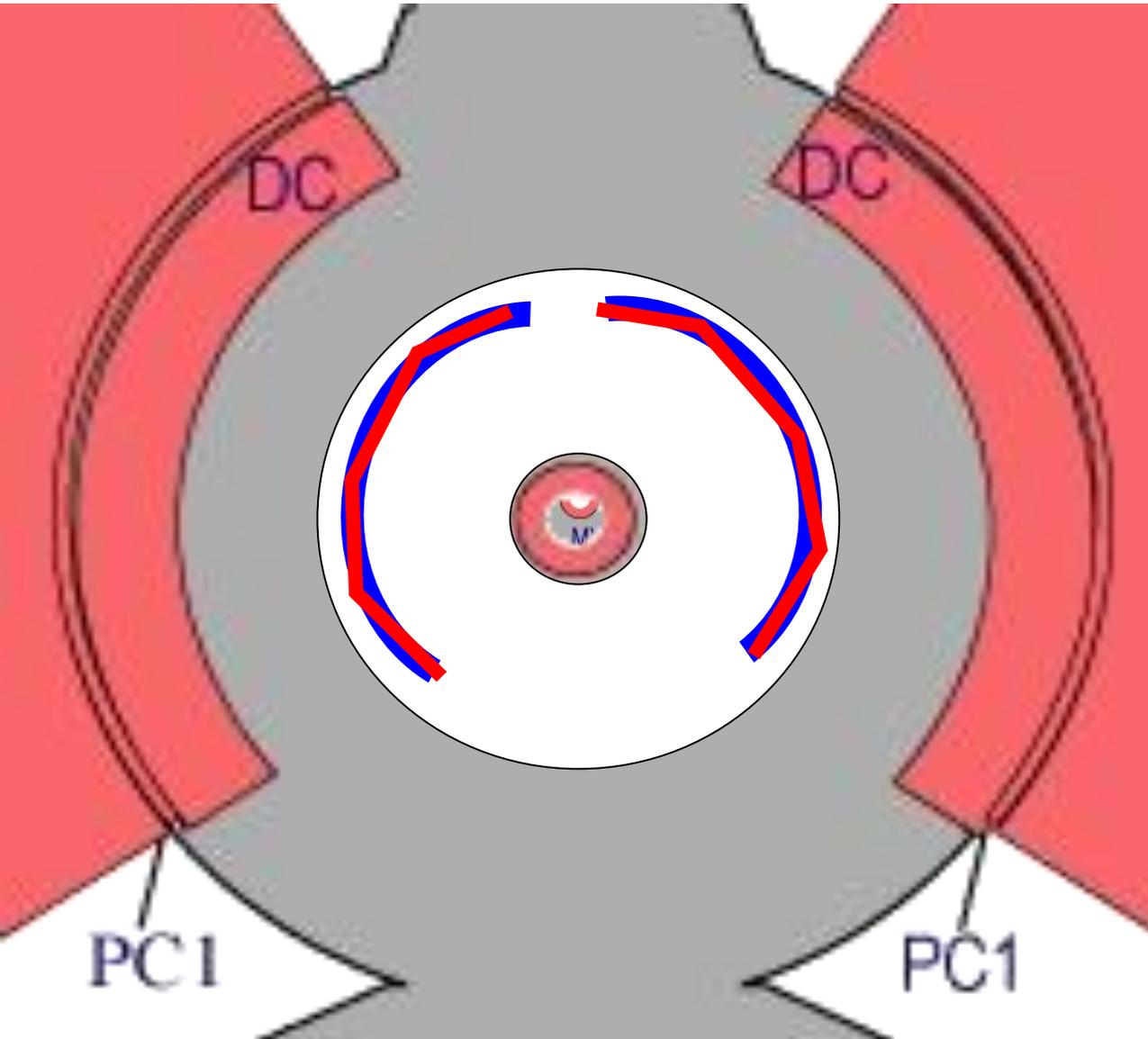
Line up bunches of dipoles



Chop up your parallel plate capacitor

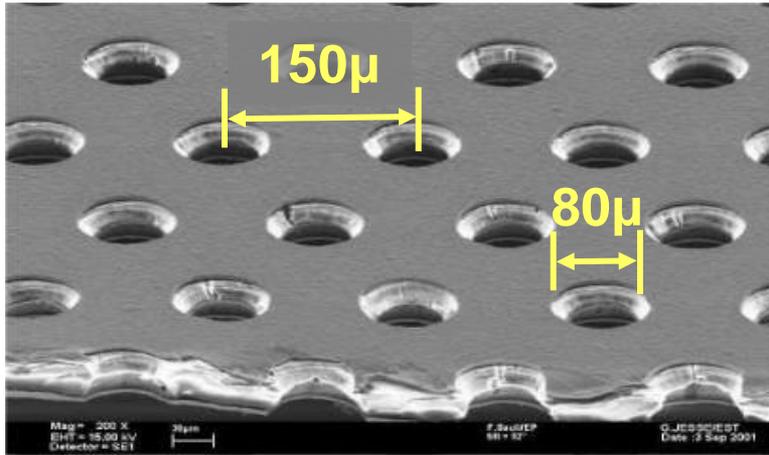
High density E-field

# Peering into PHENIX...



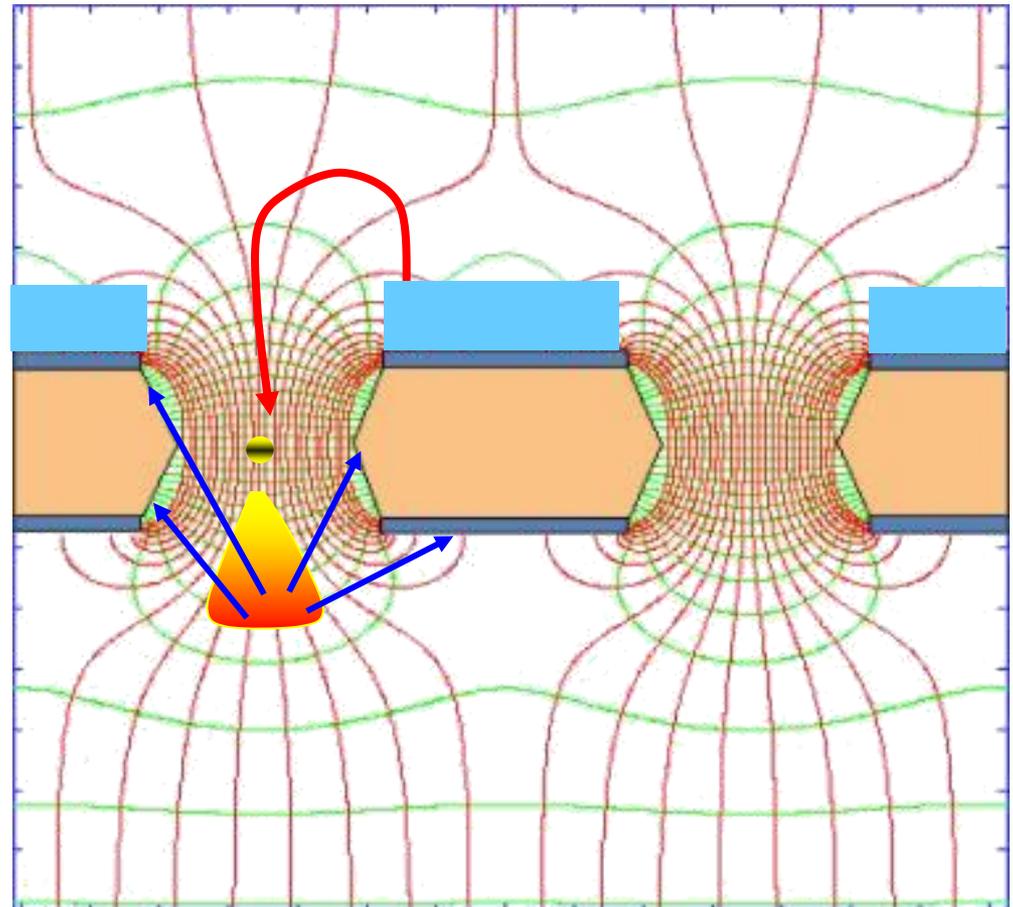
- Inner coil can cancel B-field at  $r < 60$  cm
- Not enough room for traditional optics... mirrors won't work.
- Just put the detector right in the middle of things!
- Has potential, but...
  - must be thin
  - **must detect a single UV photon and still be blind to all ionizing particles passing through it!!!**

# Gas Electron Multiplier (GEM)

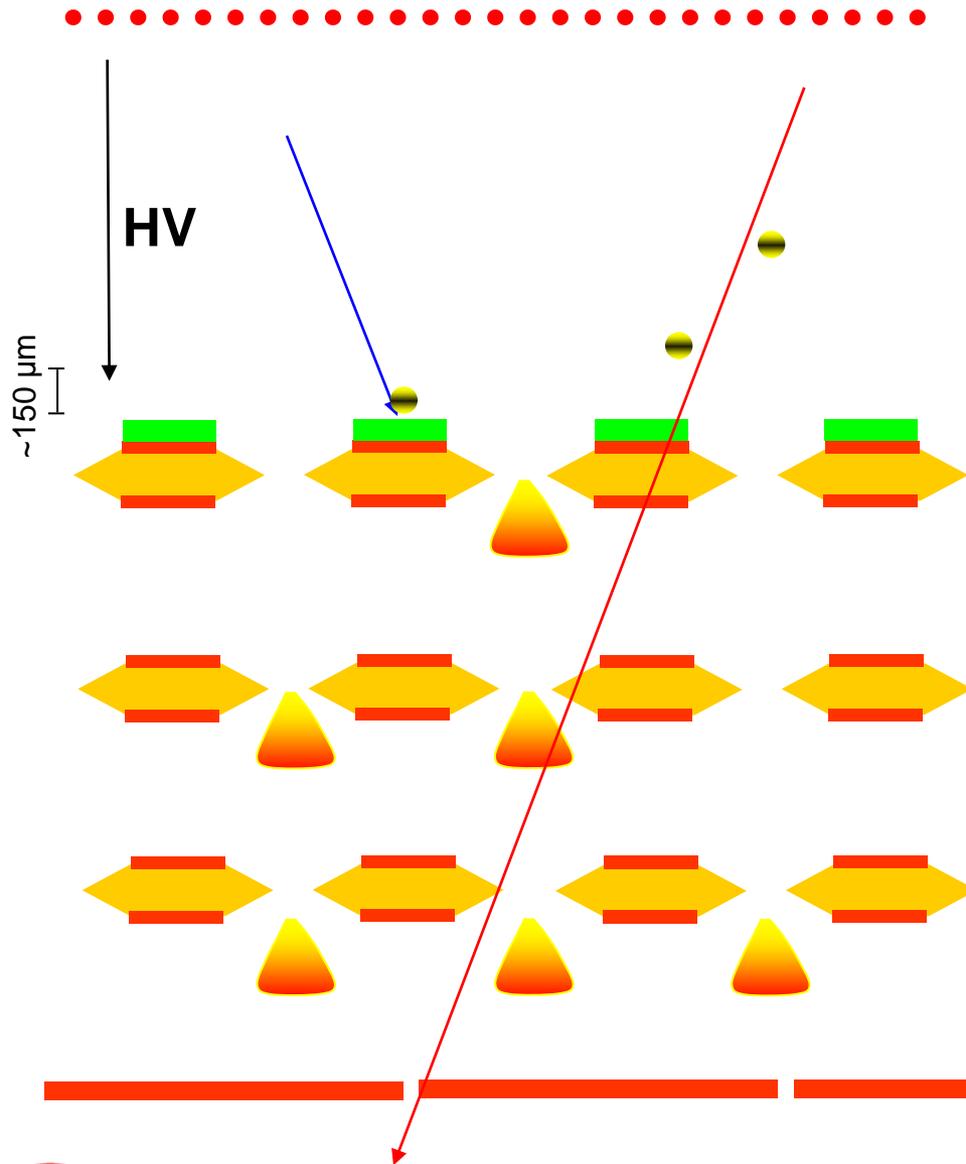


- Two copper layers separated by insulating film with regular pitch of holes
- HV creates very strong field such that the avalanche develops inside the holes
- Just add the photocathode
- By the way: no photon feedback onto photocathode

- The original idea by F.Sauli (mid 90s)  
US Patent 6,011,265
- Traditionally CHARGED PARTICLE detectors (not photons)

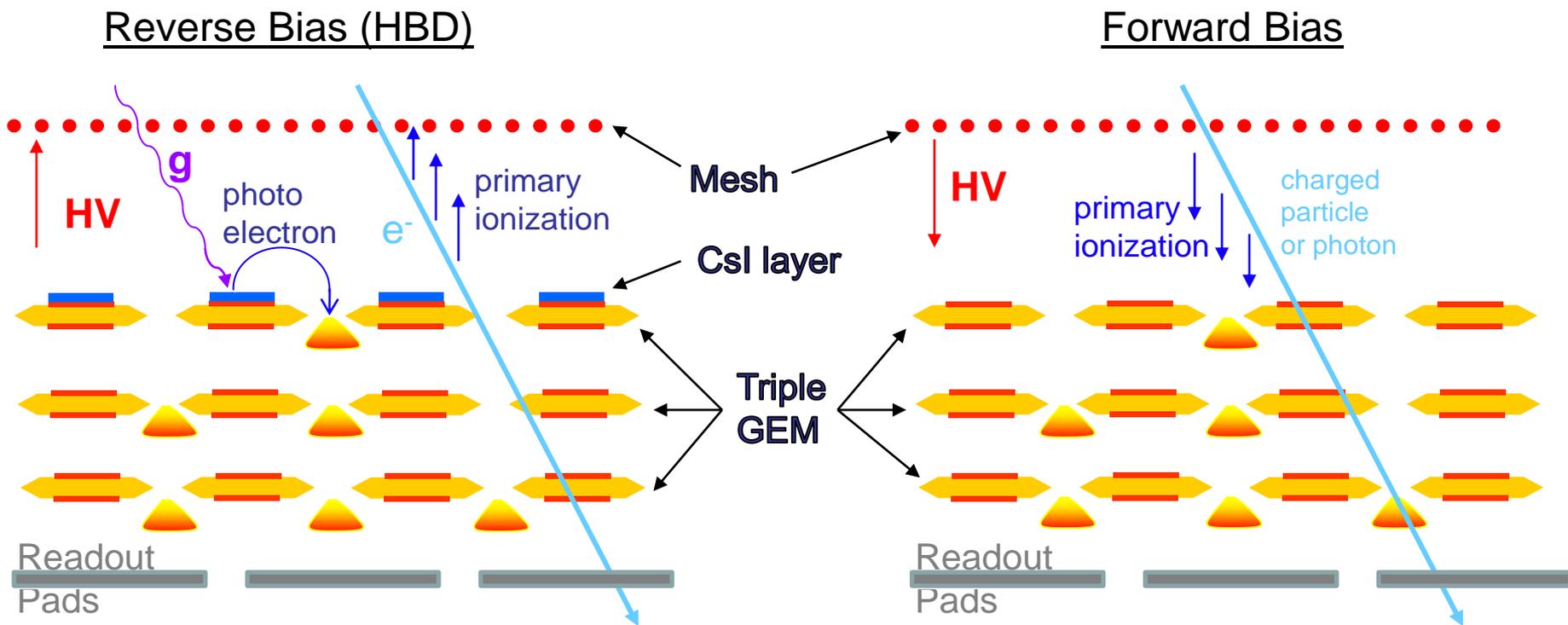


# Watch the Magic...



- Start with a GEM
- Put a photocathode (CsI) on top
- photoelectron from Cherenkov light avalanches in the high density E-field
- Use more GEMs for larger signal
- Pick up the signal on pads
- What about ionizing particles (hadrons)?
- We need a mesh with a reverse voltage on it to blow electrons away!!!
- **We have a detector sensitive to UV and blind to ionizing particles!**

# Ways to use GEM stacks

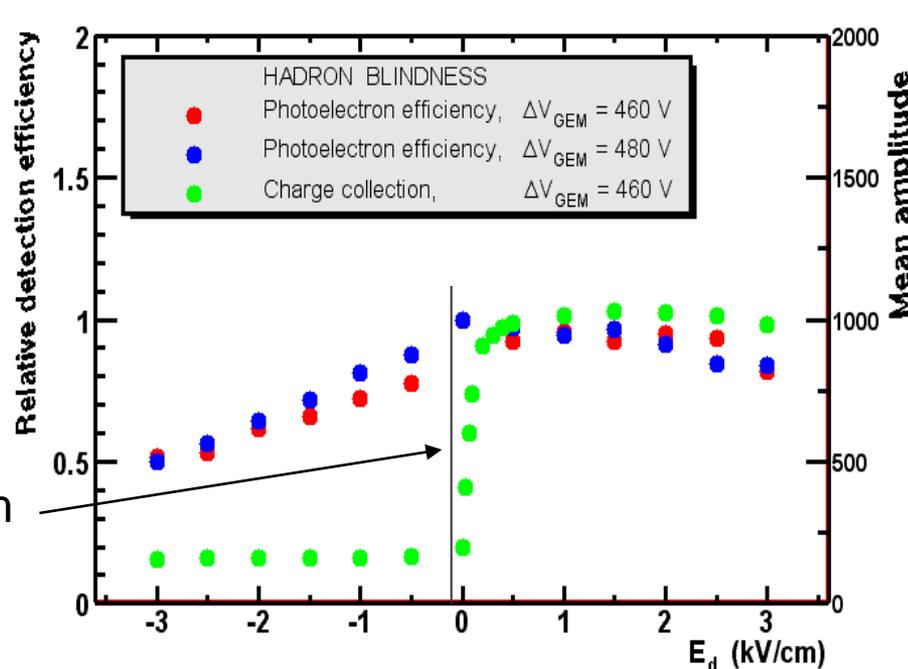


Limited by the transparency of gas  
CF<sub>4</sub>, ~1-12 eV photons

Limited by the absorption of gas  
ArCO<sub>2</sub>, 1-10 keV photons

- Lateral spread of avalanche is ~500 μm, thereby limiting resolution.
- Single electron gain ~10<sup>4</sup>

# Hadron Blindness: UV photons vs charged particles

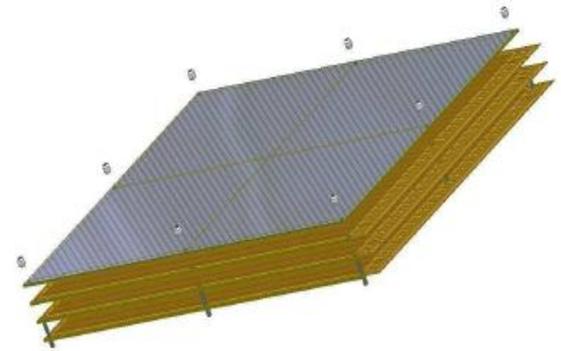


- At slightly negative  $E_d$ , photoelectron detection efficiency is preserved whereas charge collection is largely suppressed.
- Charge collected from  $\sim 150\mu$  layer above top GEM

# GEMs

## Reasons why GEMs are clever:

- Holes make high density E-field capable of initiating avalanche:
  - avalanche only happens inside holes.
- Small avalanche/gain per GEM. (ie. no runaway avalanche)
- They're *thin*. (ie. HBD radiation length  $\sim 1.5\%$ ):
  - minimizes photon-conversions.
- Can be stacked (triple stack) to achieve required gain:
  - allows for HBD to be windowless: Radiator Gas = Avalanche Gas.
- Reverse-Bias mesh allows for hadron rejection.
- CsI coating transforms GEM into a photocathode.
- The GEM itself protects the CsI from the avalanche photons:
  - avalanche photons are absorbed by GEM after each avalanche stage.



# The HBD Detector

HBD Gas Volume: Filled with  $\text{CF}_4$  Radiator ( $n_{\text{CF}_4}=1.000620$ ,  $L_{\text{RAD}}=50$  cm)

Cherenkov light forms "blobs" on an image plane ( $r_{\text{BLOB}}\sim 3.36$ cm)

Pcb pad readout ( $\sim 2\times 2$  cm<sup>2</sup>)

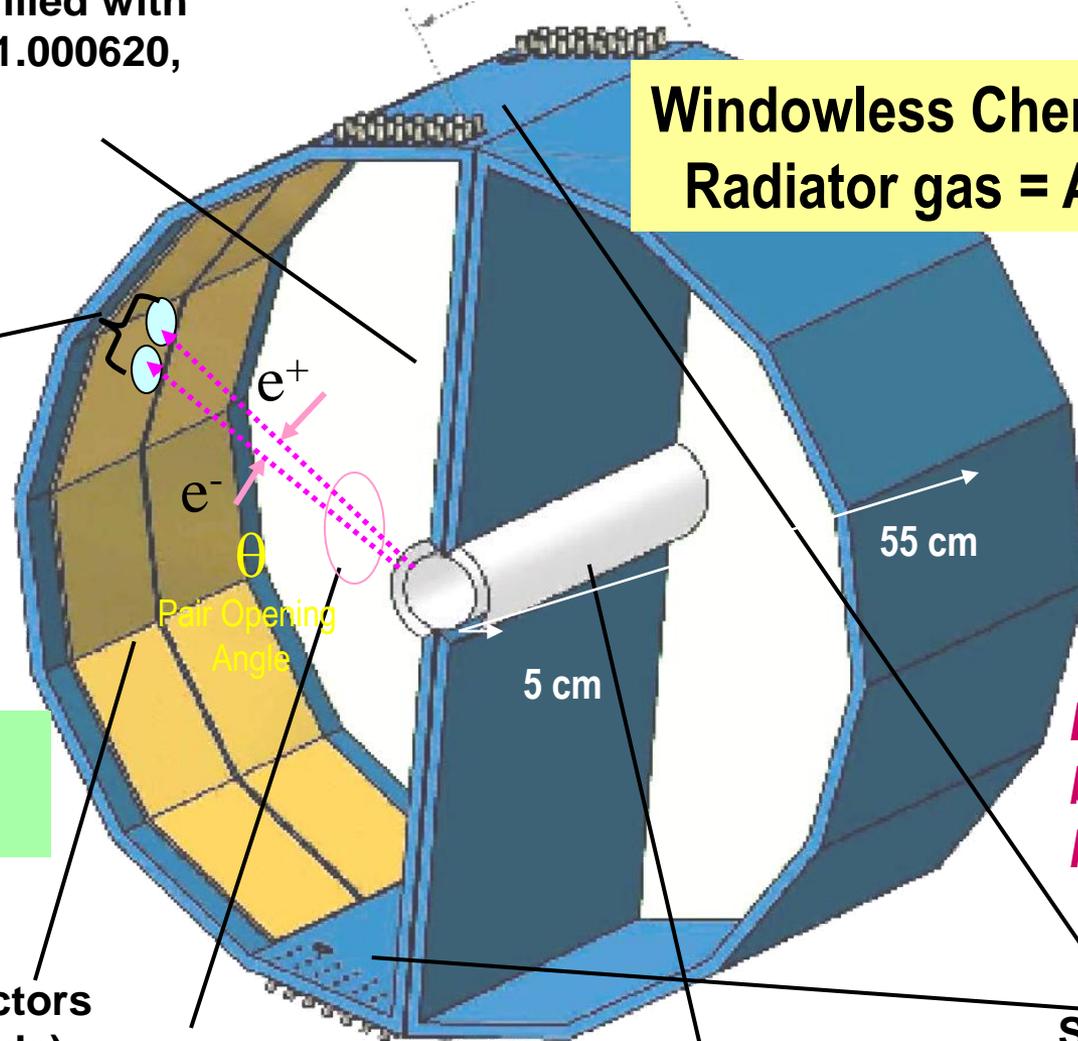
CsI photocathode covering GEMs

Triple GEM detectors (12 panels per side)

Dilepton pair

Beam Pipe

Windowless Cherenkov Detector  
Radiator gas = Avalanche Gas



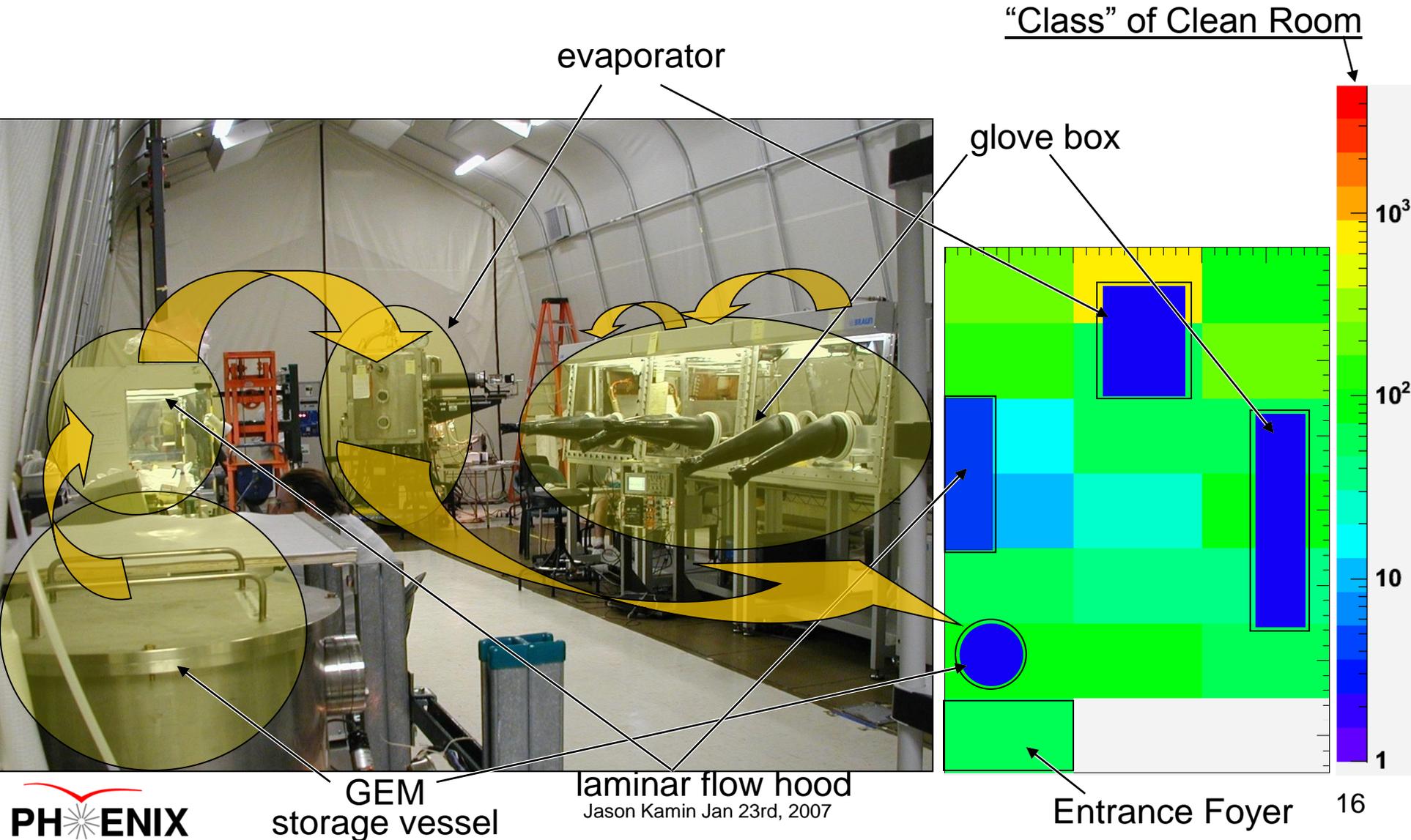
*Electrons radiate, but hadrons with  $P < 4$  GeV/c do not*

Space allocated for services

# Photocathode Production

# The Clean Tent at USB

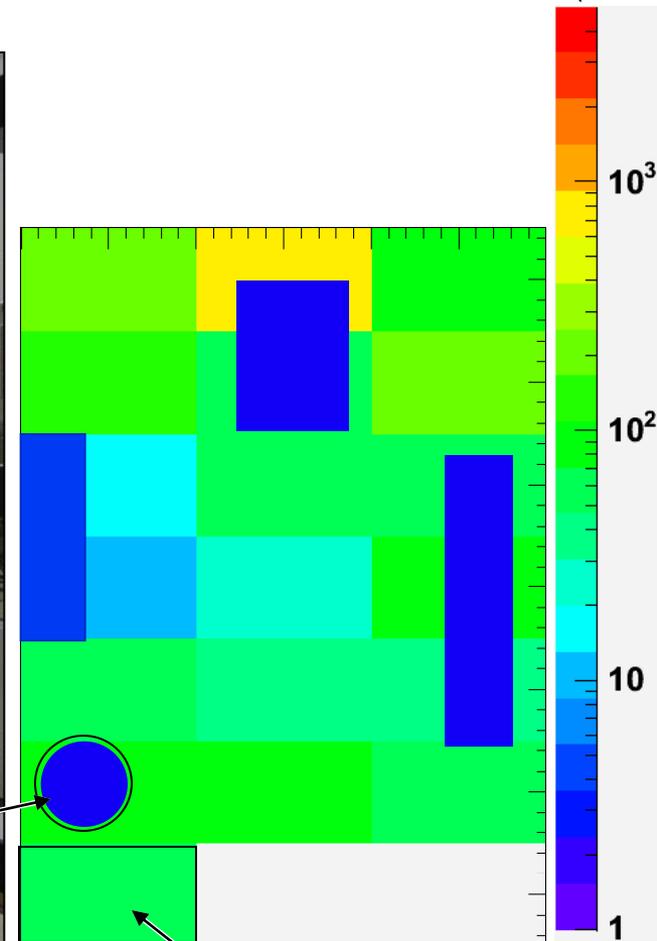
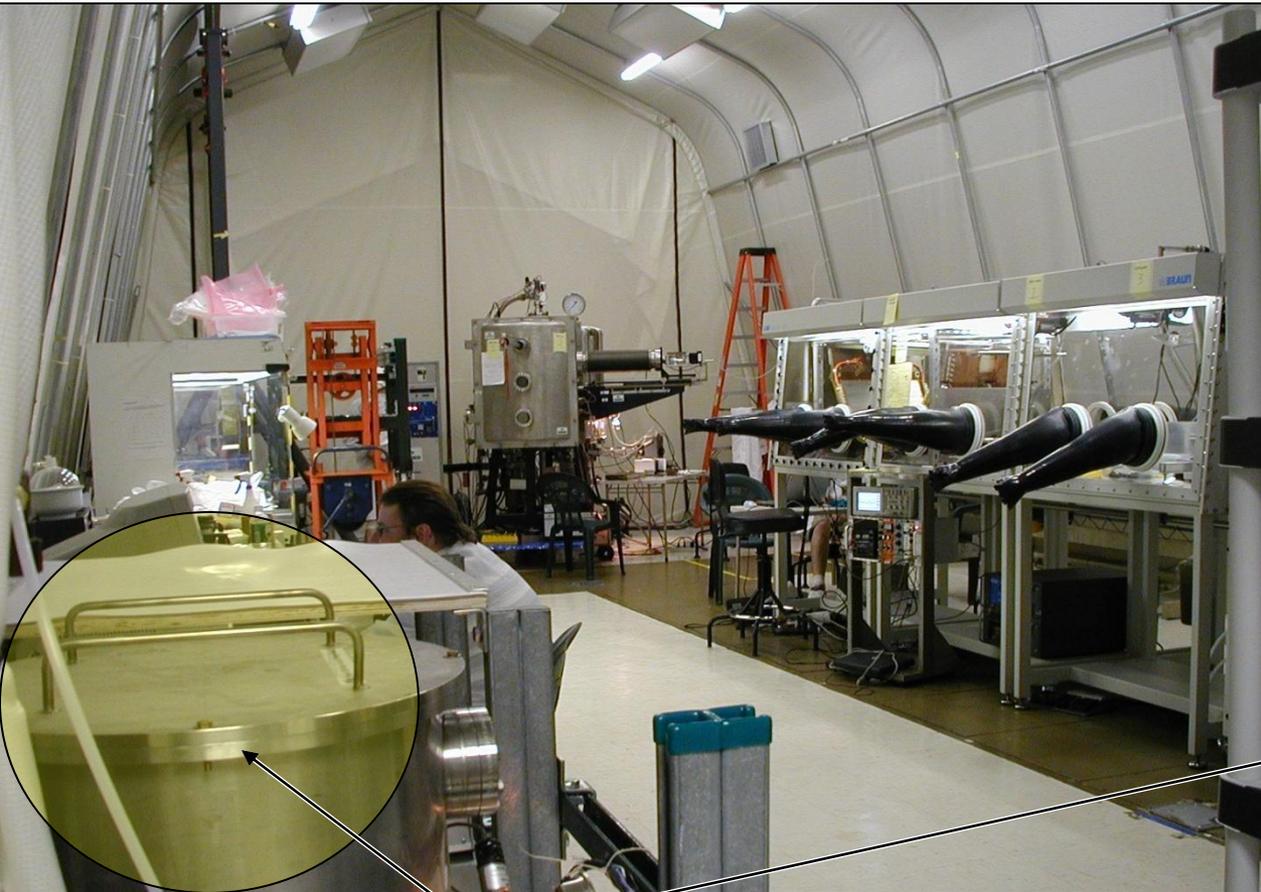
("Class": number of  $\leq 0.5 \mu\text{m}$  particles/ $\text{m}^3$ )



# Vacuum Storage Vessel

("Class": number of  $\leq 0.5 \mu\text{m}$  particles/ $\text{m}^3$ )

"Class" of Clean Room



# Storage and Handling

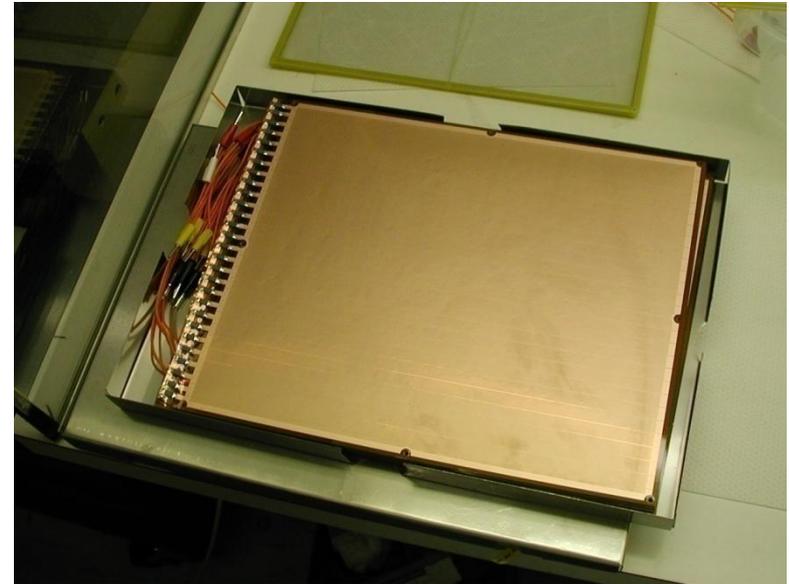
## GEM stack vacuum storage vessel:

- all GEMs are stored here until evaporation
  - actively cleans (and keeps clean) GEMs
- $\sim 10^{-6}$  torr



## “Pizza Box” GEM storage/handling:

- GEMs are stored and transported

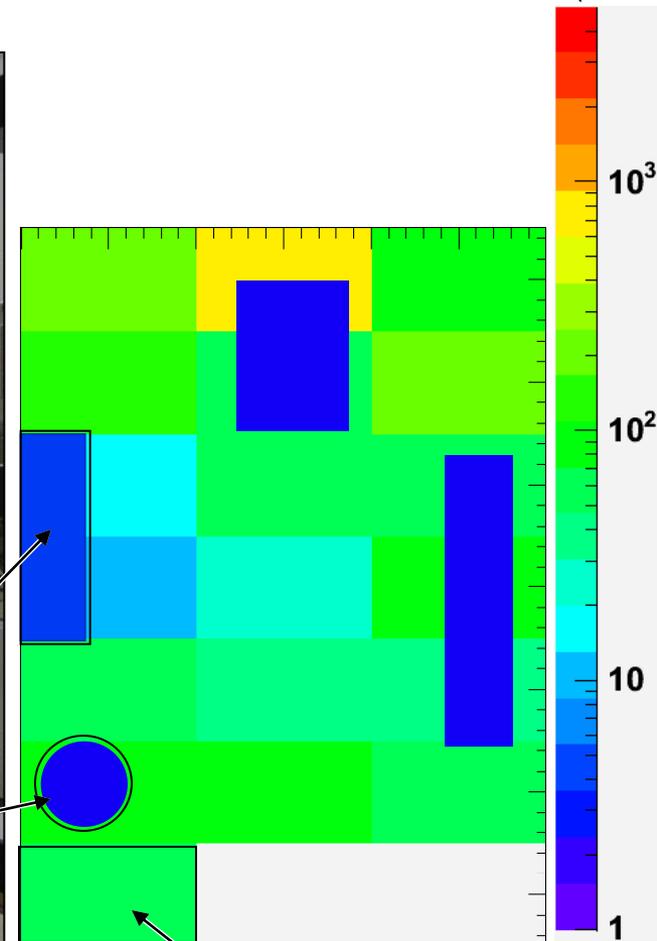
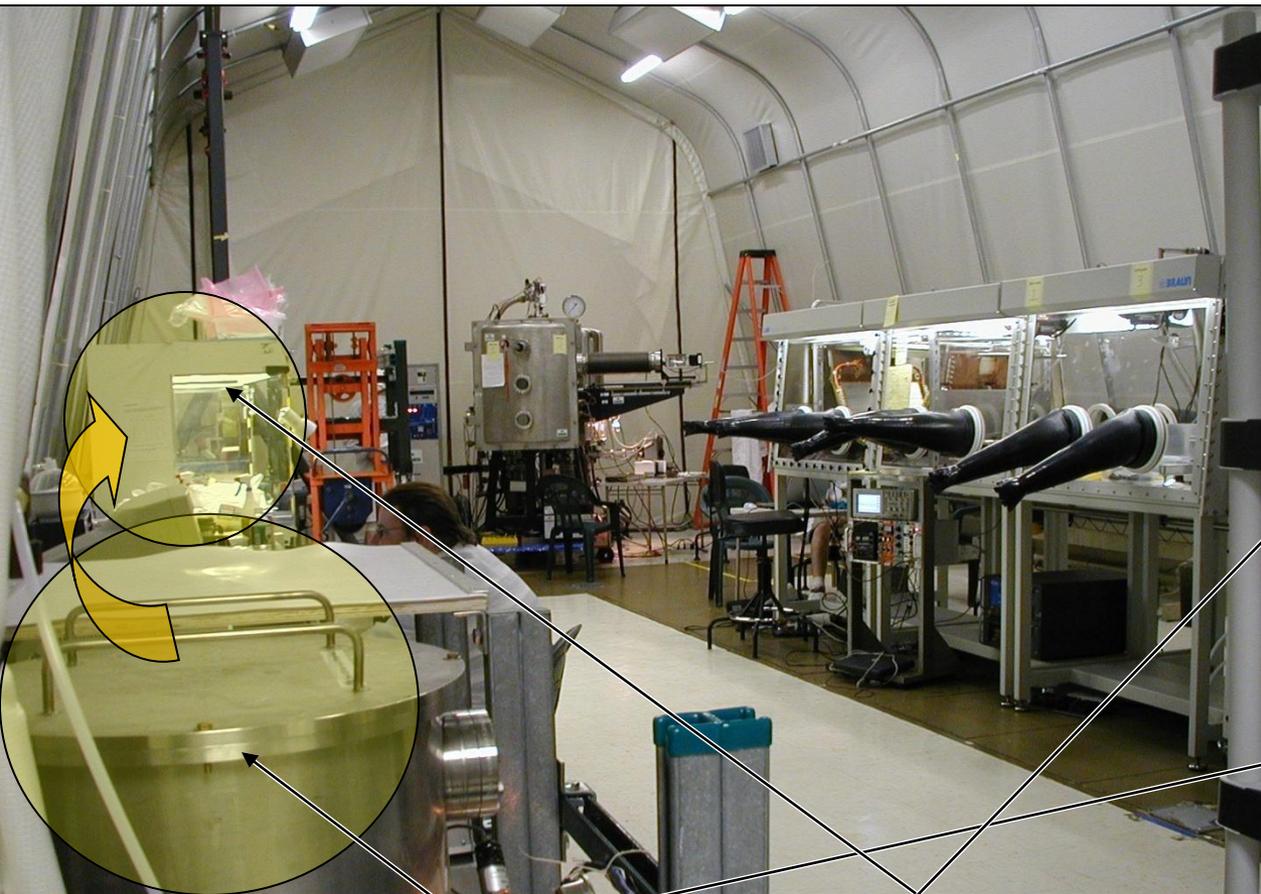


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# Laminar Flow Table

“Class”: number of  $\leq 0.5 \mu\text{m}$  particles/ $\text{m}^3$

“Class” of Clean Room



# Preparation for Evaporation

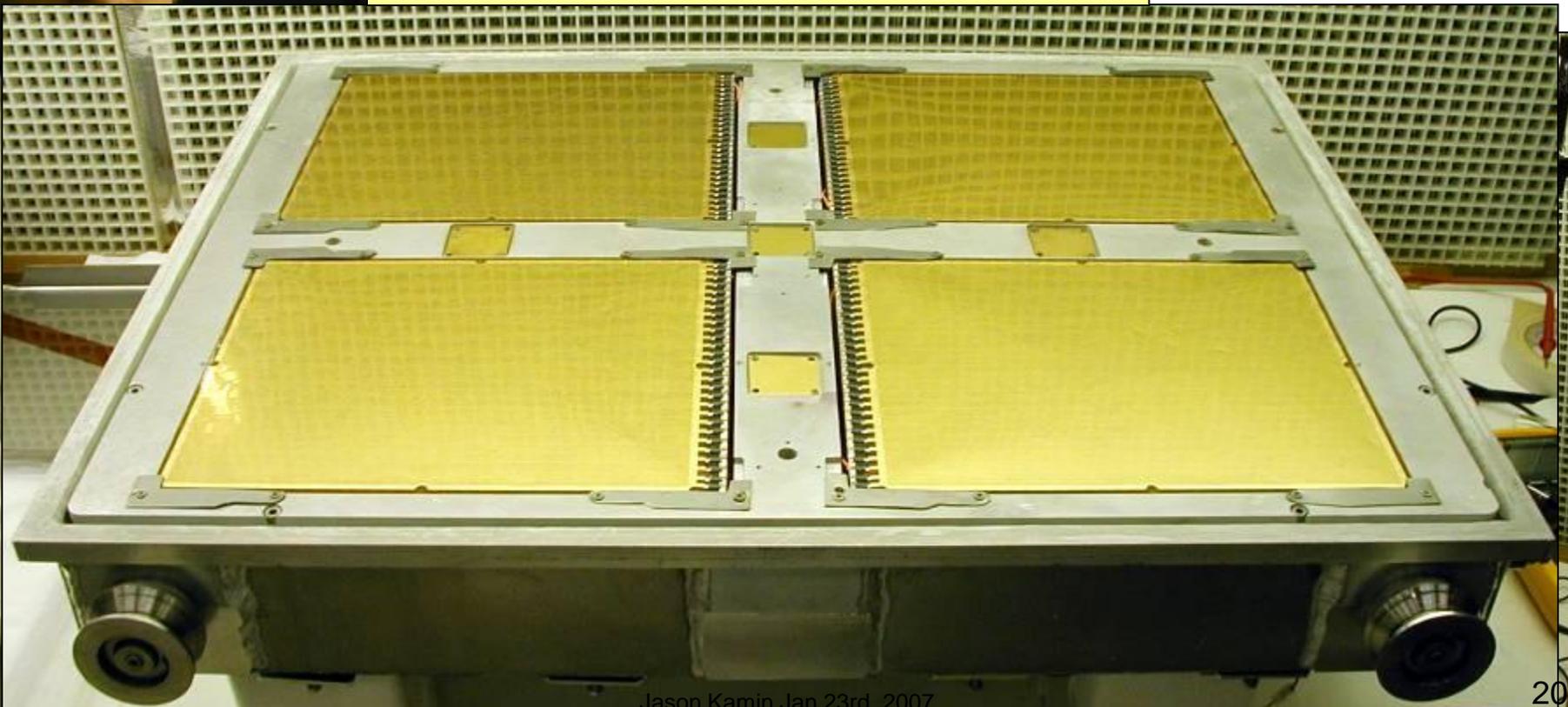
## Cleaning GEMs:

- GEMs are “de-dusted” with Ar

## Installation into Evaporation Box:

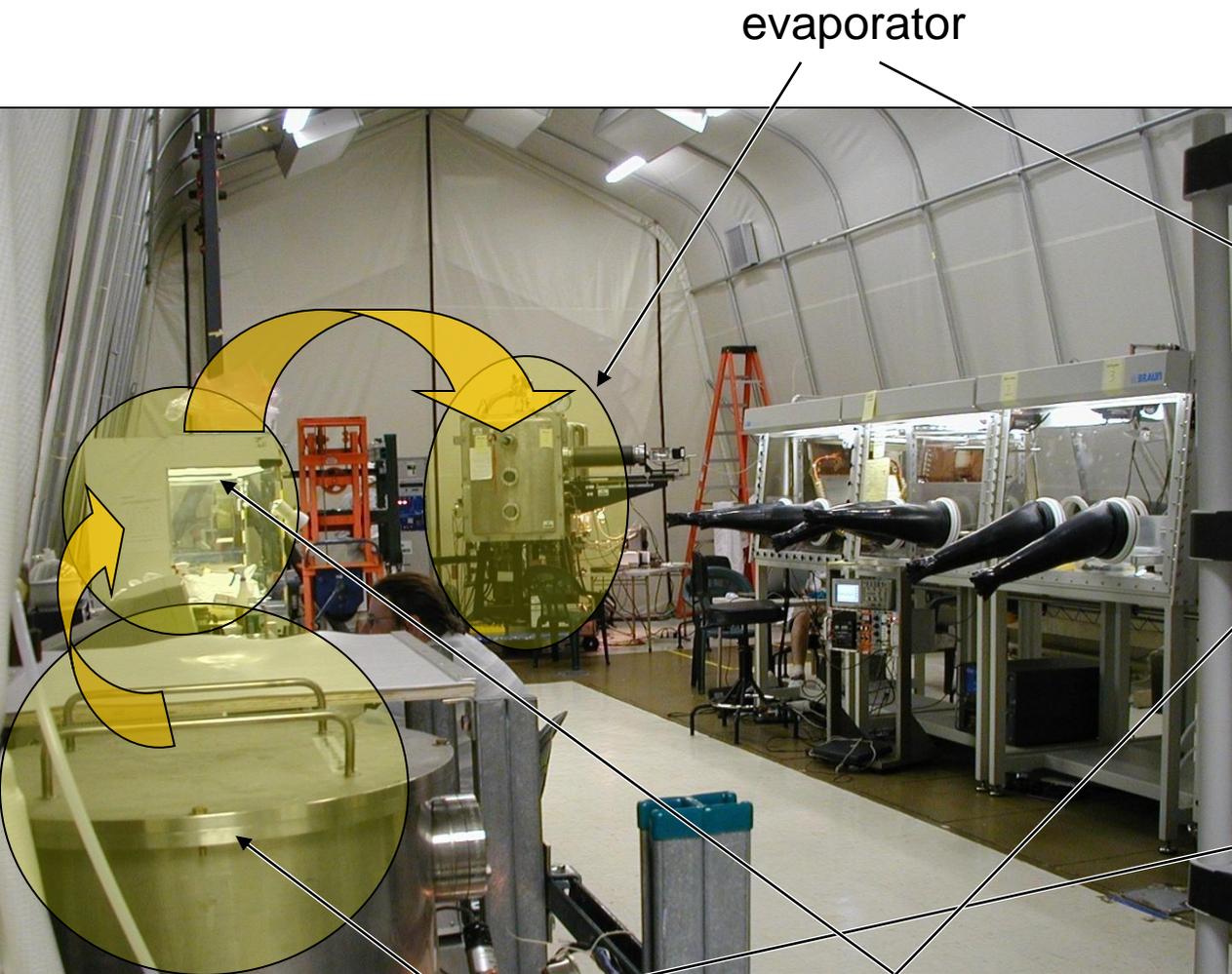
- GEMs mounted in evap box
- Leads connected underneath

READY FOR EVAPORATION

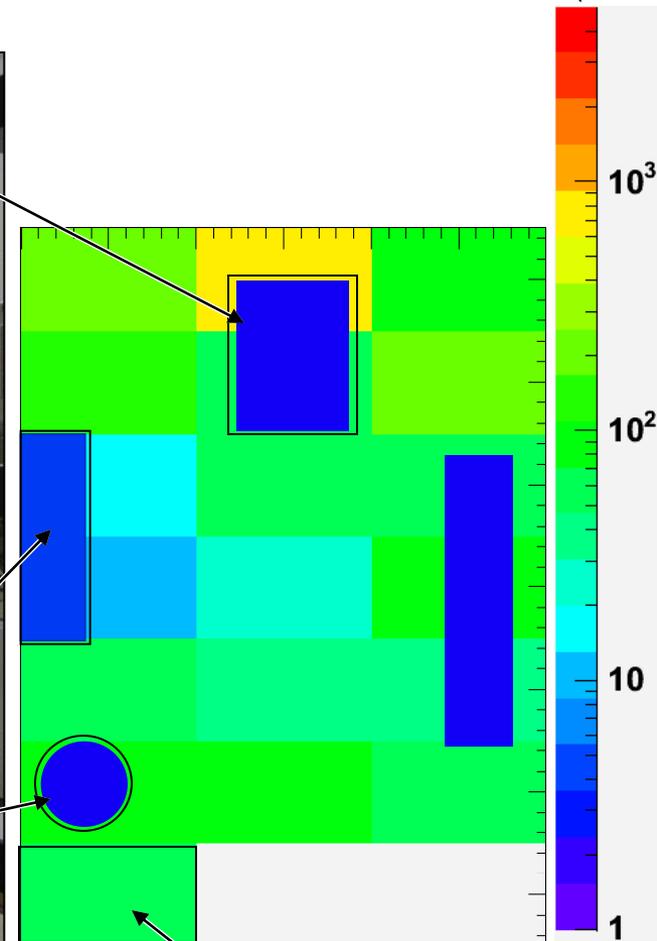


# The Evaporator

("Class": number of  $\leq 0.5 \mu\text{m}$  particles/ $\text{m}^3$ )



"Class" of Clean Room



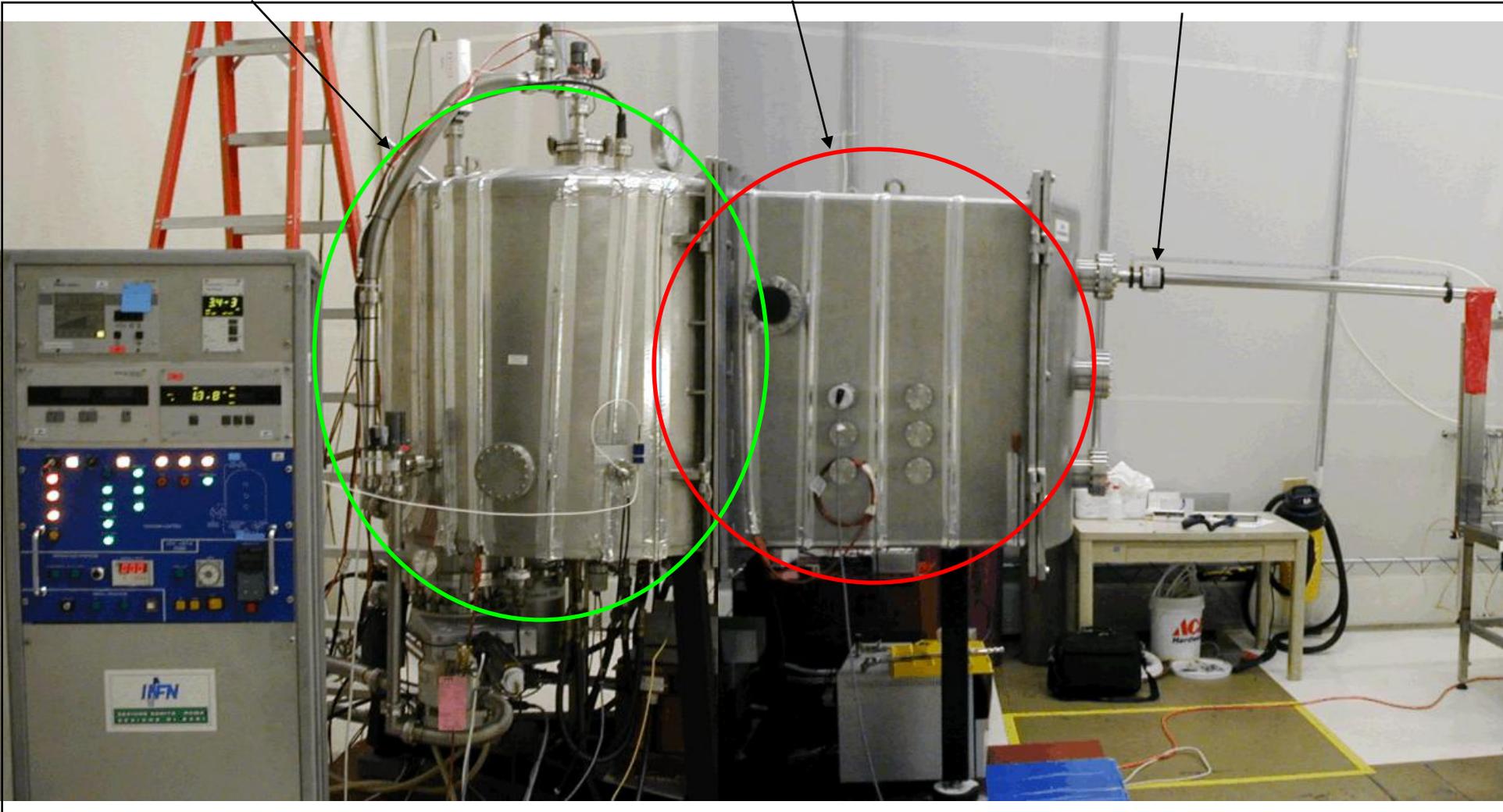
# The Evaporator

on loan from INFN Roma

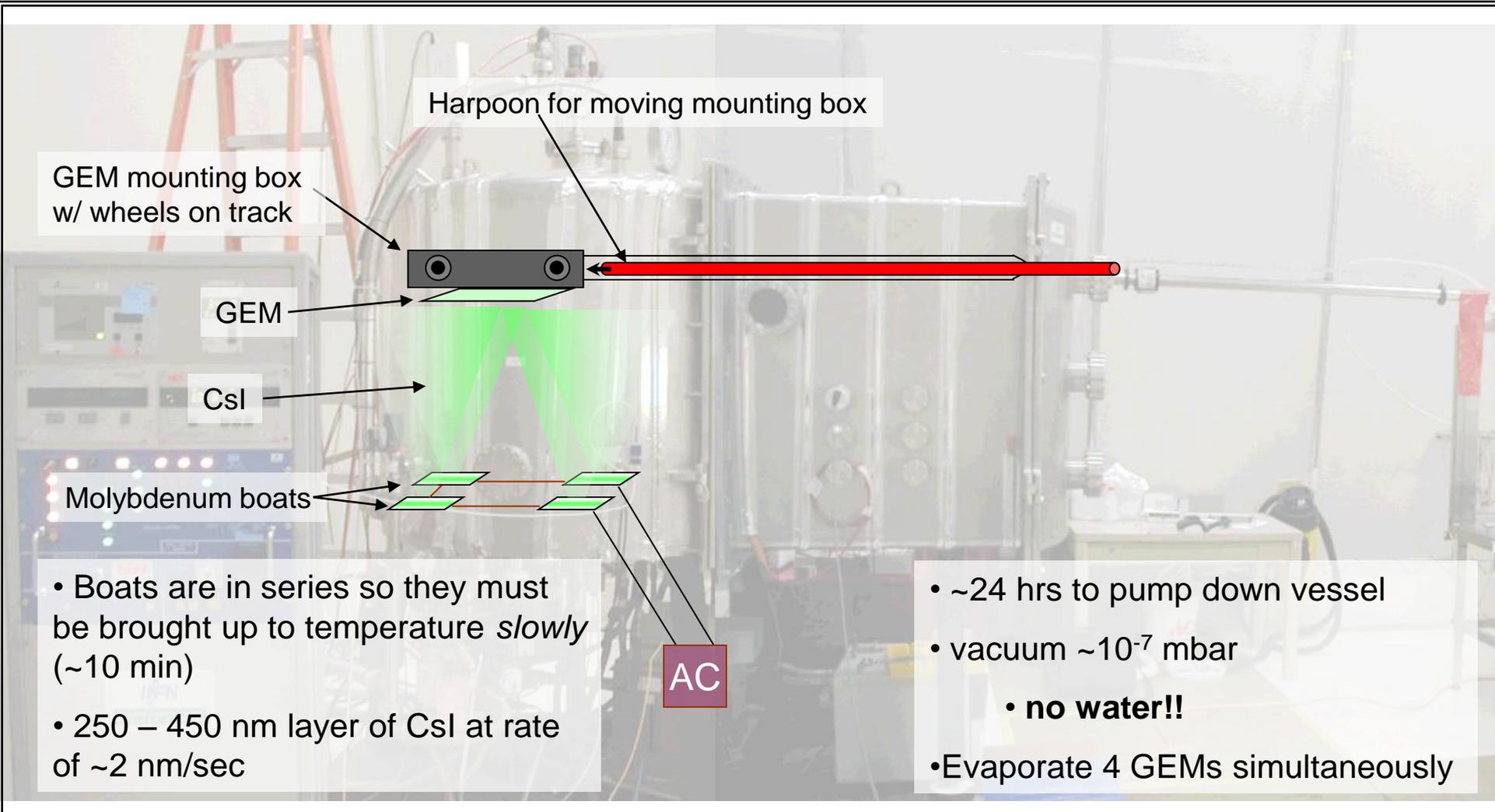
Evaporation Chamber

Quantum Efficiency Station

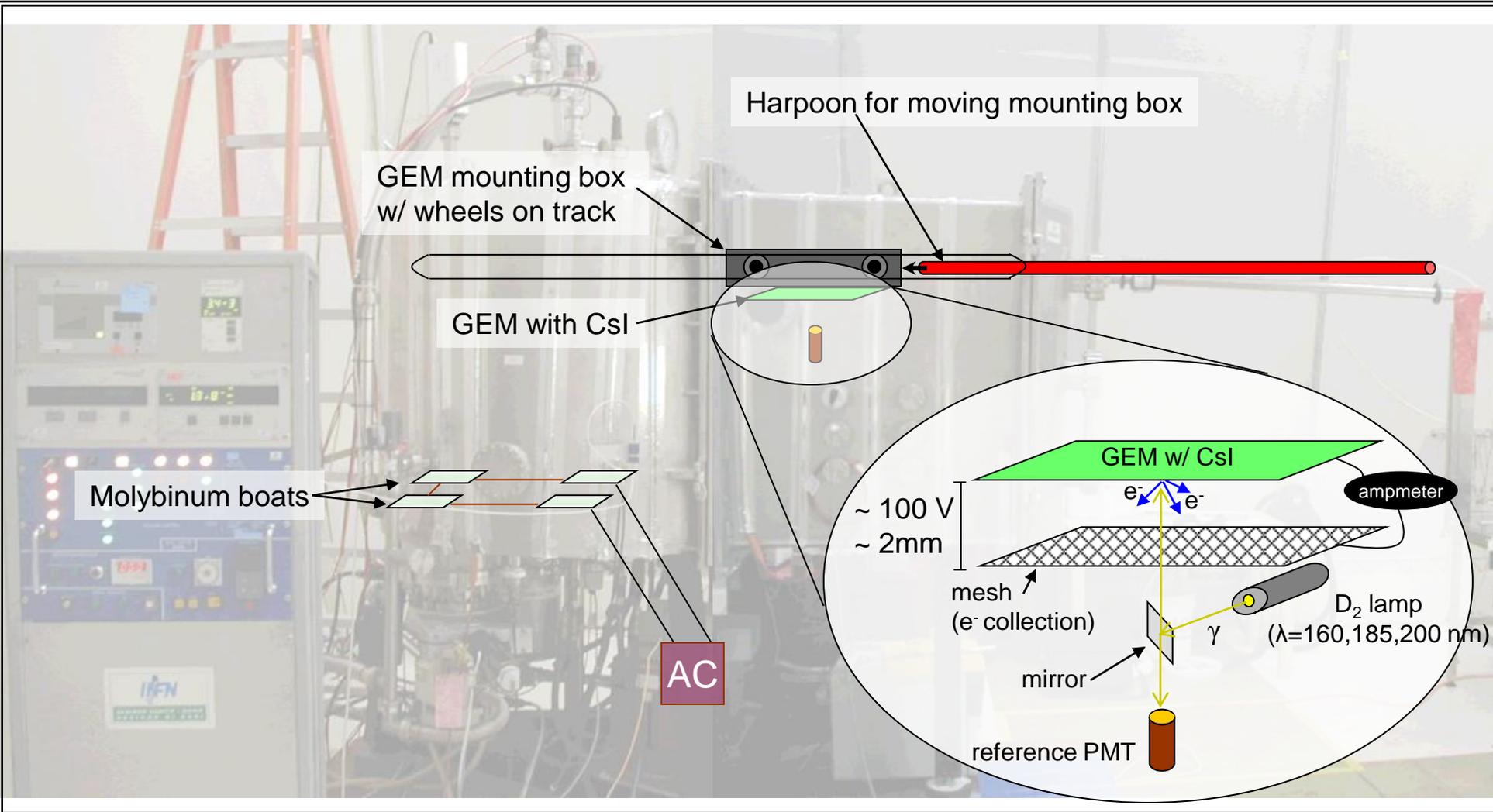
Magnetically coupled driver for moving the GEMs inside the vacuum.



# The Evaporation Chamber



# The Quantum Efficiency Station



# QE System

## Revamped QE:

- Can this system be made user-friendly??
- Of Course!!

**Instructions:**

1. Press **Run** arrow in top left corner of window.
2. Flip Toggle to **ON** position.
3. Flip Toggle to **PMT** and choose desired scan number light: and GEM number. (Make sure **one** number light **one** GEM is selected.)
4. Scan until **In The Middle** or **Safely Off GEM** flashes on.
5. Flip Toggle to **Cathode**.
6. Scan back over same GEM until **Safely Off GEM**.
7. Repeat steps 2-6 until all 3 scans are complete on each of the 4 GEMs.
8. Turn off GEM pads and Scan Number lights. Press **STOP** when finished.

**NOTE:** Please make sure to flip toggle to **Off** position when passing over GEMs without taking data.

**Note:** Before program runs please make sure that both the Evap box and Cathode/PMT system are at the "origin".

Lamp Wavelength: 160

Mirror Orientation: Cathode PMT

Over GEM Safely Off GEM

Progress: 1 2 3 4 5 6

In The Middle

View From Above

DeviceType: U120816  
DeviceIndex: 0  
Initialize First Time? ON  
StartChannel: AI 0  
NumberOfChs: 4  
InputRange: 0 - 4.096 V

Voltages: 0.0000 PMT, 0.0000 Cath., -0.5260, 1.0640 Pos.

ON OFF

STOP

## Quantum Efficiency:

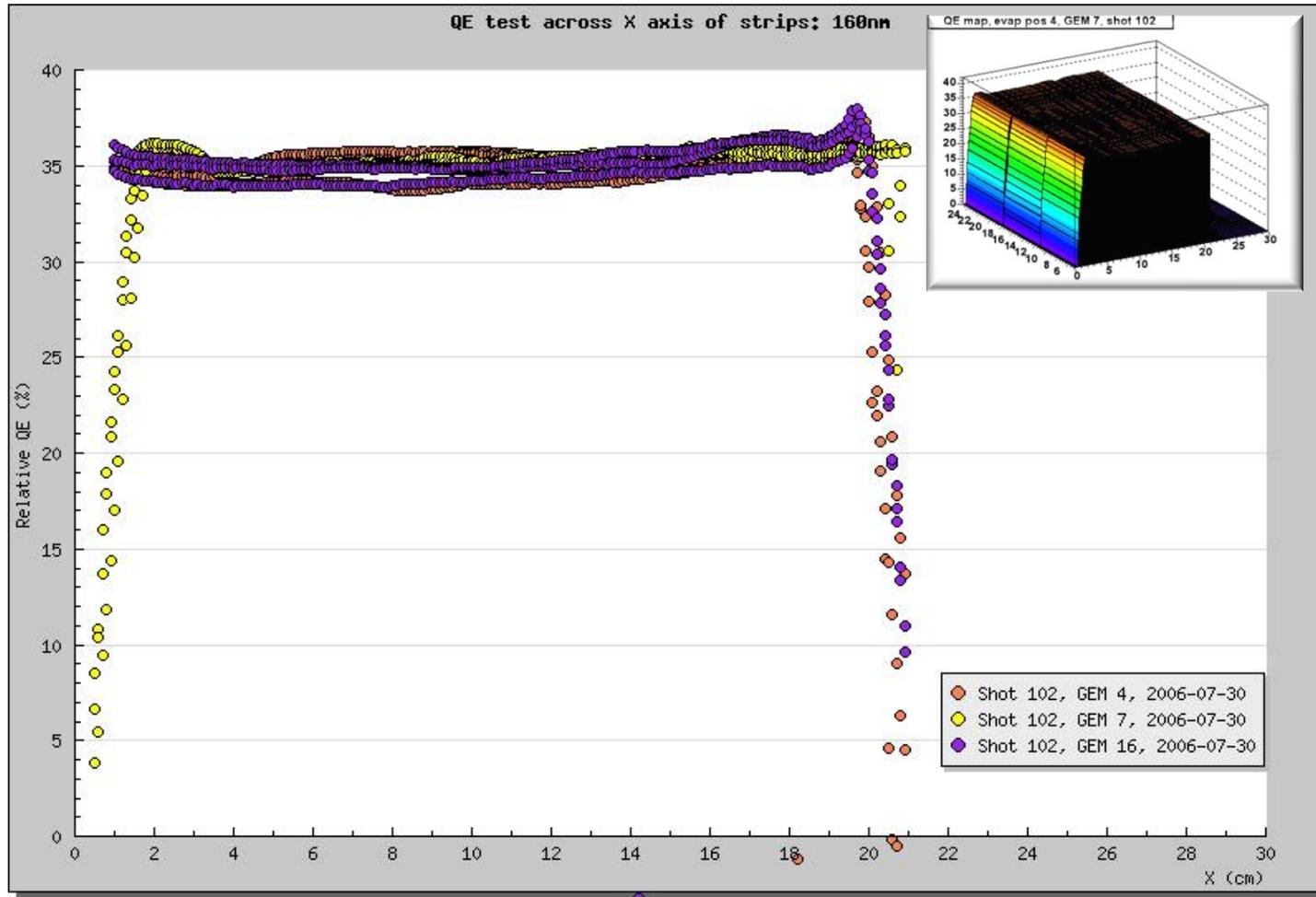
- LabView DAQ interface
- records:
  - Photocathode Current
  - Reference PMT Current
  - Mirror Orientation
  - Y-coordinate (manually)
  - X-coordinate (automatically)



String potentiometer



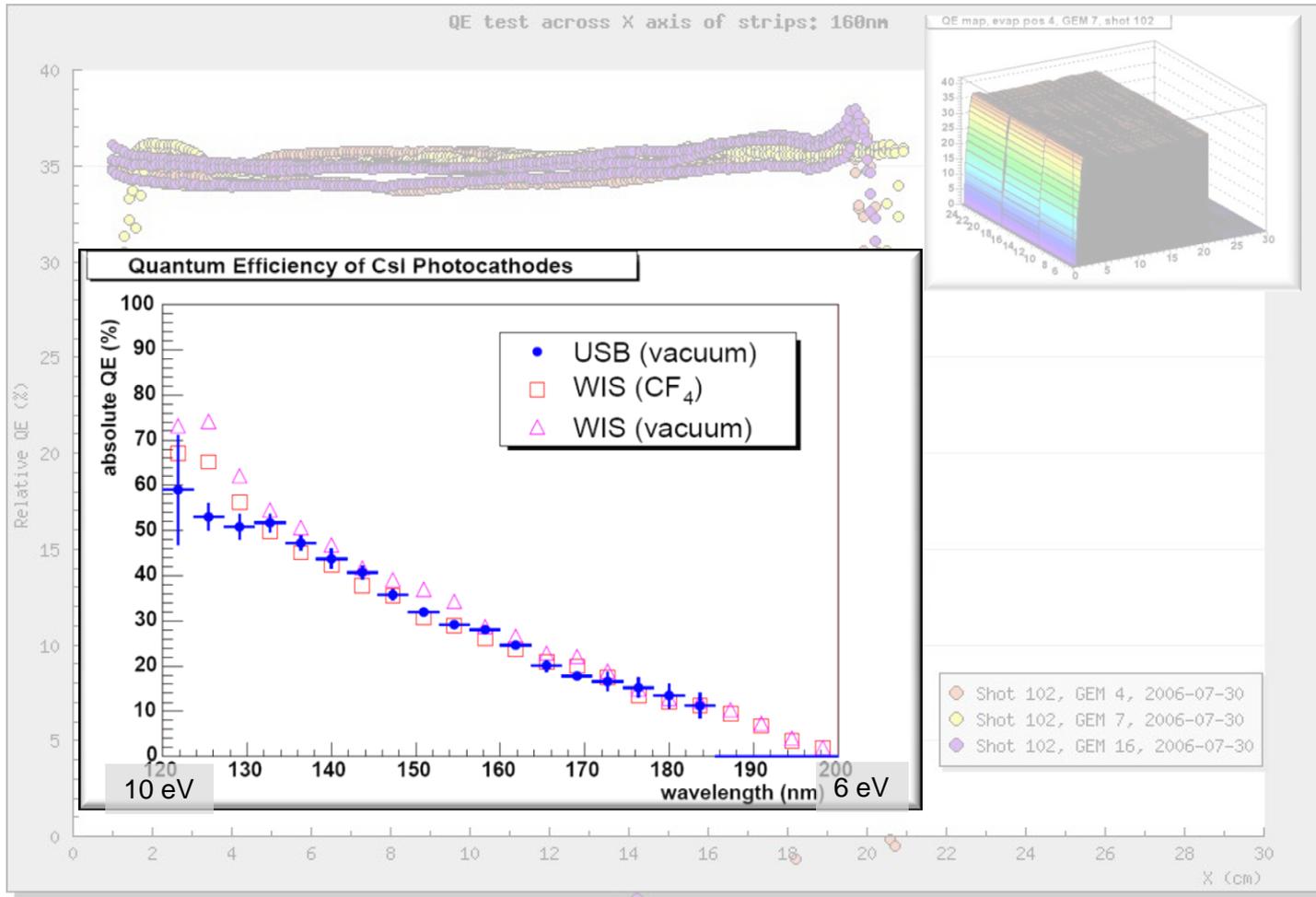
# Relative QE (results from the evaporator)



Encouraging results:

- Highly uniform QE across GEMs.

# Absolute QE (results from BNL)



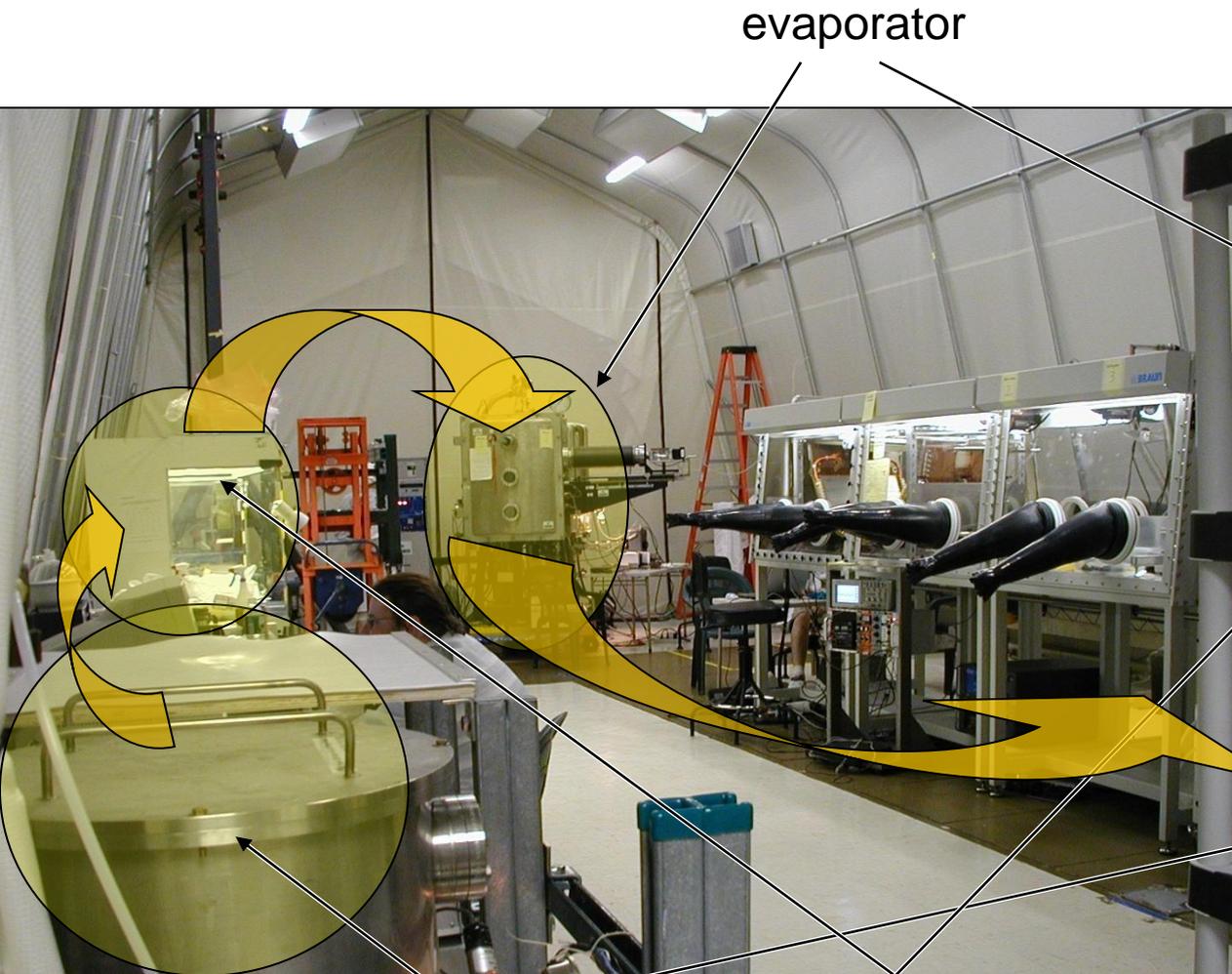
Encouraging results:

- Highly uniform QE across GEMs.
- *Chicklet* results confirm high QE.

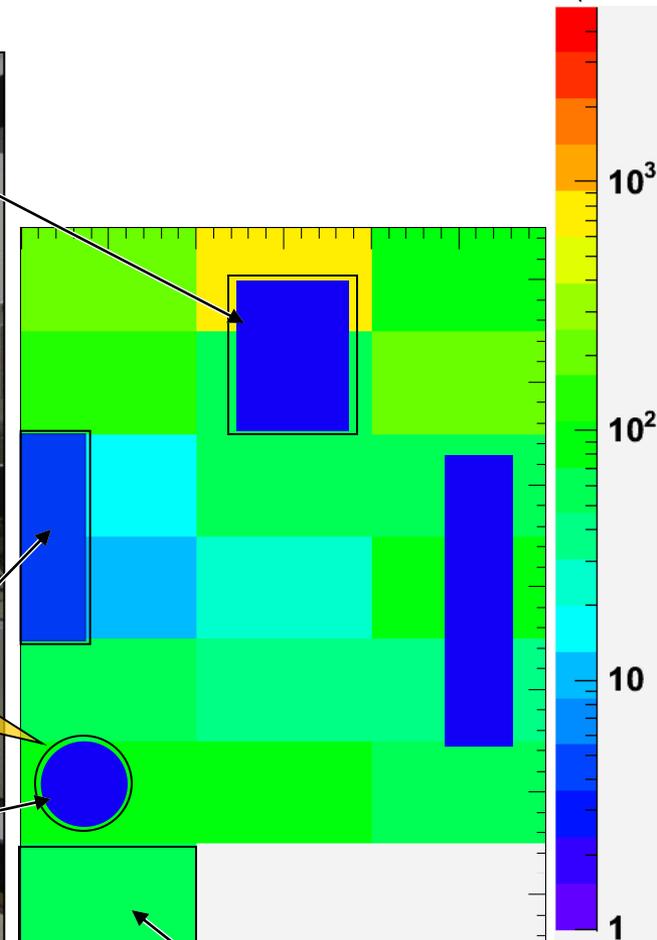
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# The Transport

("Class": number of  $\leq 0.5 \mu\text{m}$  particles/ $\text{m}^3$ )



"Class" of Clean Room



# Transport Box Removal

Moving the Transport Box:



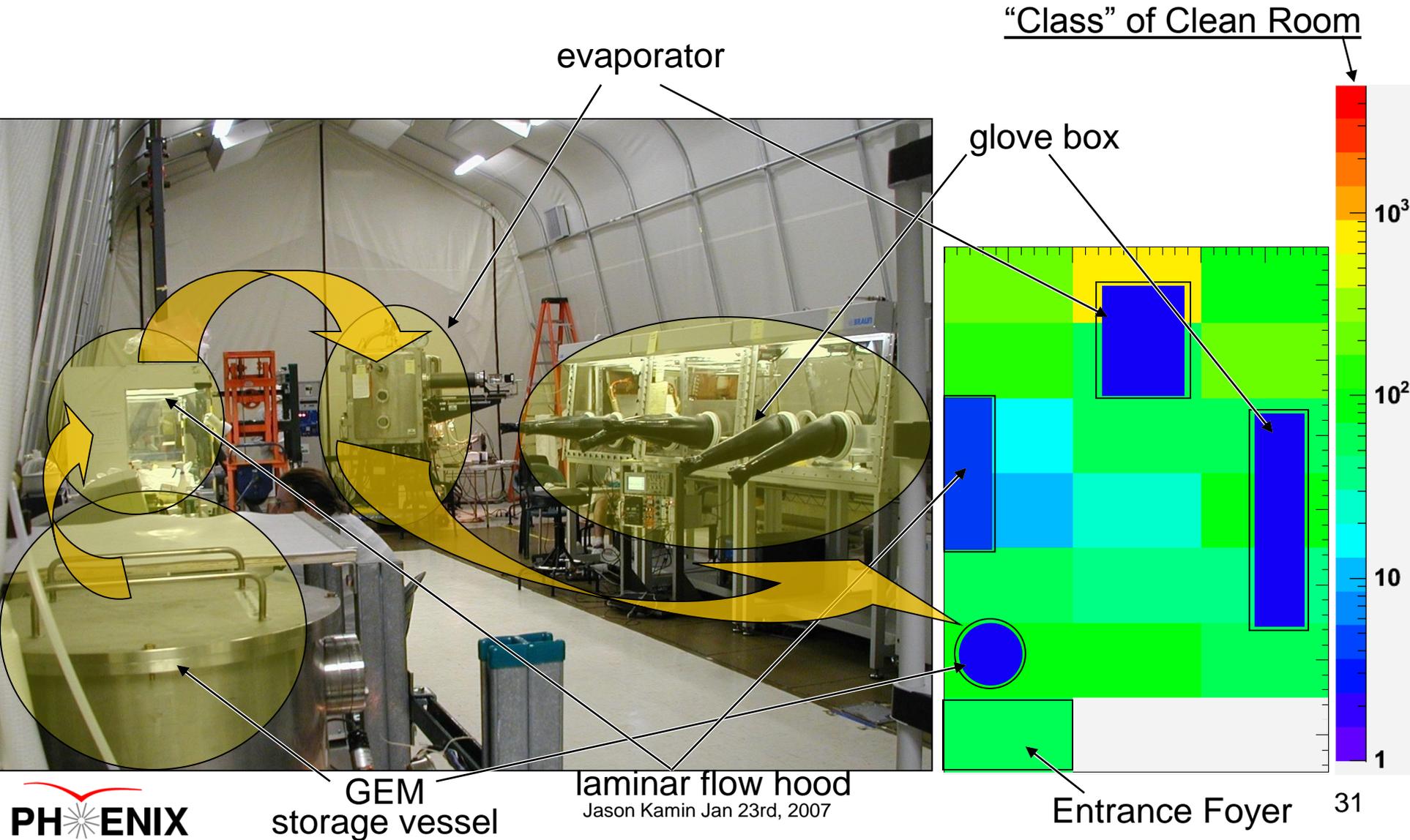
# Transport Box Entry Into Glovebox

...through the glovebox foyer...



# Railroad System

("Class": number of  $\leq 0.5 \mu\text{m}$  particles/ $\text{m}^3$ )

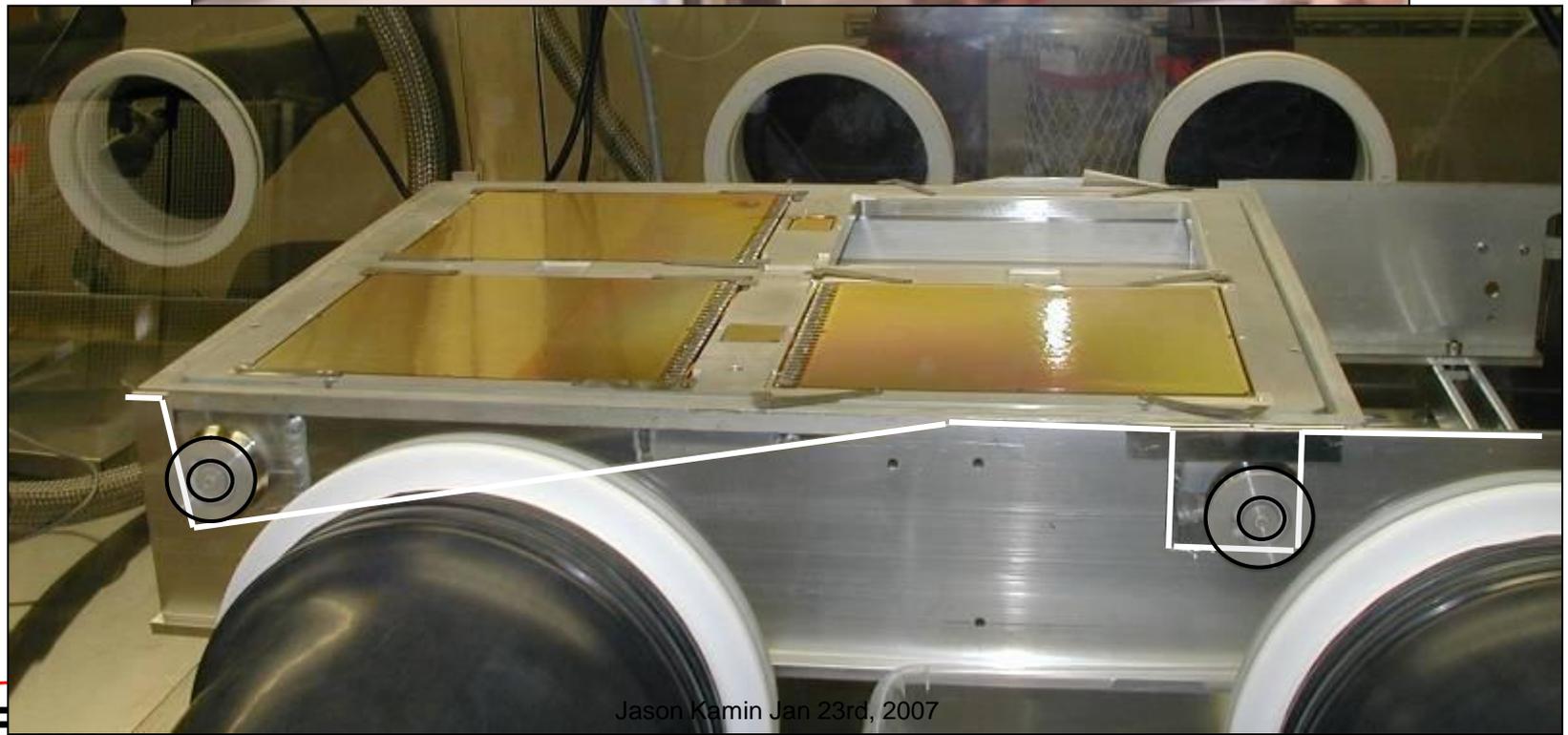
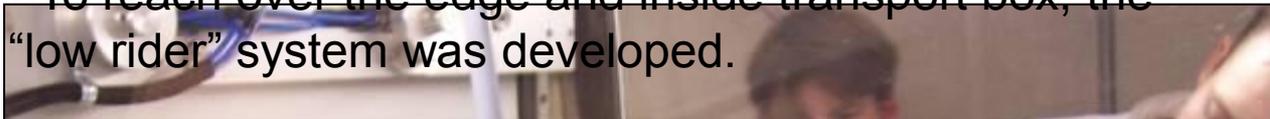


# Railroad System

“low rider”

Chuggin’ along on the railroad:

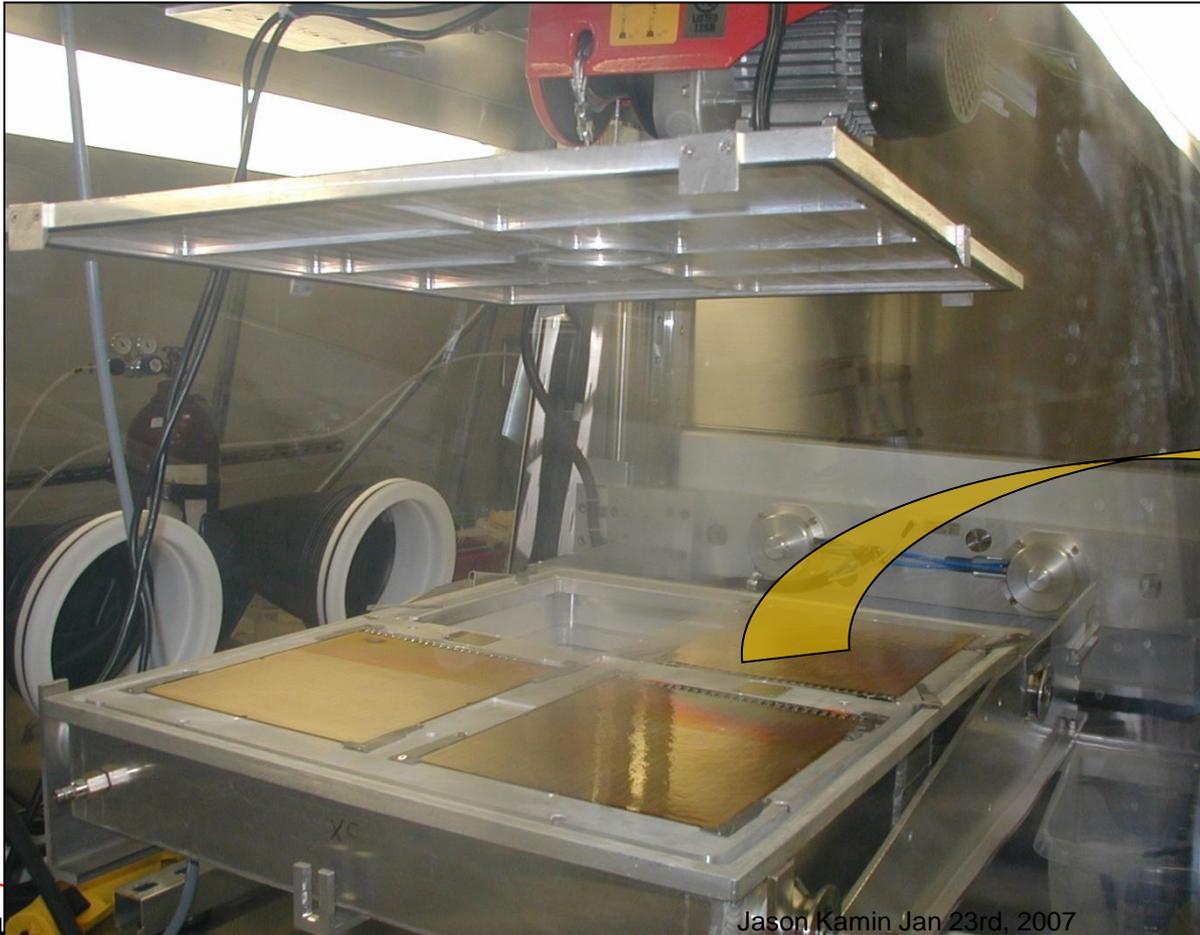
- After flushing the foyer,
- Transport box rolls effortlessly out of the airlock...
- ...and into the glovebox.
- To reach over the edge and inside transport box, the “low rider” system was developed.



# Electric Lift System (1)

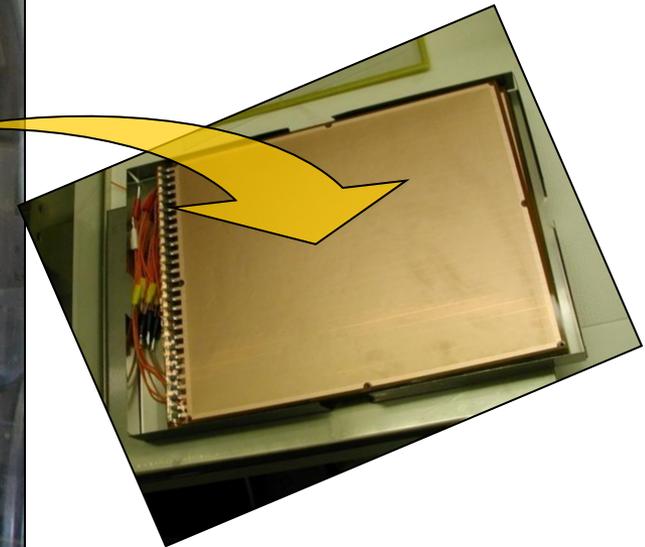
Where to store the lid of the transport box??

- Transport box lid is big and cumbersome.
- Nowhere to set the lid down during GEM extraction.
- ...nowhere but **UP**, that is!!!



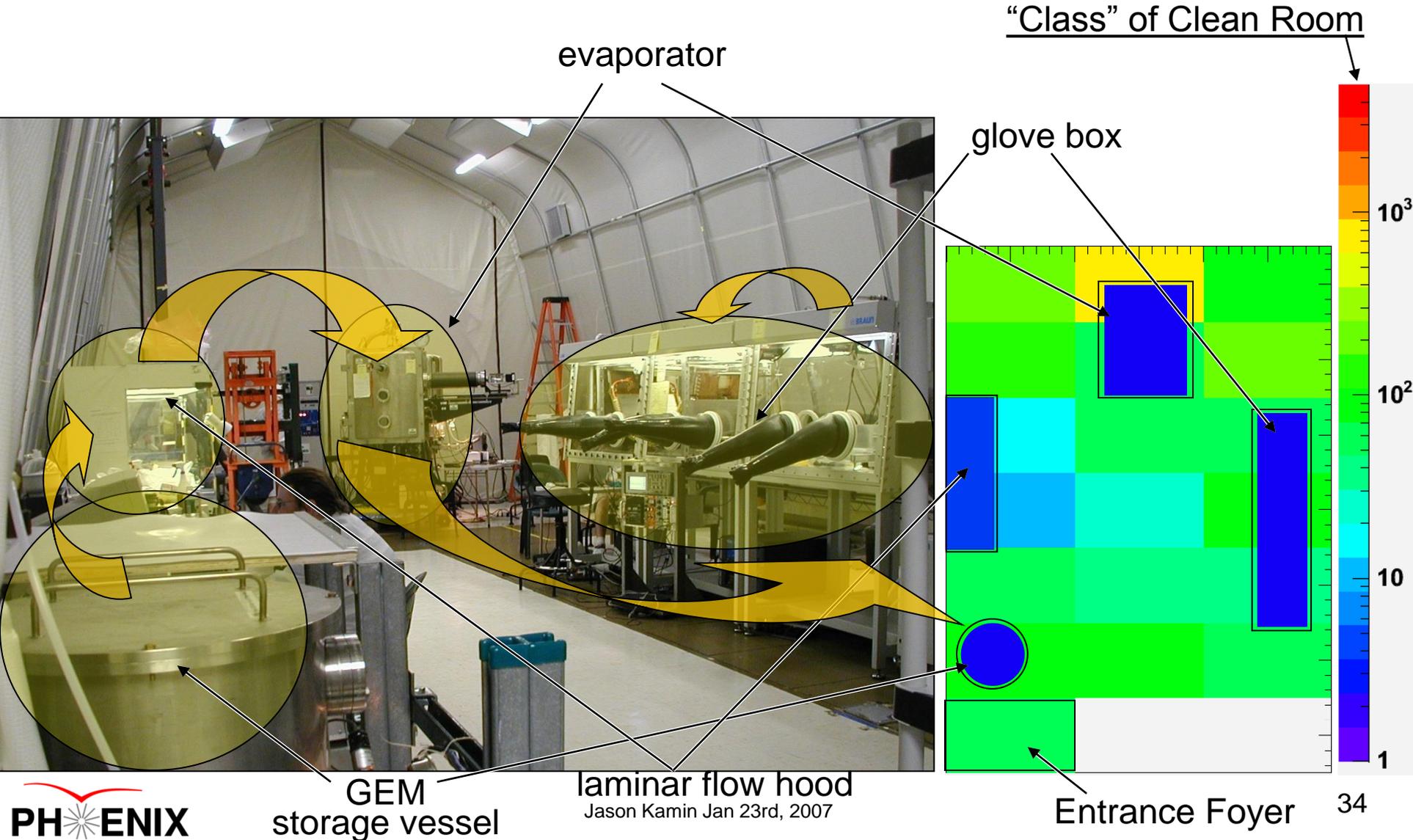
And, of course,

- out of the transport box...
- ...and into the pizza box!  
(a safe GEM is a happy GEM)



# Gain Test Box

("Class": number of  $\leq 0.5 \mu\text{m}$  particles/ $\text{m}^3$ )



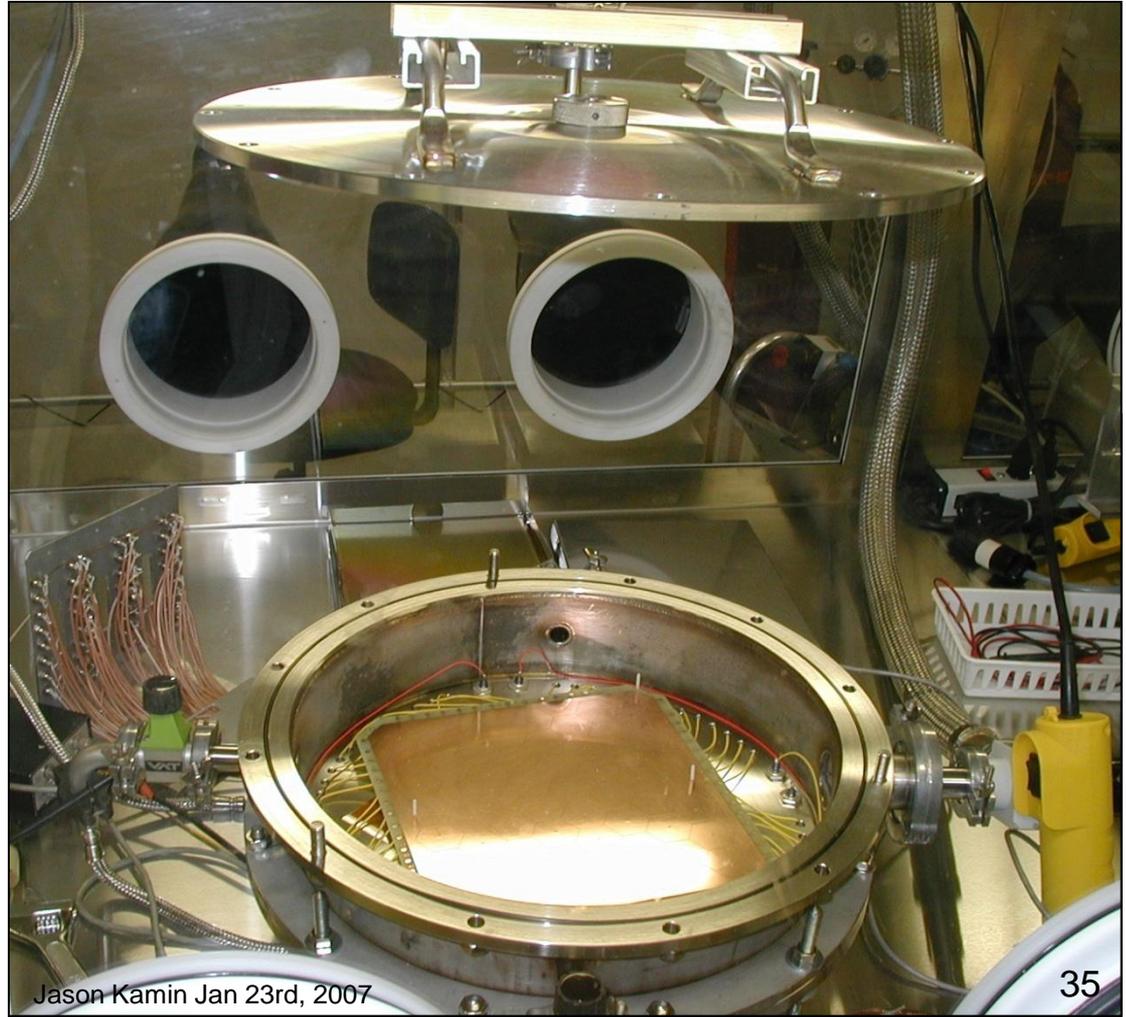
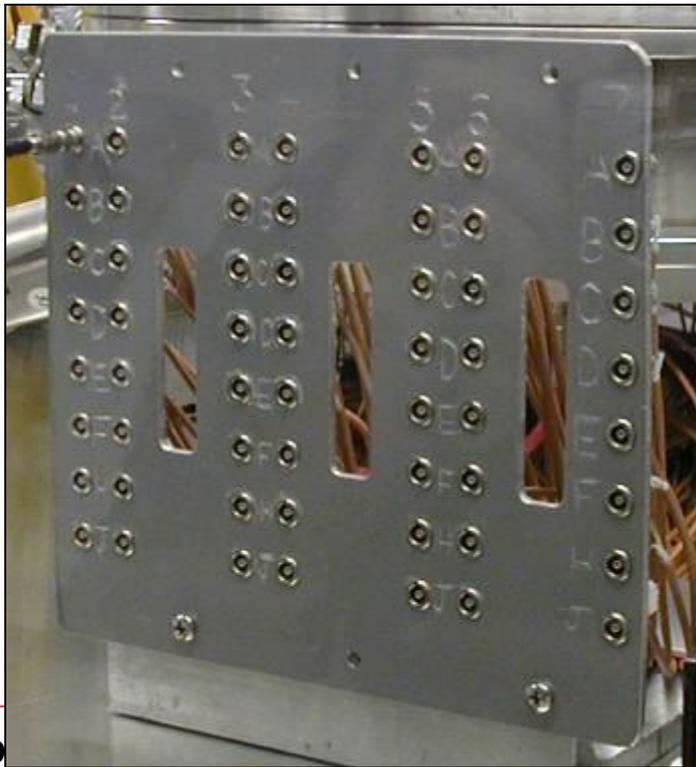
# Electric Lift System (2)

Where to store the lid of the gain box??

- Gain box lid is *heavy*.
- Nowhere to set the lid during GEM insertion/extraction.
- YEP!! You guessed it! ...**UP!**

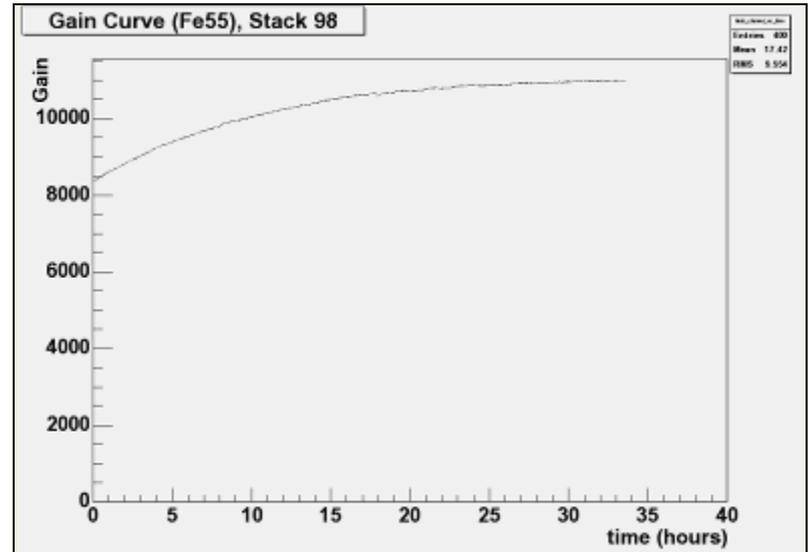
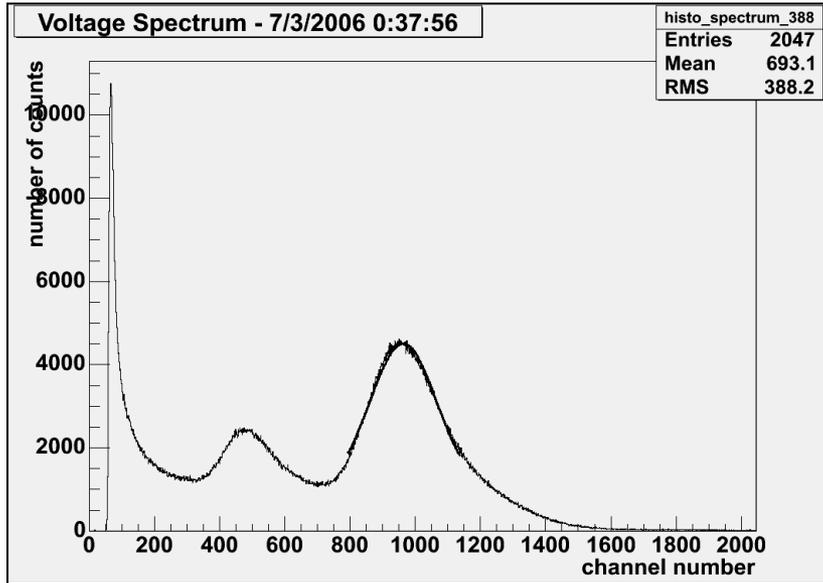
Patch Panel:

- “Plug and Chug”
- 56-pad gain map in 1 hour!!



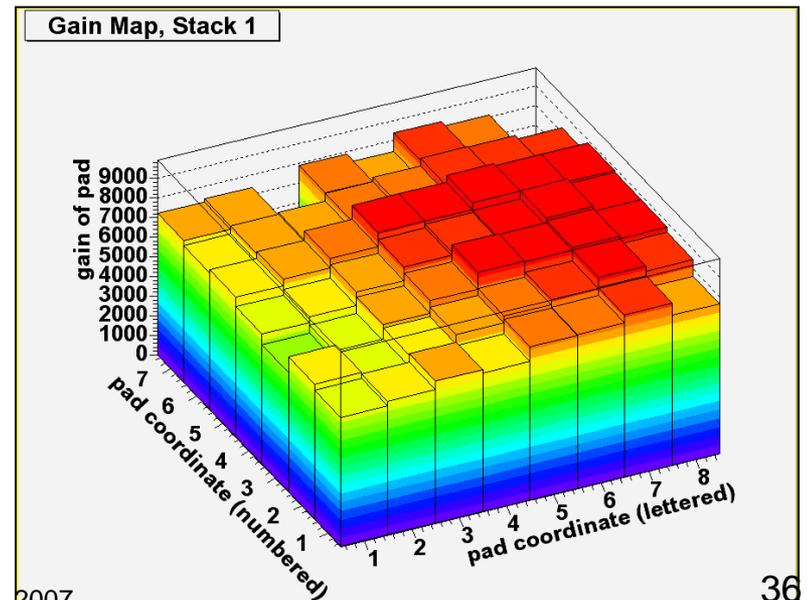
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# Gain Measurement Output



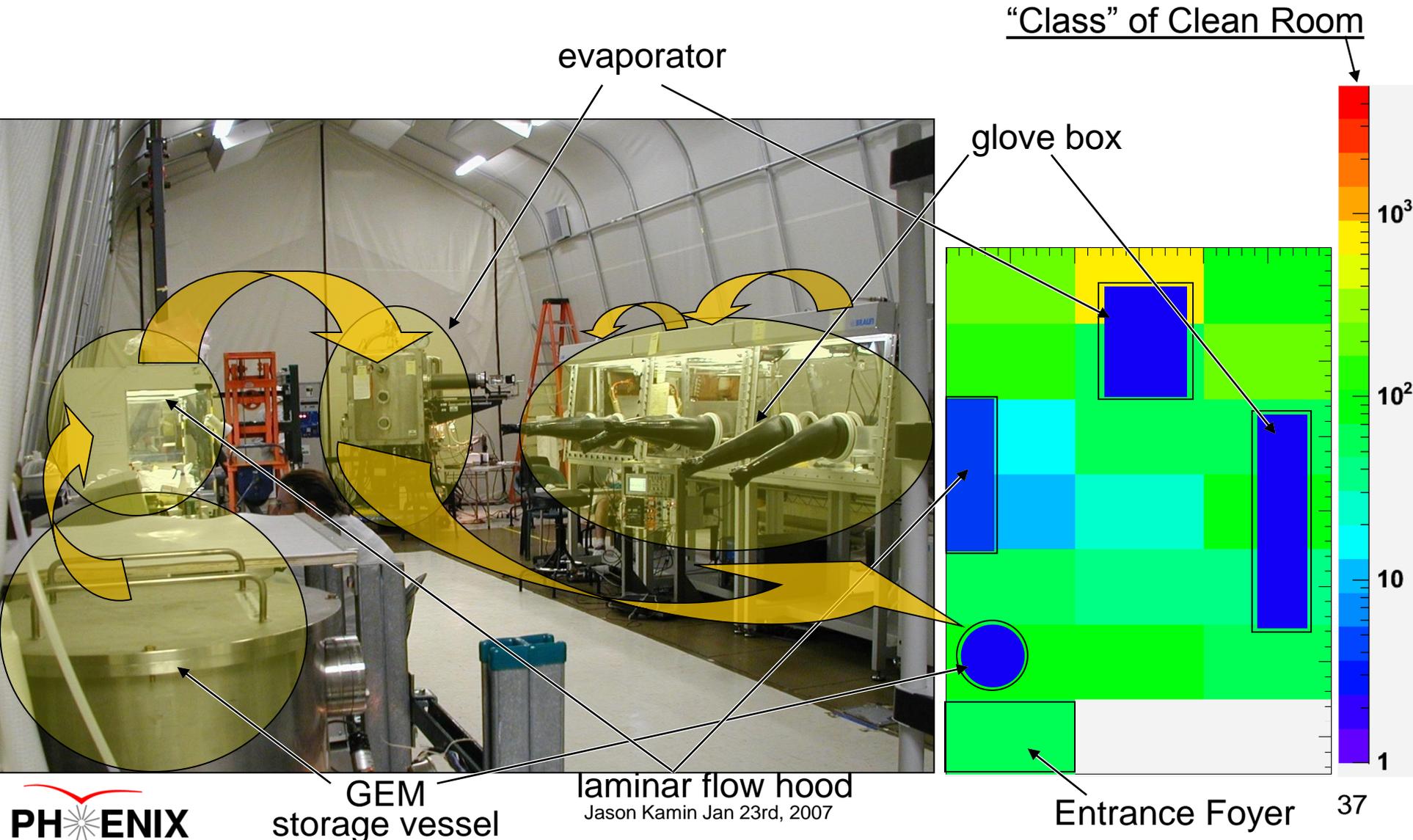
## Maestro (PC-based MCA software)

- Automated Gain Saturation:
  - One spectrum every 5 min.
  - Root macros to plot gain curve
- Automated Gain Map:
  - Prompts user *vocally* to move cable to next signal.
  - New Patch Panel eliminates 50-ohm terminators.
  - Complete map (56 pads) in 1 hour.



# The Clean Tent at USB

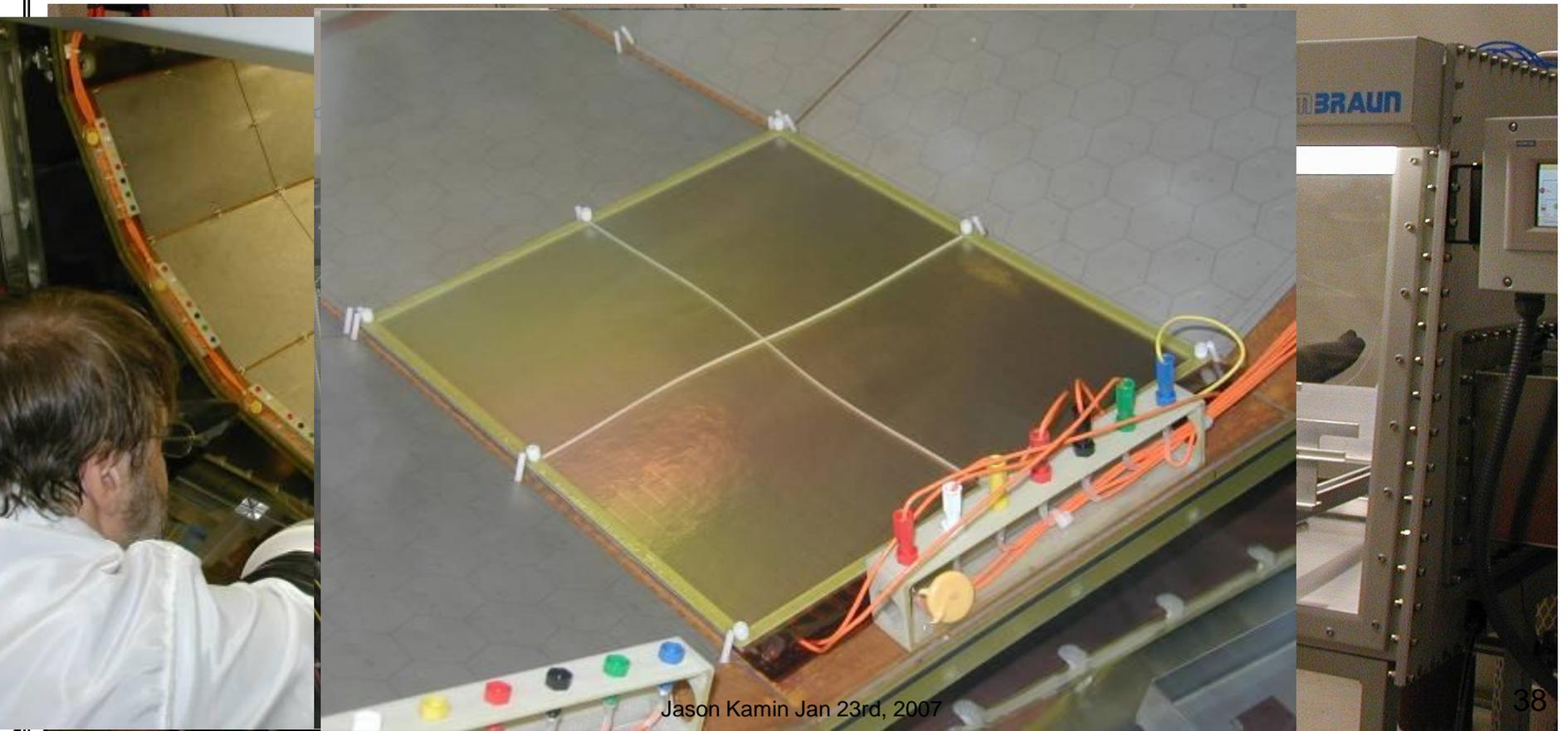
("Class": number of  $\leq 0.5 \mu\text{m}$  particles/ $\text{m}^3$ )



# GEM-stack Installation

Glovebox is fully operational:

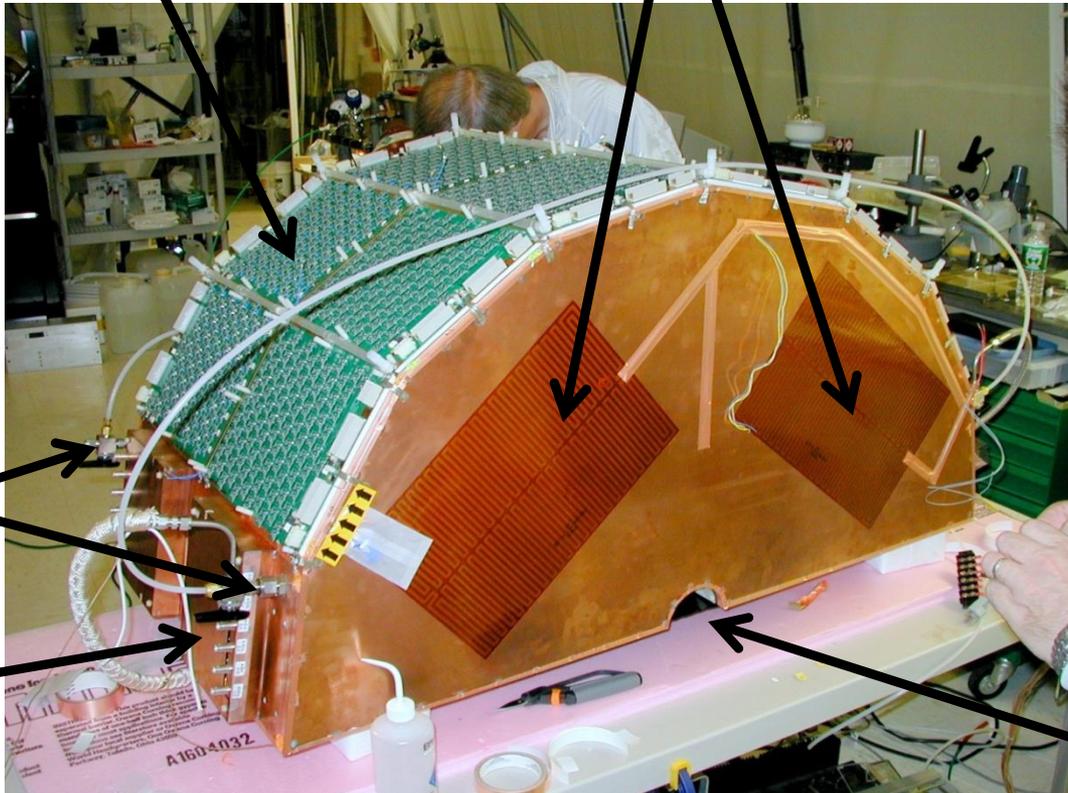
- HBD Vessel sat in the left third of the glovebox.
- All GEMs were successfully installed.
- Both HBD halves were finished by the end of September.
- Note: Rainbow-like CsI sheen on top GEM.



# HBD East

96 pre-amps/board  
(1152 per HBD)

Minco heaters to help in H<sub>2</sub>O evaporation



Gas valves

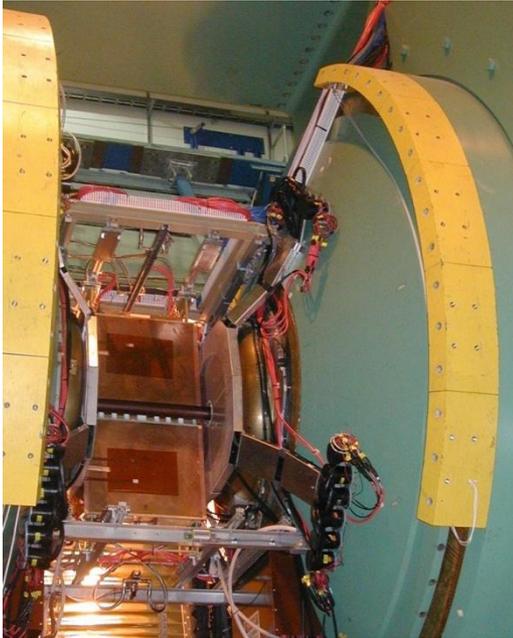
HV panels

Beampipe

# HBD Installed

- HBD is fully installed inside the heart of PHENIX.
- We see cosmic rays in CF4.
- Commissioning is in full-swing:
  - Presently conditioning GEMs with high voltage
- BRING US MORE COFFEE!!

HBD West



HBD East

