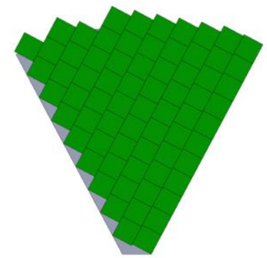
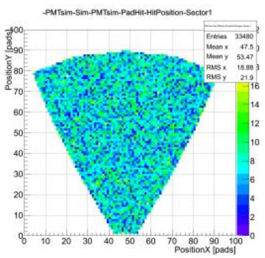
# Concept study for a photomultiplier readout of the HADES RICH

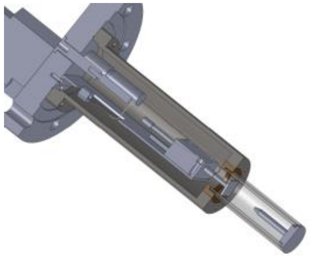
**Korbinian Schmidt-Sommerfeld**

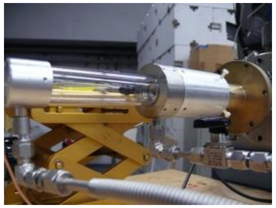
Hamamatsu.com



1. **Introduction / Motivation**
2. **Simulations**
3. **Scintillation measurements**
4. **Outlook**





# HADES

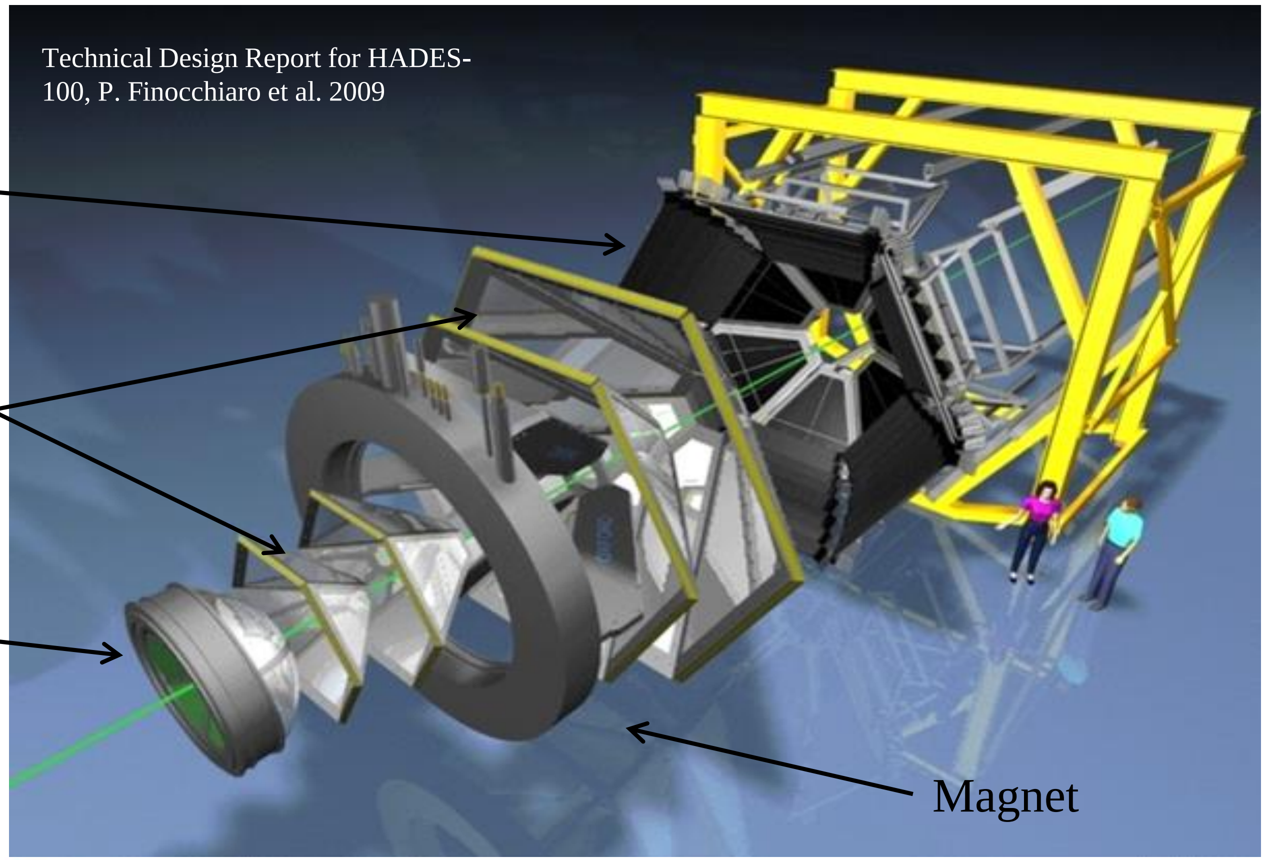
***H***igh-***A***cceptance ***D***i***E***lectron ***S***pectrometer (1999 – FAIR ?)

HI reaction dynamics & hadron in-medium modifications

Au + Au @ $E_{kin} = 1 - 8$ AGeV: i.e. $\rho, \omega \rightarrow e^+ + e^-$

Components:

- TOF wall
- Tracking system
- RICH




Technical Design Report for HADES-100, P. Finocchiaro et al. 2009

# The HADES RICH detector

***R**ing-**i**maging **Ch**erenkov detector*

Hadron blind device for

$e^+/e^-$ identification

VUV photon detector

MWPC ($CH_4$)

CsI photo cathode

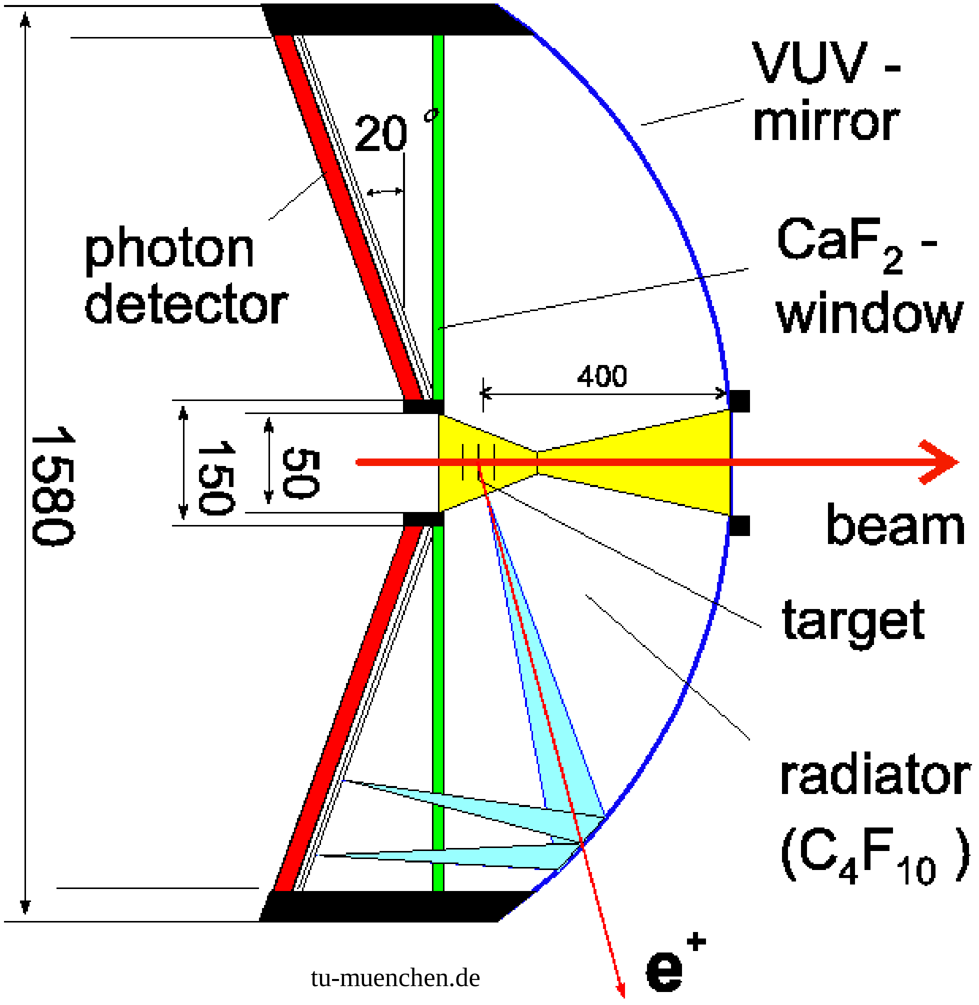
$< \epsilon_{se} > \approx \mathbf{60\%}$ (2002)

(G. Agakichiev et al.,

EPJ A41 (2009), 243)

**Aging =>**

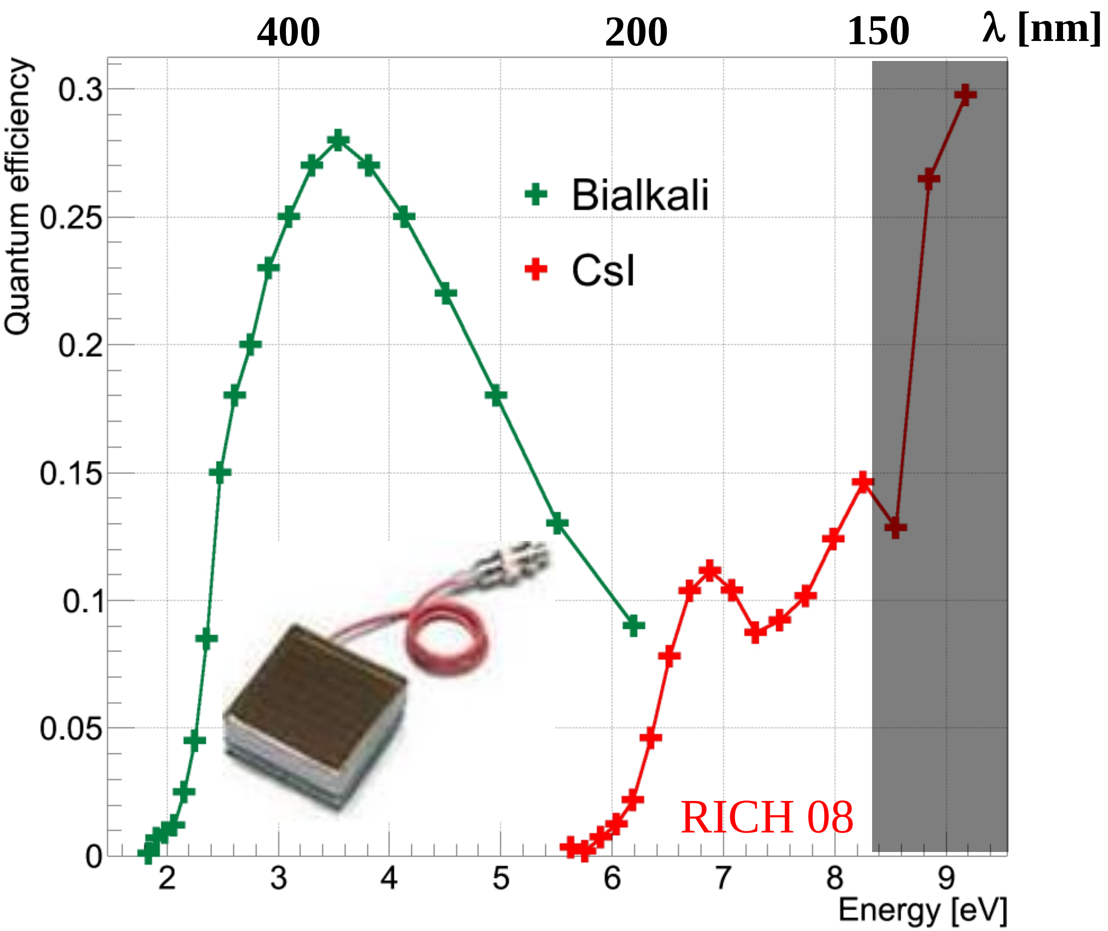
$< \epsilon_{se} > \approx \mathbf{35\%}$ (2008)




tu-muenchen.de

# New photon detector

Proposal: Hamamatsu **H8500C**




- 8x8 channels
- $52\ mm \cdot 52\ mm$
- Gain: $1.5 \cdot 10^6$

Simulation:

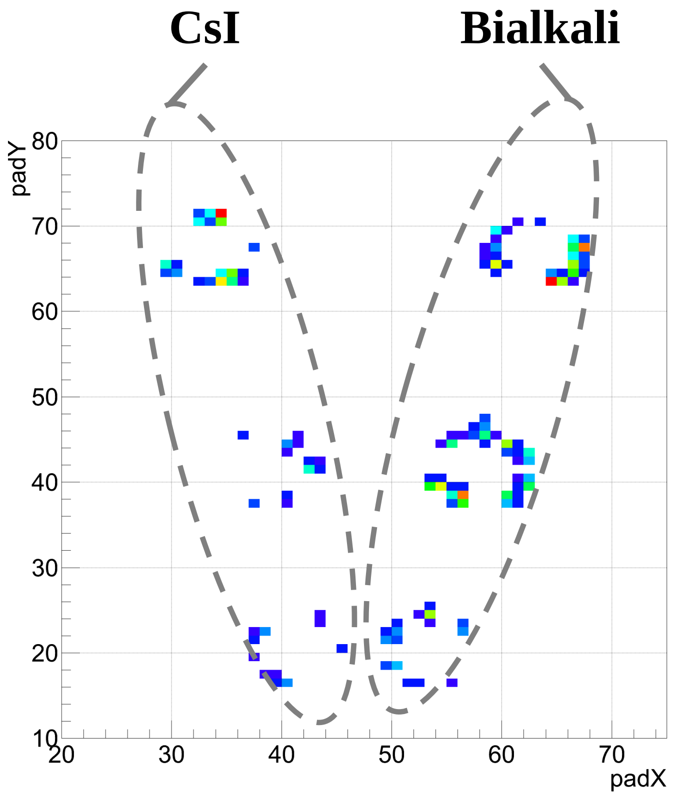
- Electrons
- Whole acceptance
- p = 50 - 200 MeV/c
- $N(\Theta) = const.$
- HGEANT
- Old RICH digitizer
- QE of MAPMT

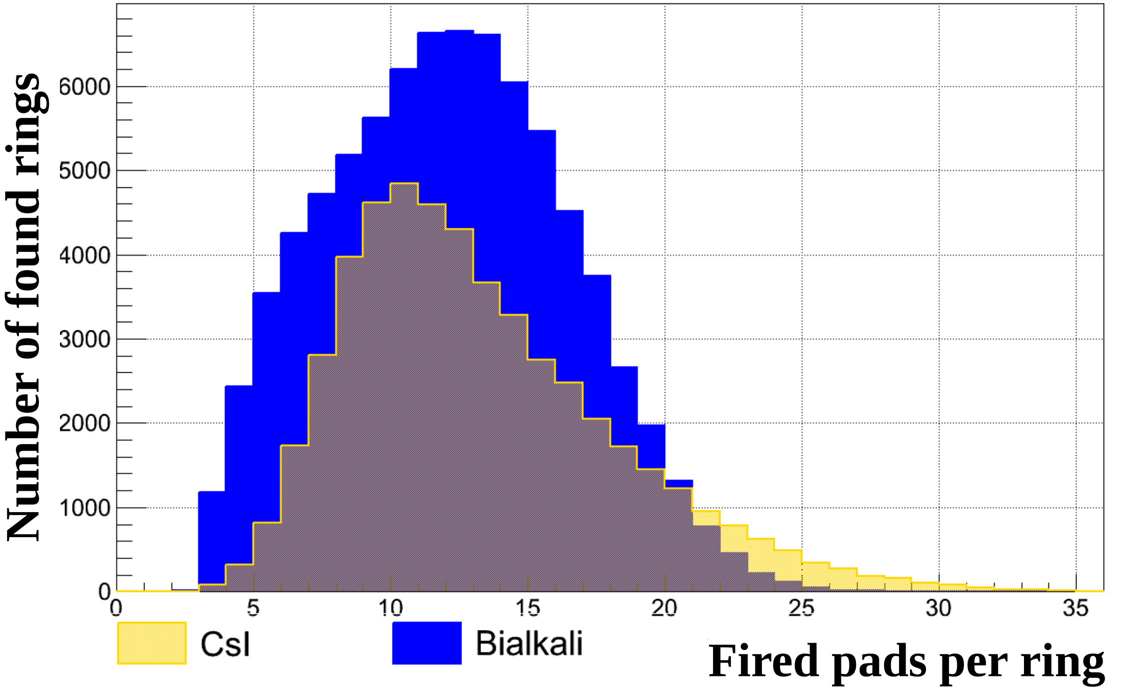
# Simulation

$< \epsilon_{CsI} > \approx 50\%$

$< \epsilon_{Bialkali} > \approx 80\%$

$< N_{ph} > \approx 140$

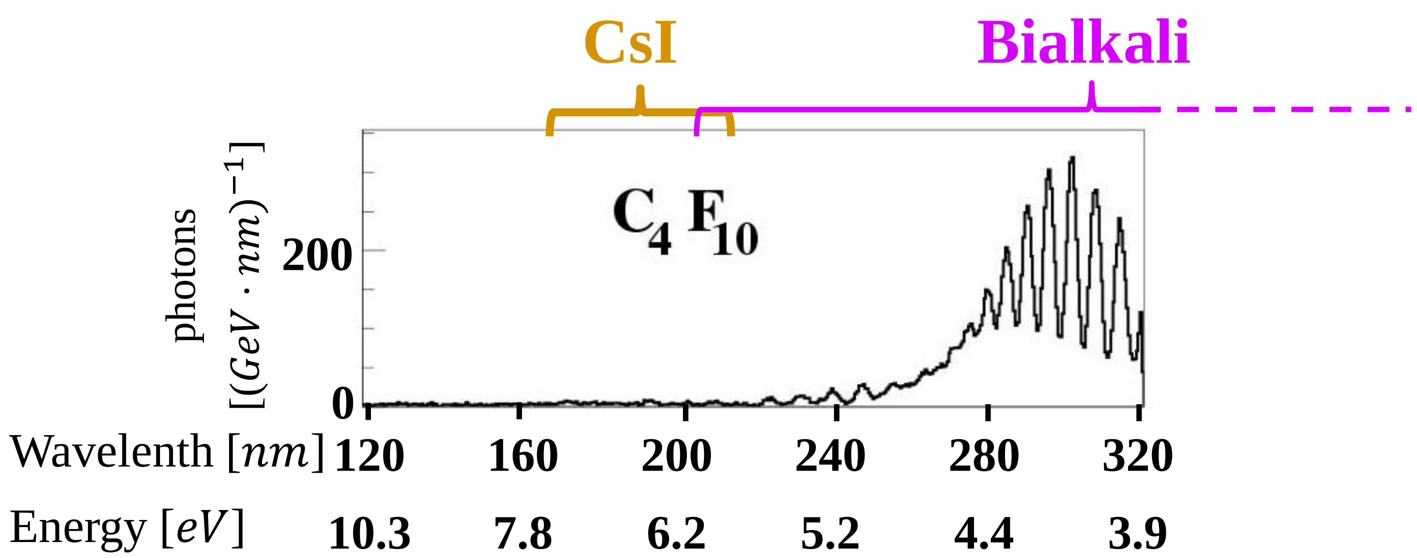



- Ring finder **not yet optimized** for bialkali QE.
- No significant influence by **new pad geometry**.

# Background: Radiator scintillation

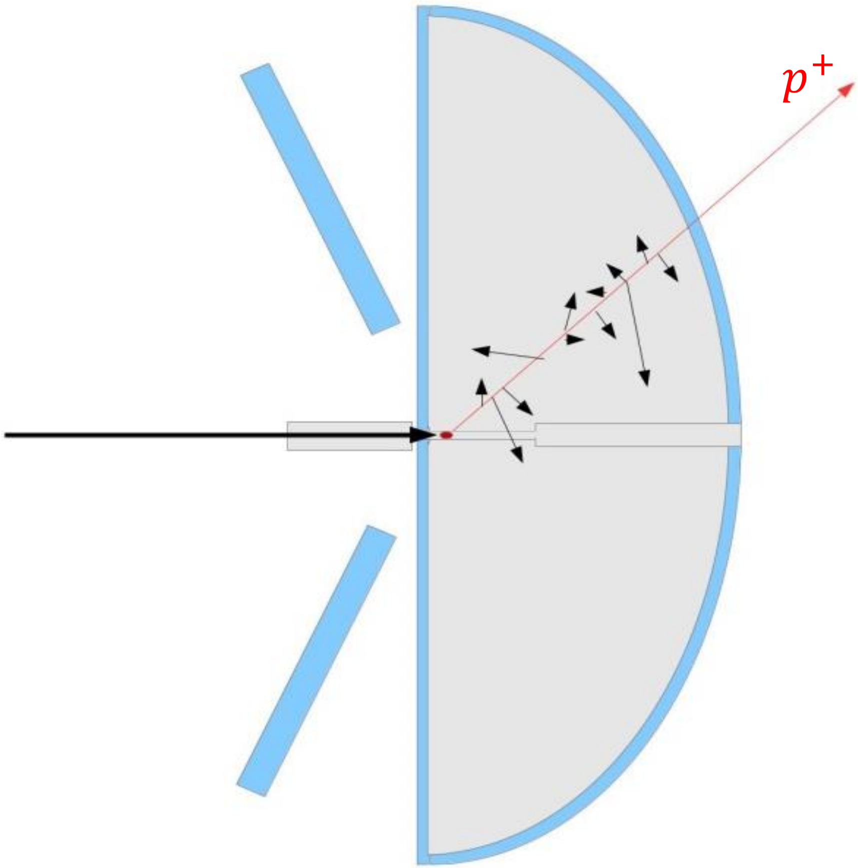
- Energy loss by charged particles: $\langle dE \rangle \approx 1 MeV$ / ch. p.
- Scintillation photons from $C_4F_{10}$ $E < 5.4\ eV$
- Detectable with MAPMT
- Estimate for $C_4F_{10}$: **20** Photons / ch. p.




R. Gernhäuser et al., NIM A371 (1996) 300

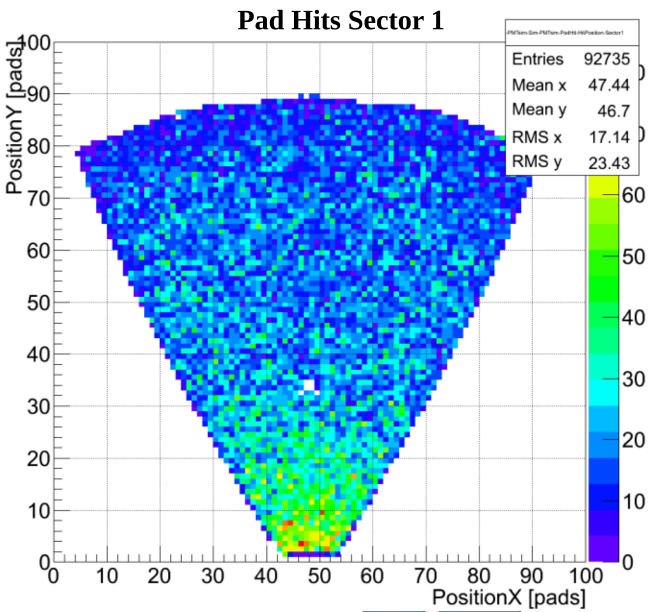
# Scintillation simulation

$C_4F_{10}$ scintillation not yet implemented in GEANT




Param. ch. p. distribution:

- $N, p, \theta$ from $Au + Au$ experiment
- $\langle N \rangle \approx 120$ / evt.
- 90% $p^+$ & 10% $\pi^{+/-}$
- $p^+$ p = 500 - 1900 MeV/c
- $\pi^+, \pi^-$ p = 200 - 500 MeV/c
- $N_{ph} = f(\theta) \approx$ **2300** / evt.



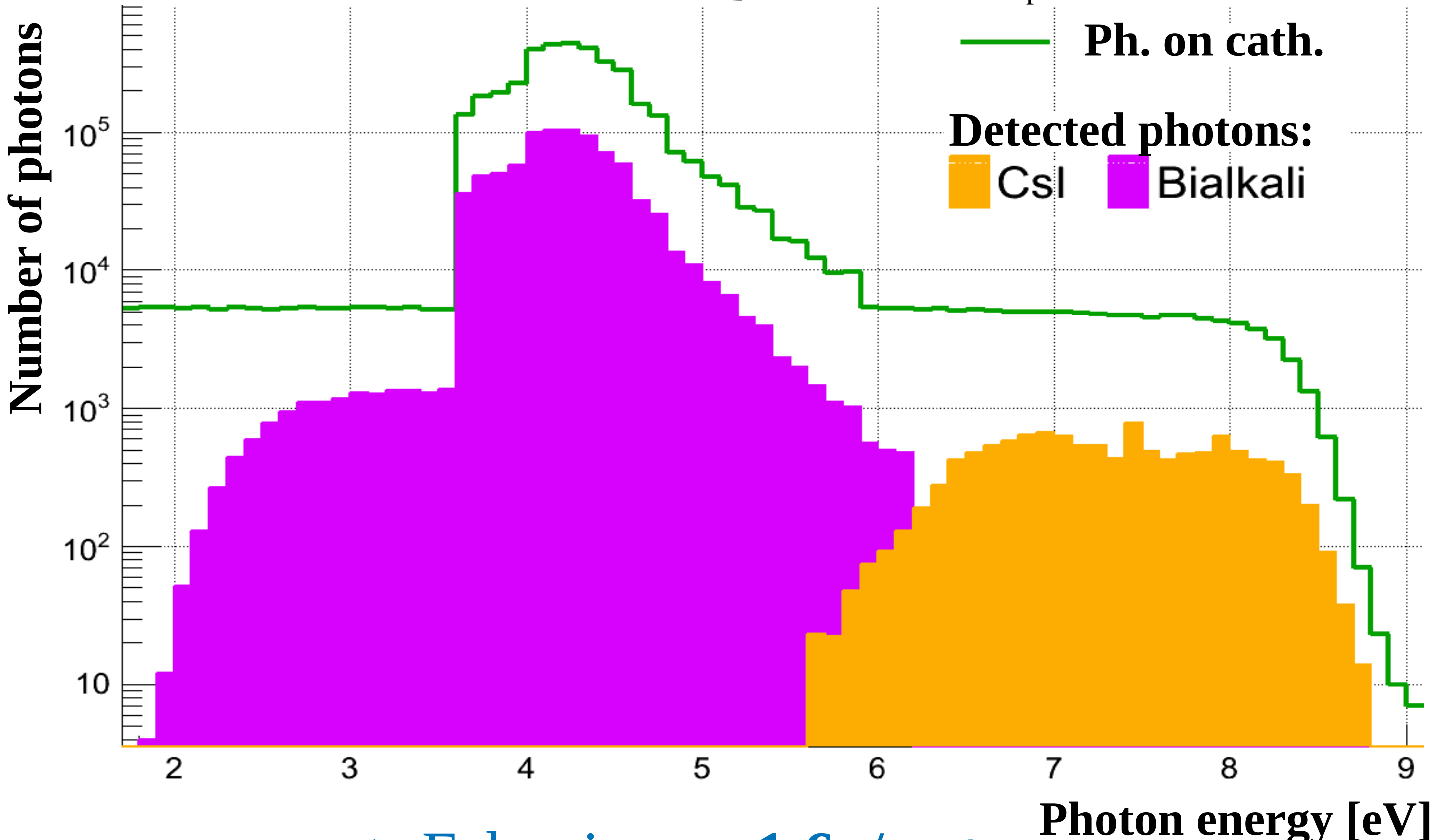
# Photon yield in Au + Au

Estimated scintillation photon yield:

$N_{cath} \geq$ 3.2 ph / 1 ch.p.

**CsI** $N_{pads} \approx$ 1 / 120 ch.p.

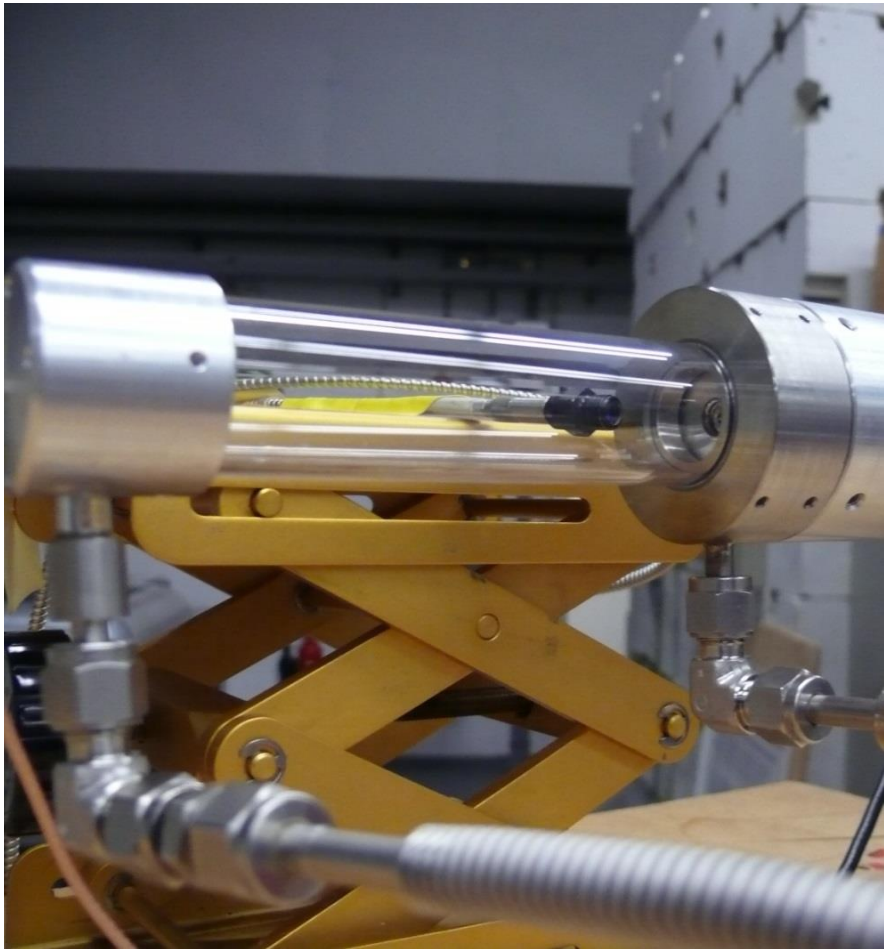
**Bialkali** $N_{pads} \geq$ **80** / 120 ch.p.




=> Fake rings = **1.6 / evt.**

# Scintillation measurement I

Tandem, Munich $\quad {}^{32}_{16}S^{8+}, E_{kin} = 90\ \text{MeV} \longrightarrow C_4F_{10}, Ar, N_2 \ldots$

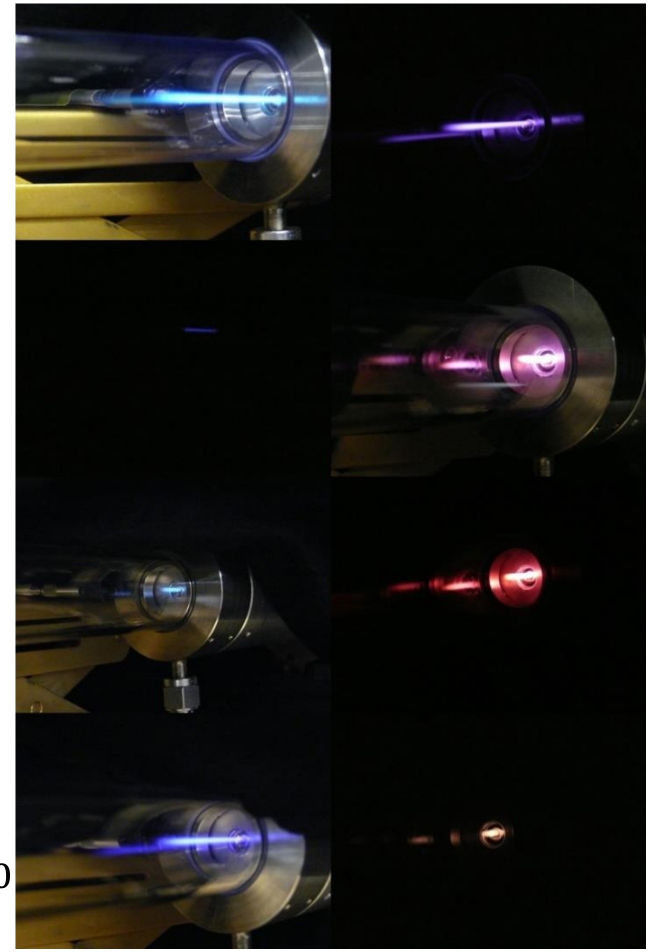


$Ar$ $\quad N_2$

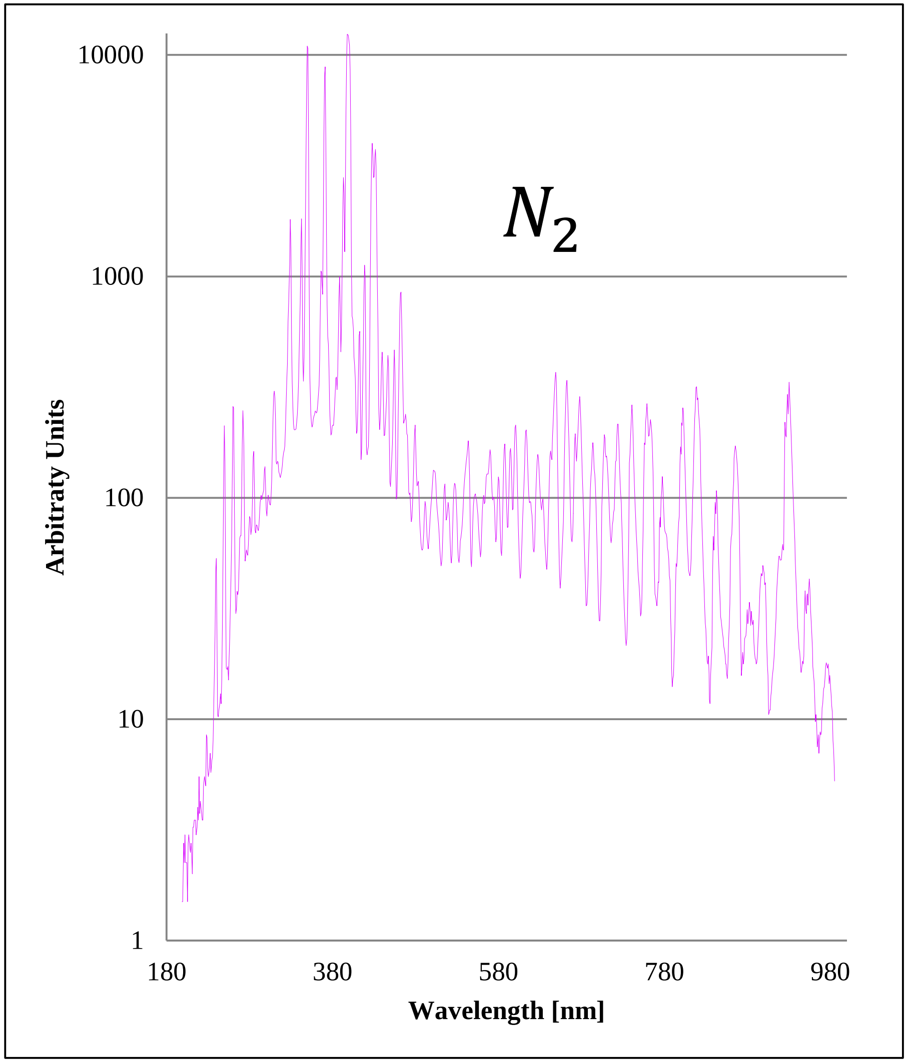
$CO_2$ $\quad CF_4$

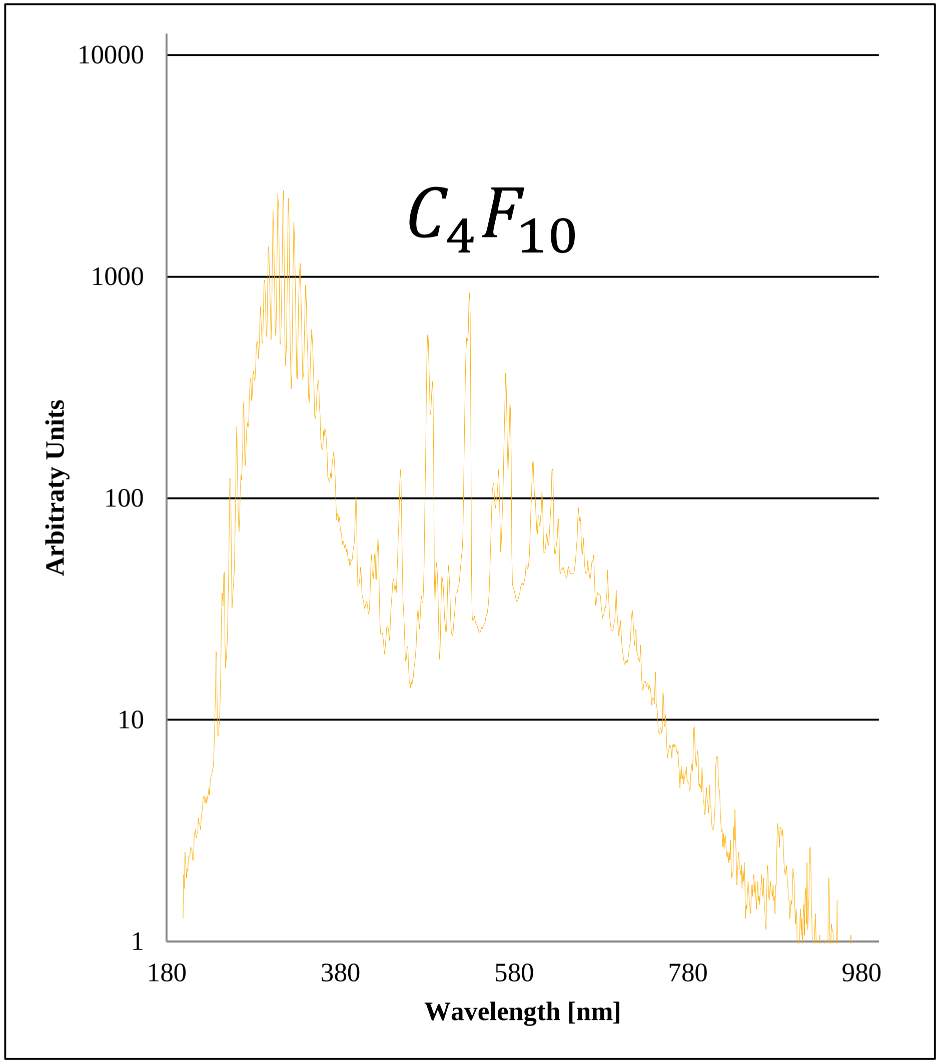
$CH_4$ $\quad C_3F_8$

$C_4F_{10}$ $\quad C_4H_{10}$



# Spectral distributions



# Scintillation measurement II

Absolute yield measurement => $N_{ph}$ / MeV

Energy deposit by α – particles => $\Delta E \approx 1 - 4$ MeV

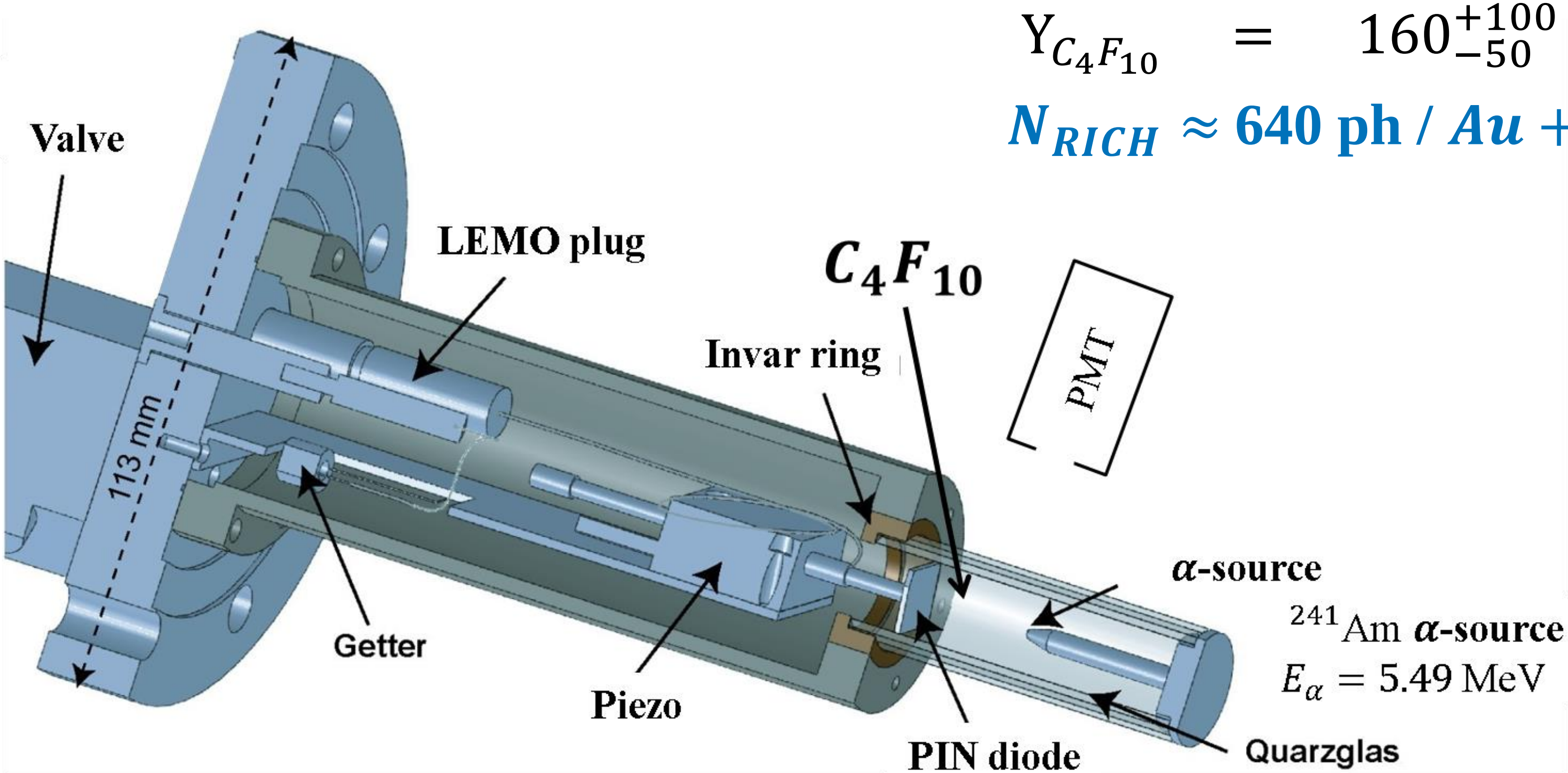
Nomalization via $N_2$ 337nm line

(Fluorescence of nitrogen and air
T Dandl et al., 2012 JINST 7 P11005)

Result:

$$Y_{C_4F_{10}} = 160^{+100}_{-50}\ MeV^{-1}$$

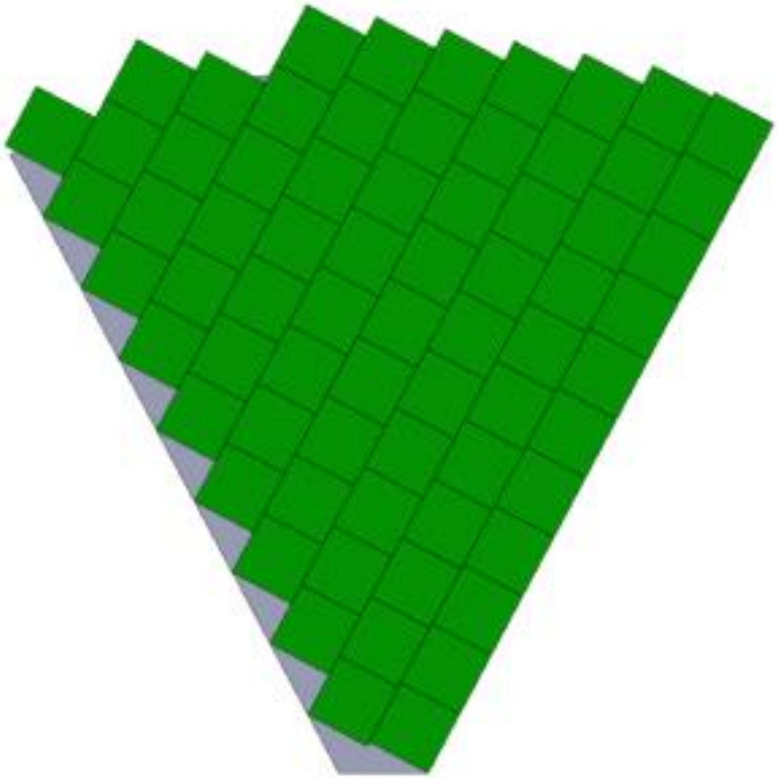
$$\boldsymbol{N_{RICH} \approx 640\ \text{ph} / Au + Au}$$



# Conclusion & outlook

## Results:

- MAPMT is a better photon detector
- $C_4F_{10}$ leads to scintillation rings
- **~ 10 fake rings per Au + Au event**
- Other radiator gases under study

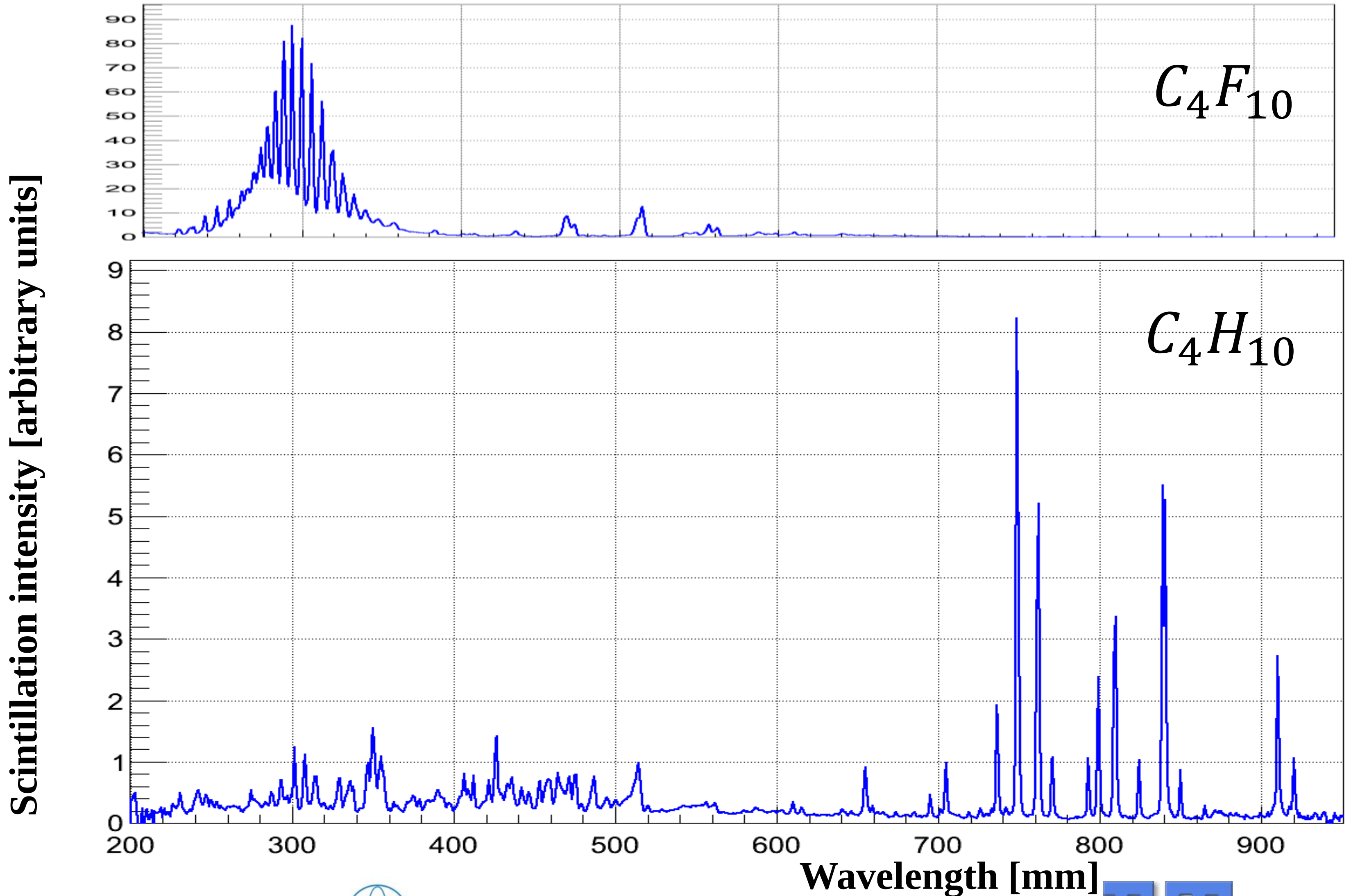


## To be done:

- Adjustment of ring finder
- Geometric arrangement of MAPMTs


korbinian.schmidt-sommerfeld@ph.tum.de

# Scintillation of $C_4H_{10}$

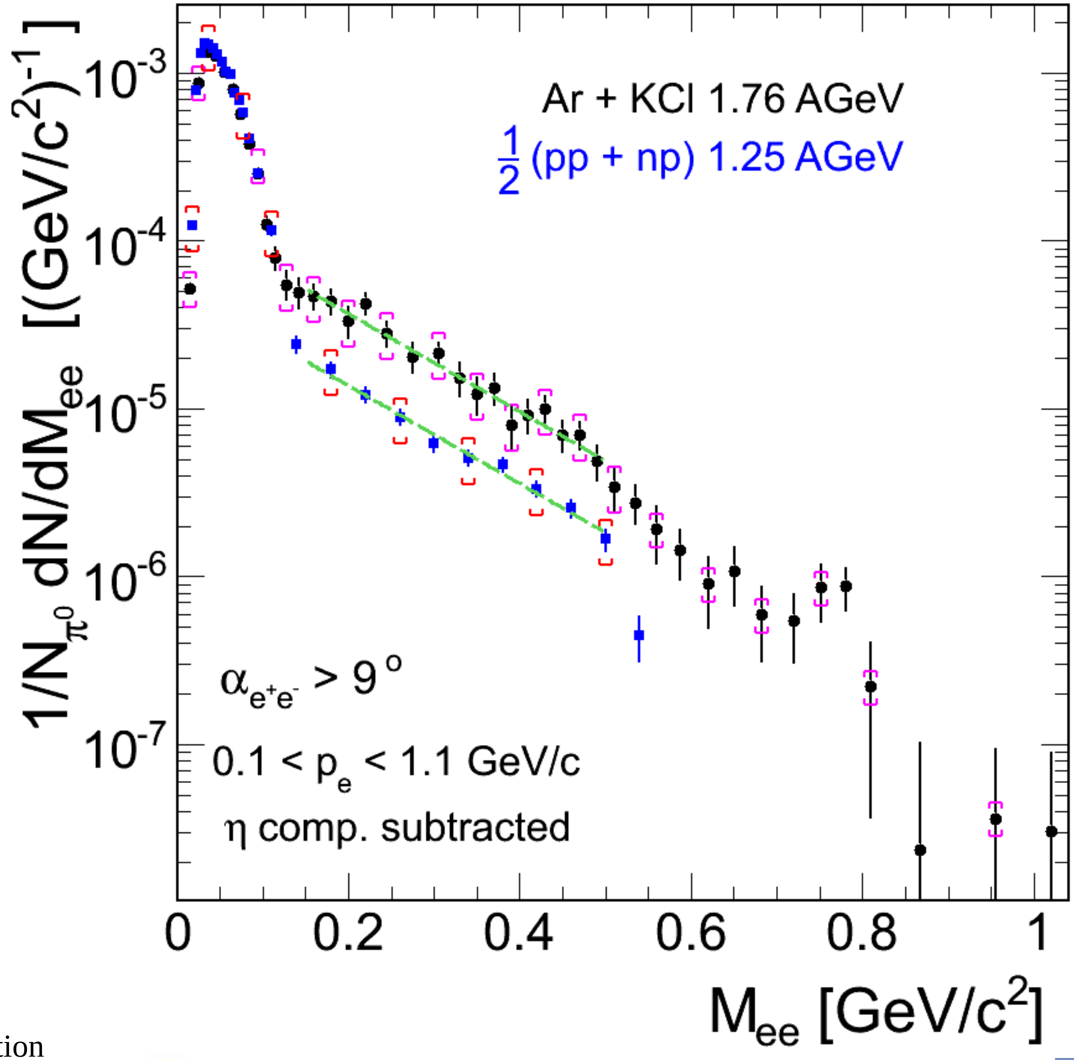


# Thank you!

# BACKUP

Korbinian Schmidt-Sommerfeld

# Dielectron emission in HI reactions




HADES Collaboration

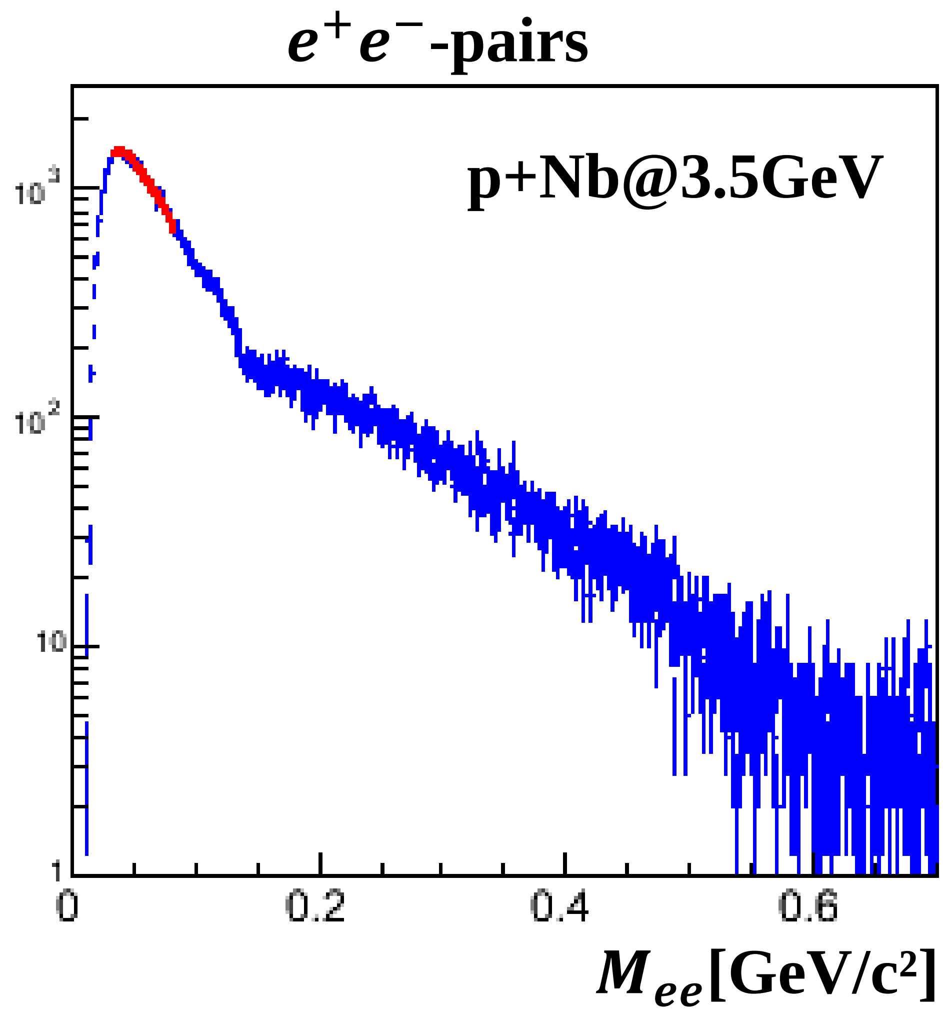
# Searching a Dark Photon with HADES

**Possible Dark Matter candidate:**

- Dark photon $U'(1)$
- mixing of $U(1)$ and $U'(1)$ of strength $\epsilon^2 = \frac{\alpha'}{\alpha}$
- Observable signal in em processes

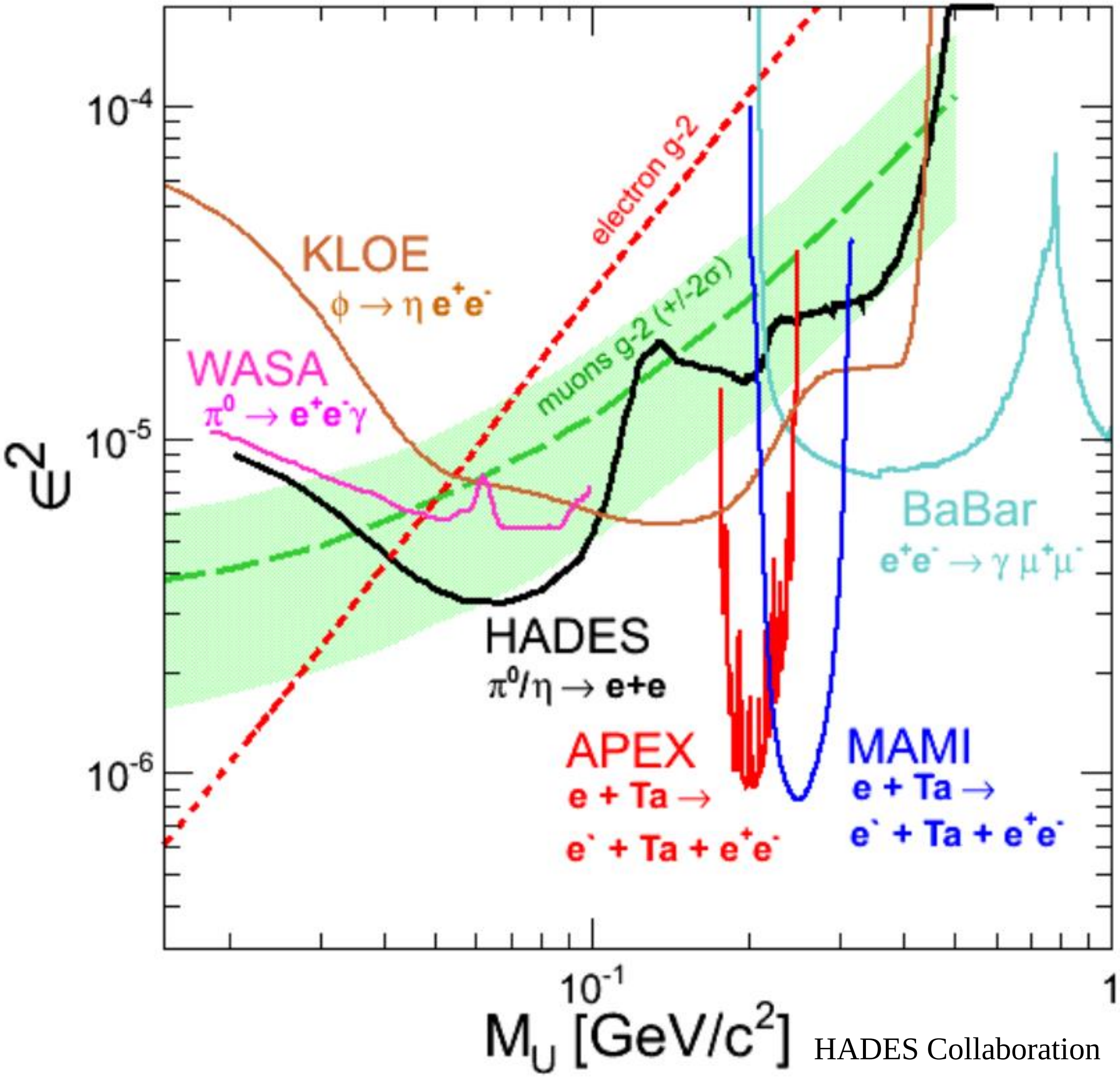
$$\pi^0, \eta, \phi \rightarrow \gamma\gamma^* \rightarrow \gamma e^+e^-$$

at level $\epsilon^2$ $\rightarrow$ $\gamma U \rightarrow \gamma e^+e^-$




HADES Collaboration

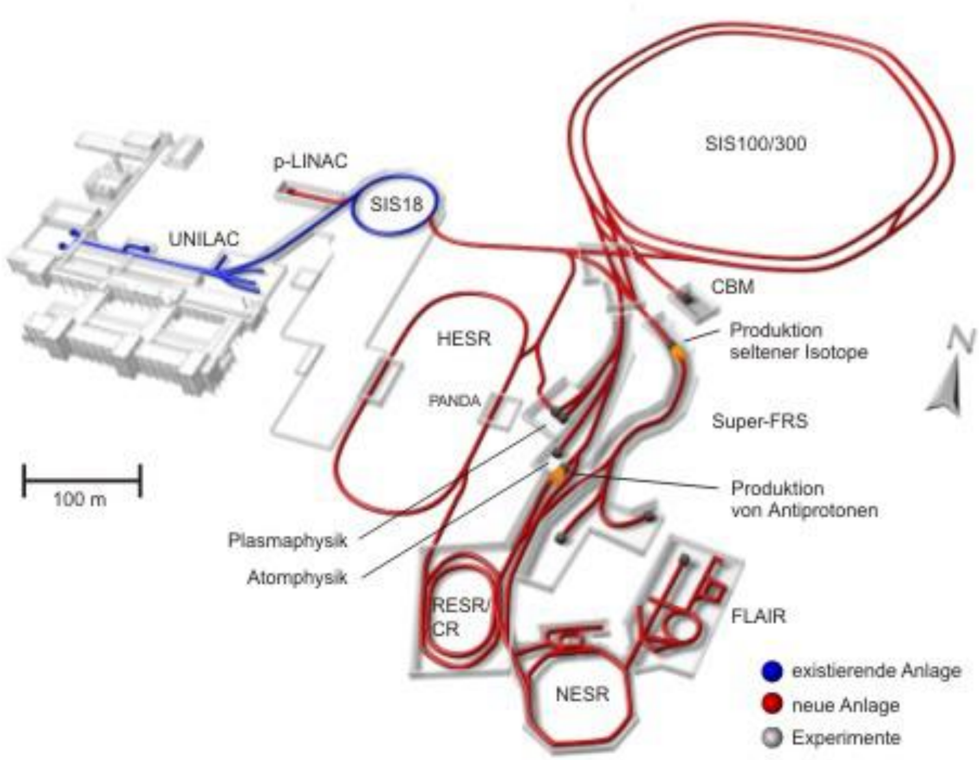
# Dark photon exclusion plot




HADES Collaboration

# Facility for Antiproton and Ion Research (FAIR)

## Future research with HADES at higher energies

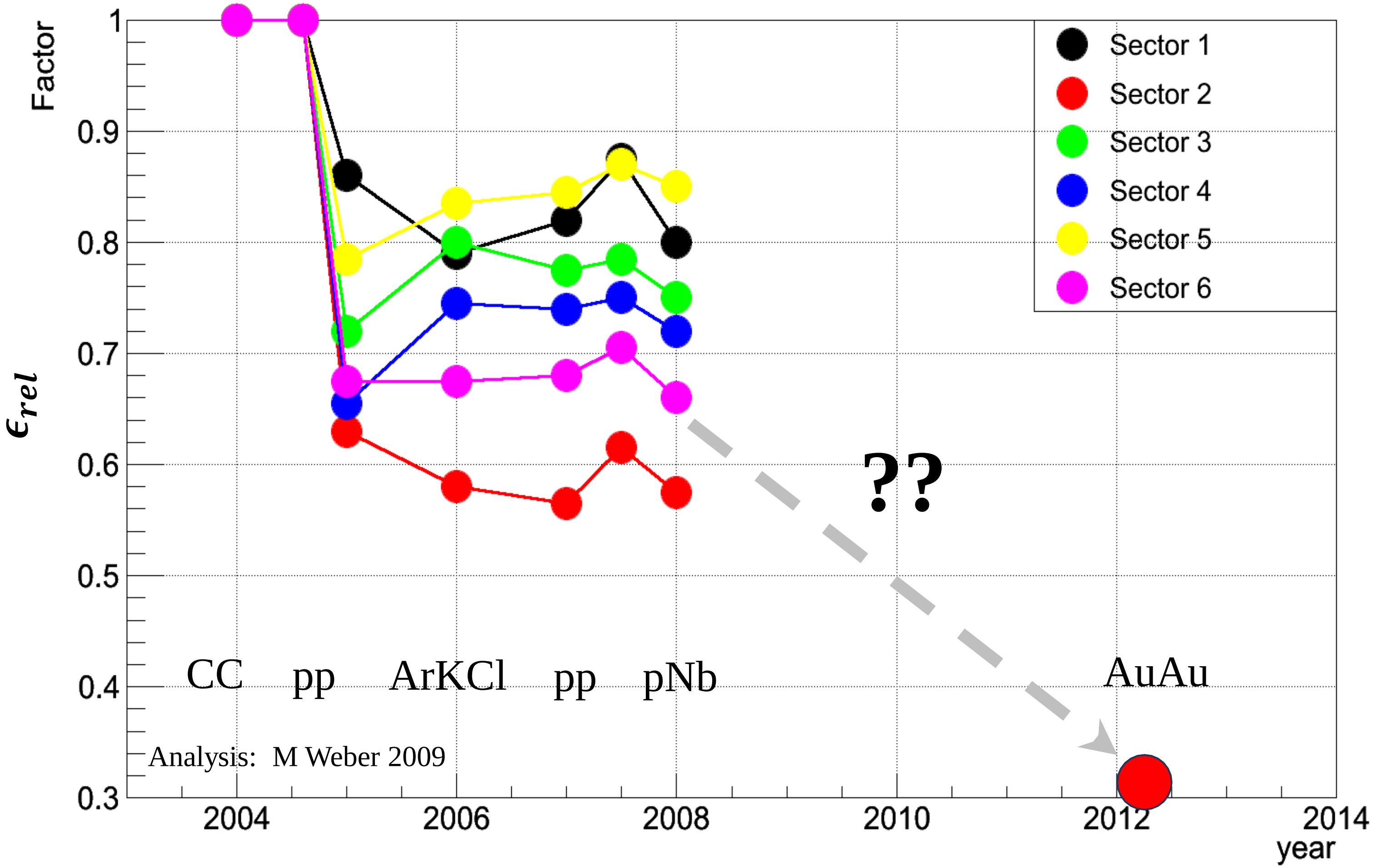



fair-center.de

| | SIS18 | SIS100 |
|---|---|---|
| **Energy [AGeV]** | $1 - 2$ | $\approx 10$ |
| **Temperature [MeV]** | 80 | 120 |
| **Baryonic density** | $3 \cdot \rho_0$ | $\approx 6 - 8 \cdot \rho_0$ |

# Ageing & Efficiency loss

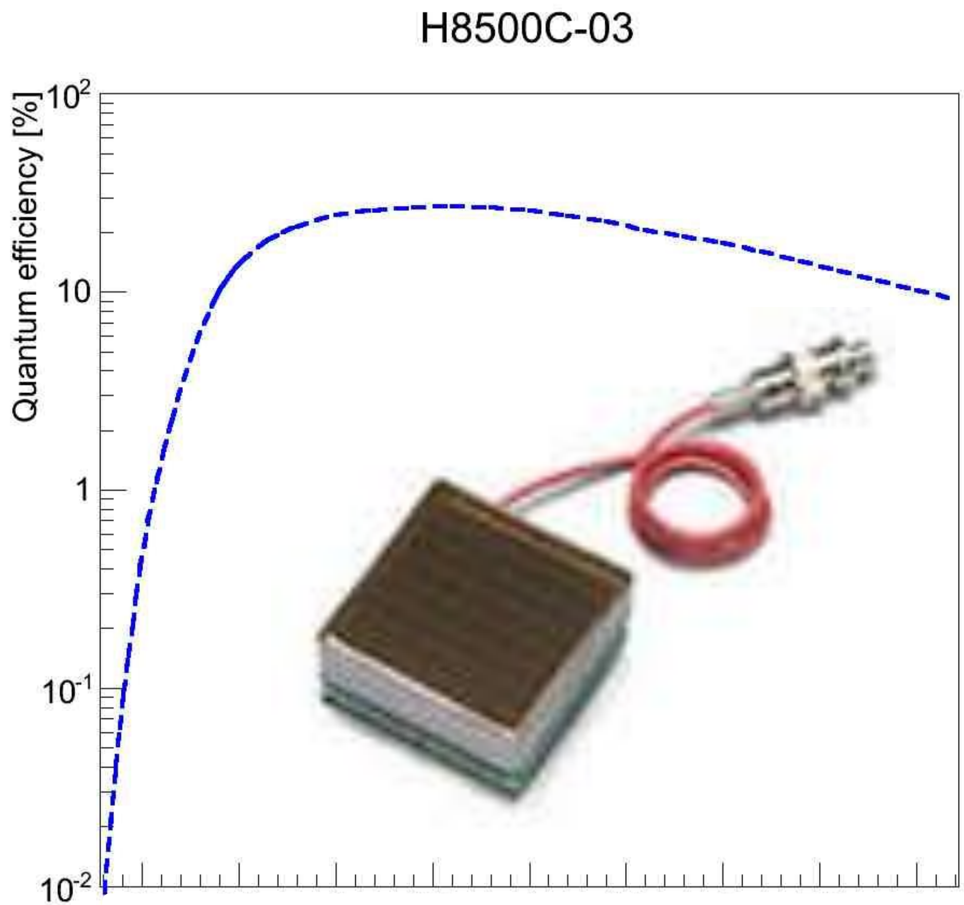
**<ε tot> (04) ~ 60%**



# Multi anode photomultiplier

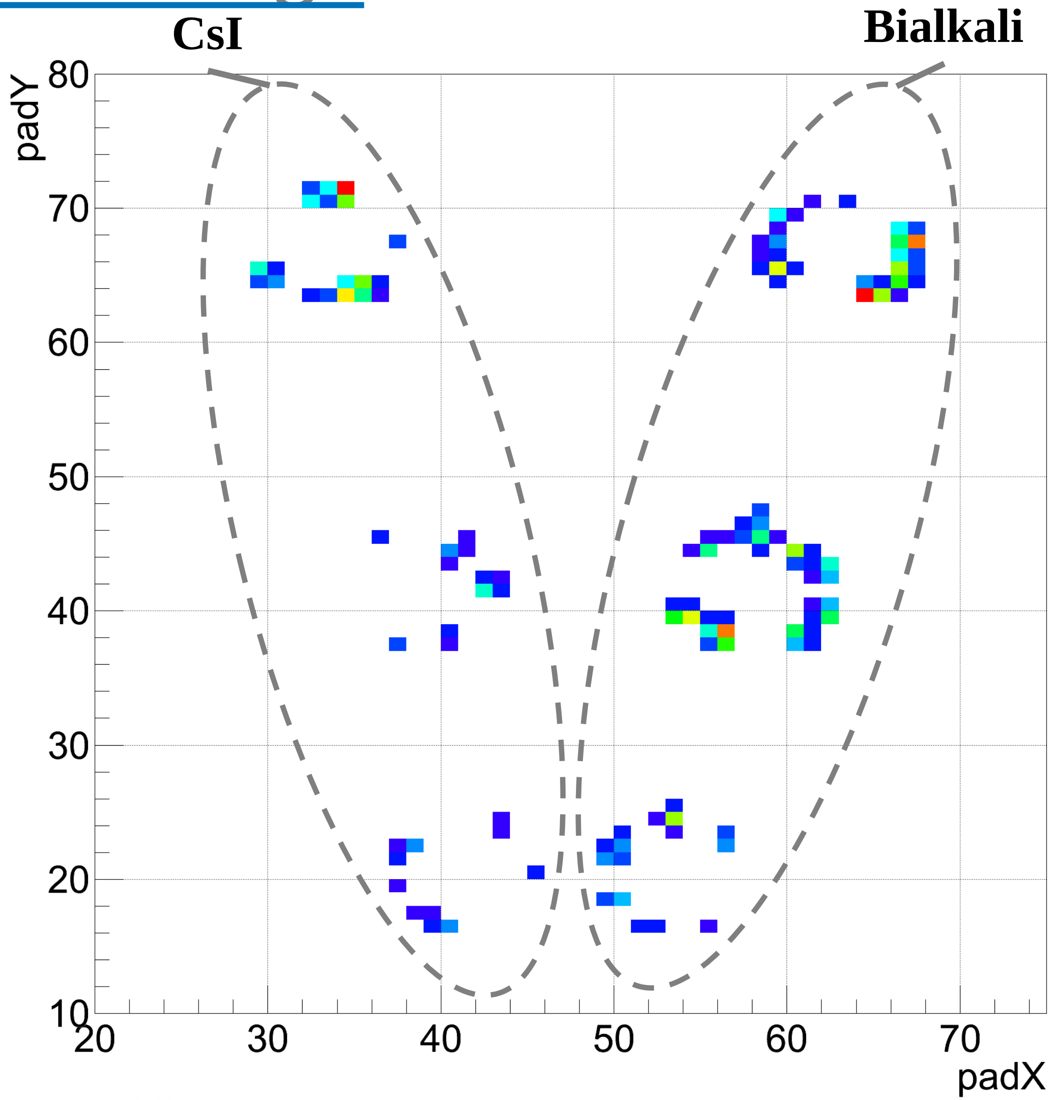
Proposal: Hamamatsu **H8500C - successor** (same as CBM)

- 8x8 channels
- $52\ mm \cdot 52\ mm$
- Gain: $1.5 \cdot 10^6$
- Bialkali photo cathode
- Sensitivity: $1.9$ - $6.7 eV$
- $\mathrm{QE_{max}} = 28\ \%\ @\ 400\ nm$

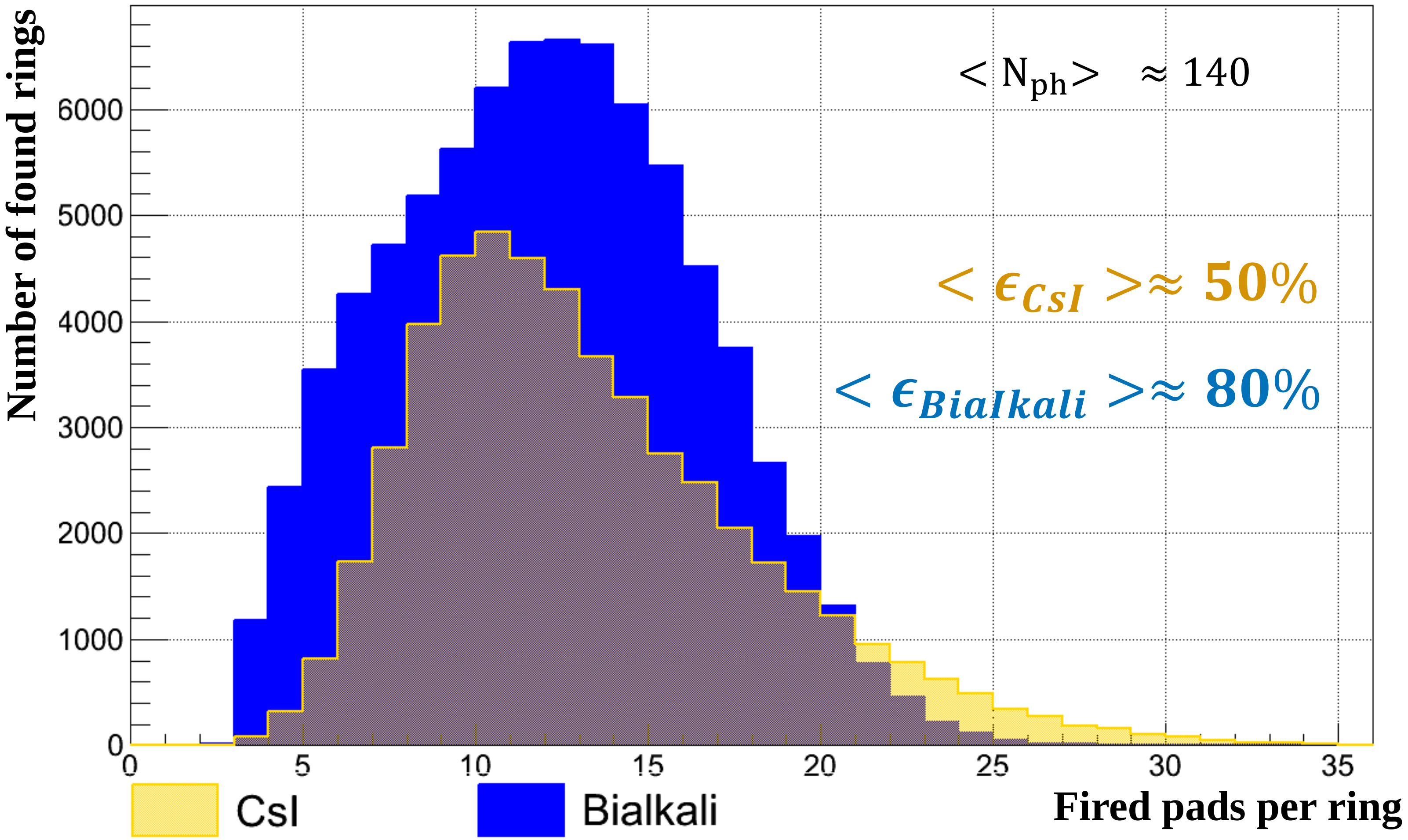



| | | | | | |
|---|---|---|---|---|---|
| **Energy [eV]** | **2** | **3** | **4** | **5** | **6** |
| **Wavelength [nm]** | **610** | **413** | **310** | **248** | **207** |

# Cherenkov Rings

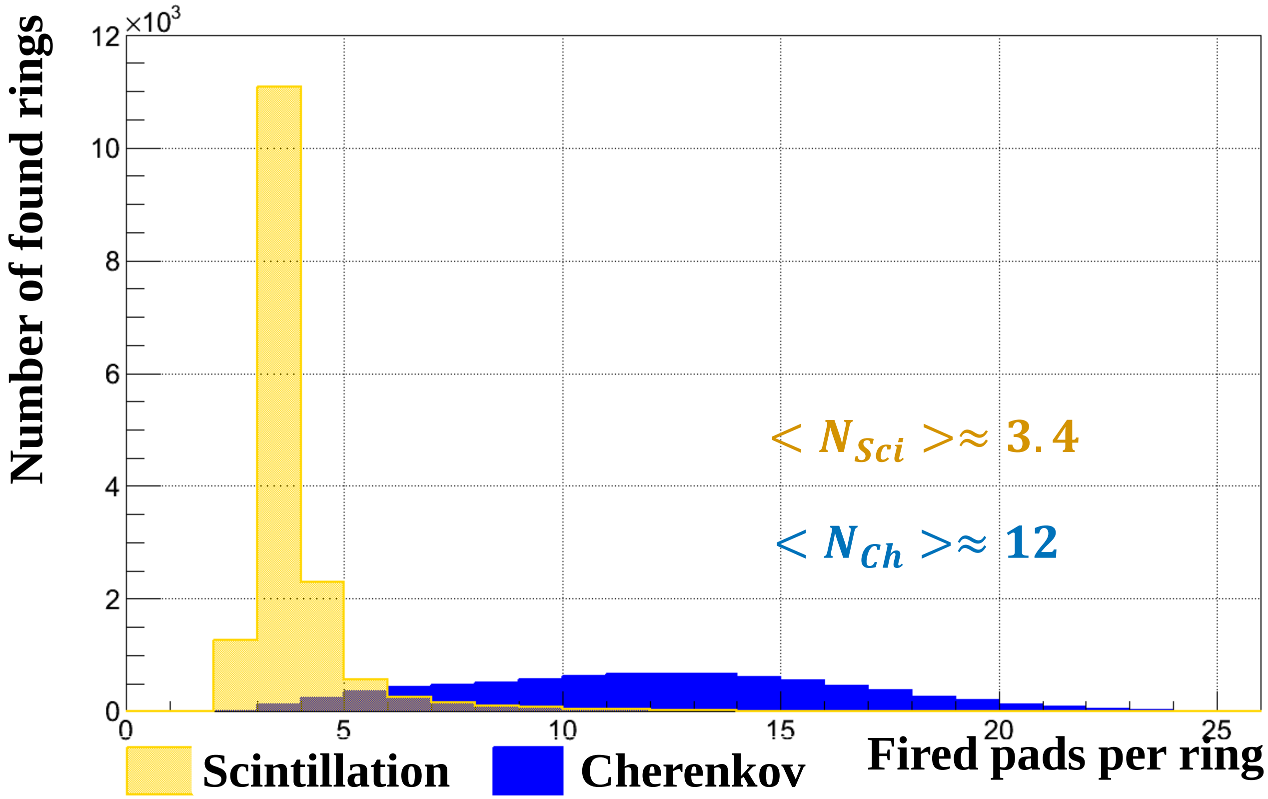


# Simulation results




- Ring finder **not yet optimized** for bialkali QE.
- No significant influence by **new pad geometry**.

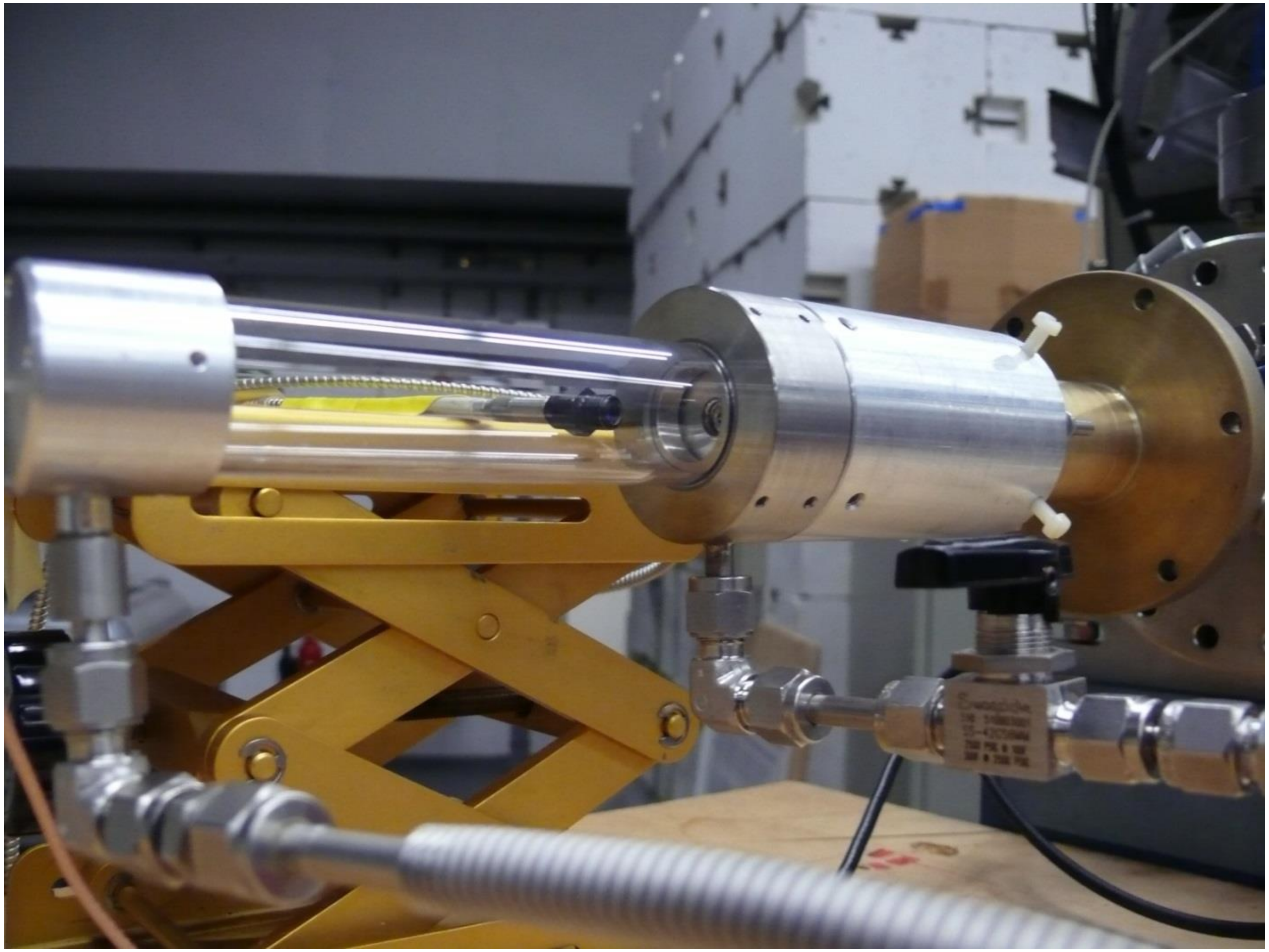
# Fake scintillation rings




- $N_{ph} \approx 80$ / evt.
- Fake rings = **1.6 / evt.**
- Preferred at small angles

**=> Fake rings can be rejected by adjusting ring quality parameters**

# Scintillation light measurement



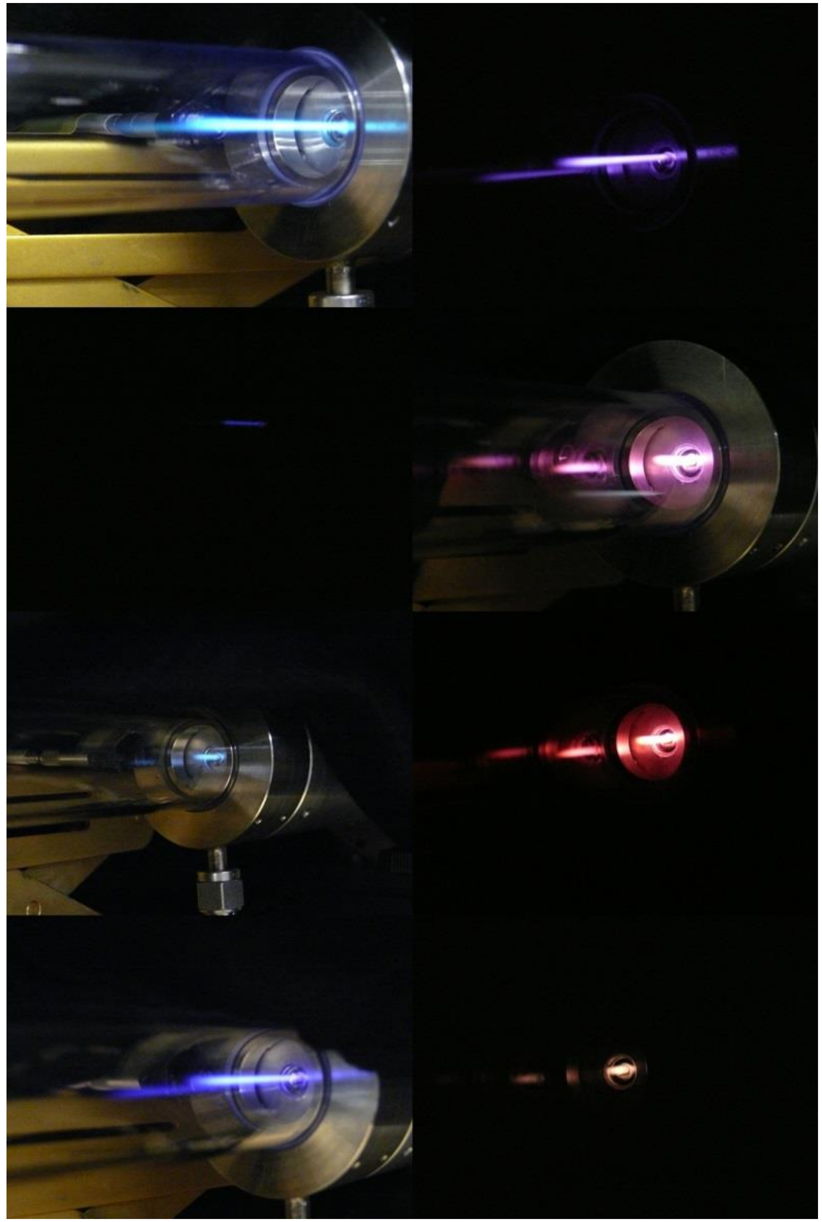
Setup: MLL Tandem, Munich

$^{32}_{16}S^{8+}, E_{kin} = 90$ MeV $\rightarrow C_4F_{10}, Ar, N_2 \ldots$

Spectrometer:

Ocean Optics QE65000


korbinian.schmidt-sommerfeld@ph.tum.de



$Ar$ $N_2$

$CO_2$ $CF_4$

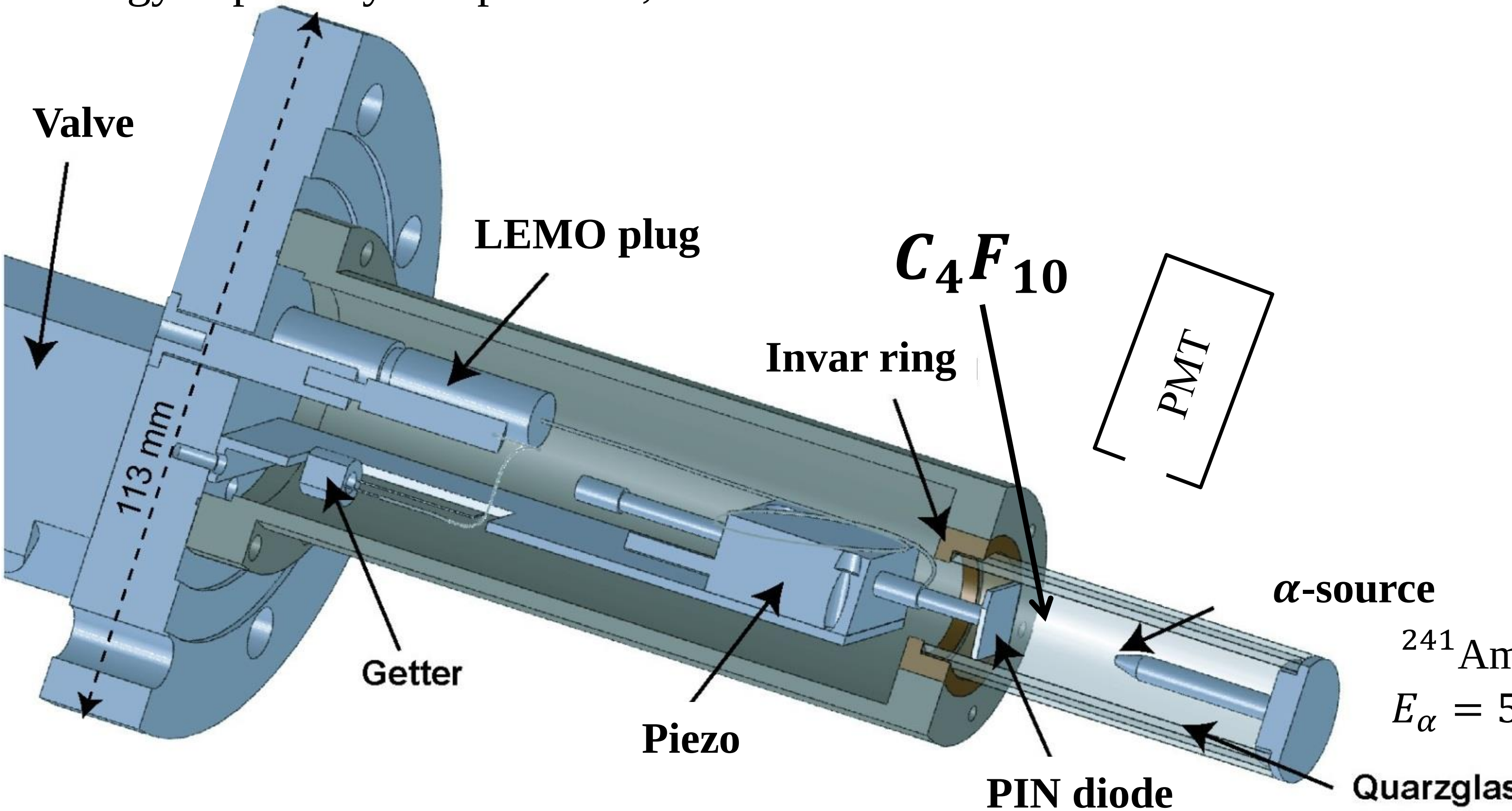
$CH_4$ $C_3F_8$

$C_4F_{10}$ $C_4H_{10}$

# Scintillation measurement II

Absolute yield measurement => $N_{ph}$ / MeV

Energy deposit by α – particles; distance calculated from $\alpha$-rate




$^{241}$Am $\alpha$-source

$E_\alpha = 5.49$ MeV

# Scintillation measurement II

Spectra normalized to number of coincidences at $d = 4.2$ mm

Energy loss calculated with GEANT

Yield: $Y_{N_2}^{337nm} = 92 \pm 20\ \mathrm{MeV}^{-1}$

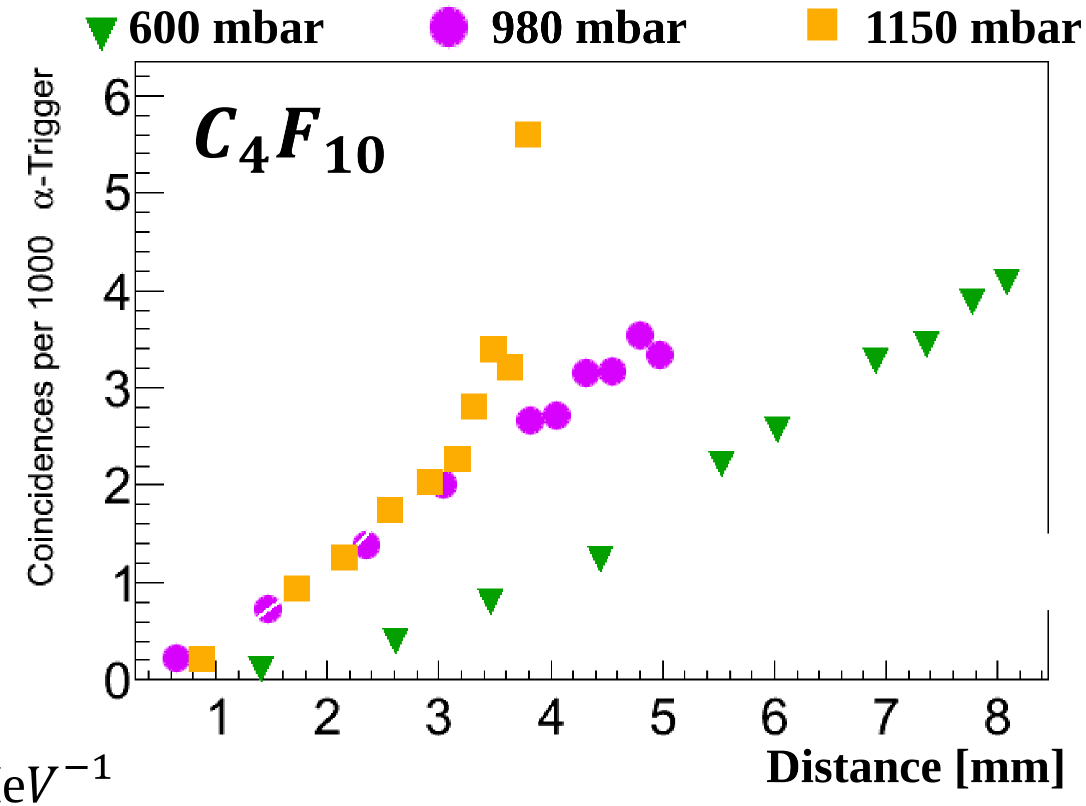
(T. Dandl, et al. Jour. Inst, 7(11):P11005, 2012)

$\Rightarrow \quad Y_{Ar} = 5000\,^{+3000}_{-1500}\ \mathrm{MeV}^{-1}$

Lit: $\mathrm{Y_{Ar}} = 17000 \pm 3000\ \mathrm{MeV}^{-1}$

A. Buzulutskov et al., EPL 94(5):52001, 2011

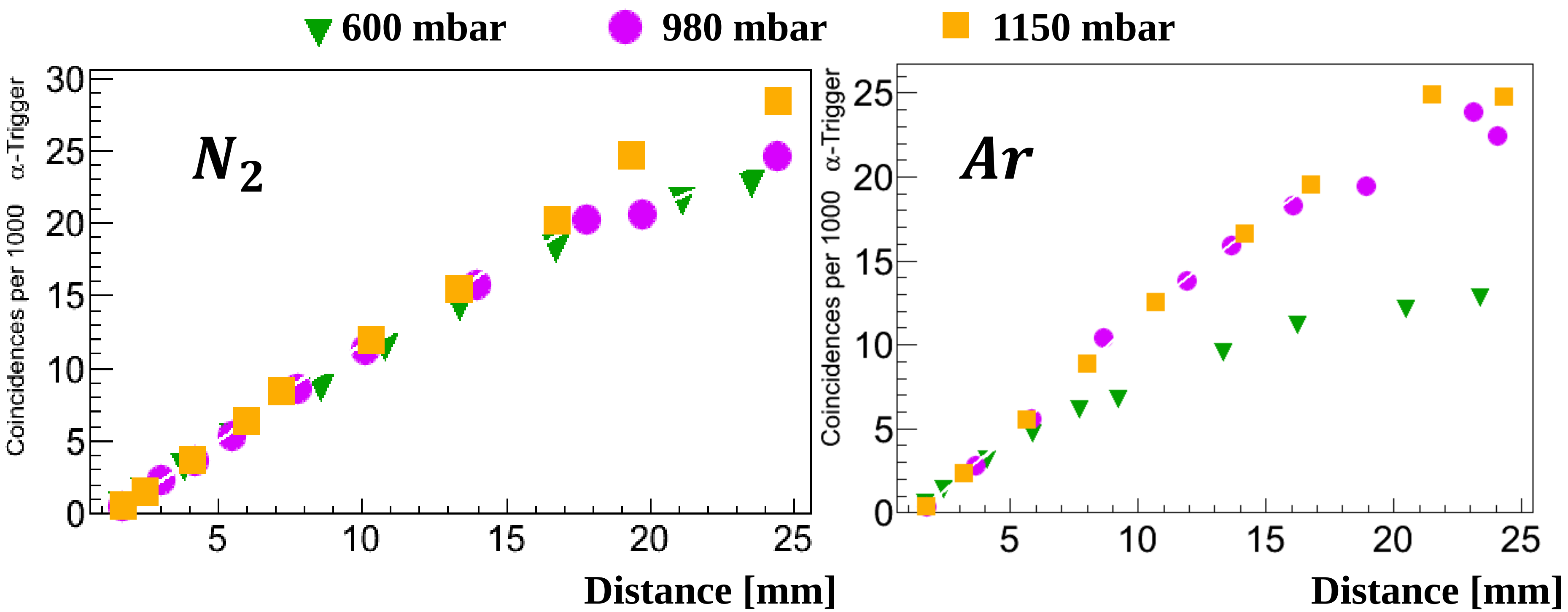
$\Rightarrow \quad \mathrm{Y}_{C_4F_{10}} = 160^{+100}_{-50}\ \mathrm{MeV}^{-1}$




Detected by the RICH:

$N_{ph} \approx 640$ **ph /** $Au + Au$

# Scintillation measurement II

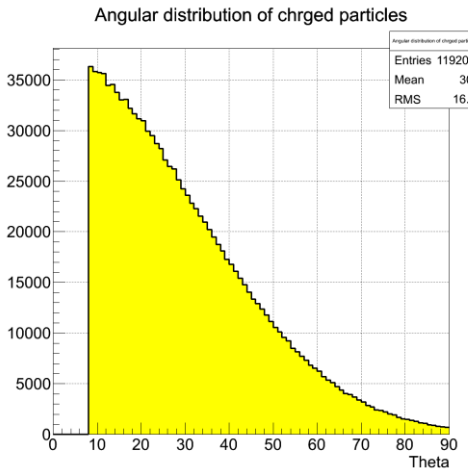


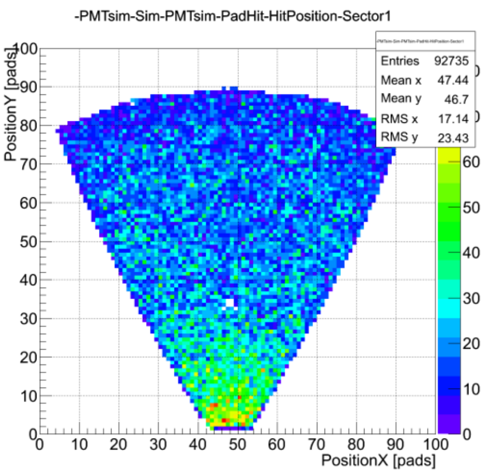

- Distance calculated from $\alpha$-rate
- Dynamic quenching in $N_2$

# Scintillation simulation

## A simulation with realistic parmeters is performed.

- Simulation of $Au + Au$ events
- On avarage 120 charged particles per event
- 90% $p^{+}$ & 10% $\pi^{+/-}$
- Number of scintillations photons depending on $\theta$ of the primary particle
- Angular and energy distribution from the last beam time
- Approximately 2300 Scintillation photons per event



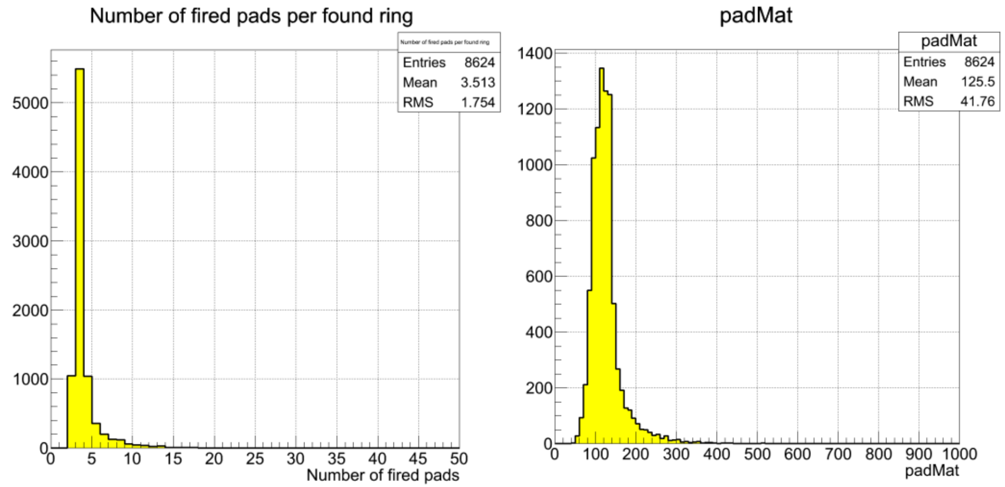



# Scintillation results

## Resulting fake rings can be filtered out.

- On avarage 320 photons on the pad plane per event
- Found rings all over the rich
- Accumulation at small angles
- Low quality rings
  - Fired pads ≈ 3.5
  - padmat ≈ 125
  - centroid ≈ 2.0

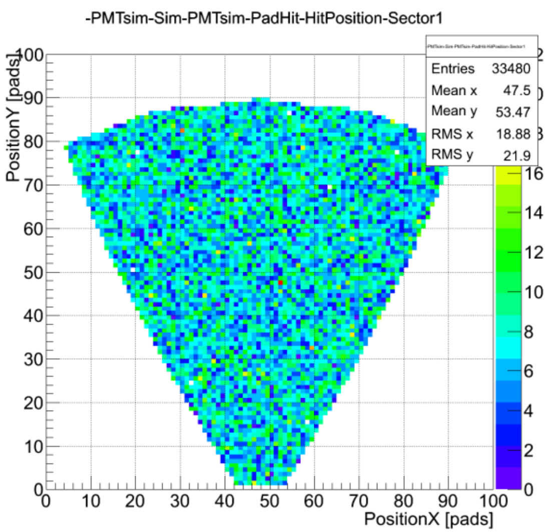
**=> Necessary adjustment of ring quality parameters**

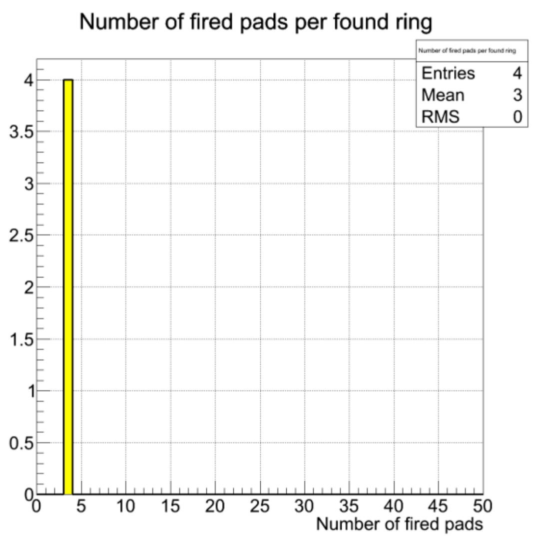


# Comparison with electronic noise

## Filtering fake rings is already done by the electronics.

- Electronic noise of the data readout
- statistically independent firing pads
- Necessity of quality cut for rings
- 4 found rings of poor quality in $10^4$ events



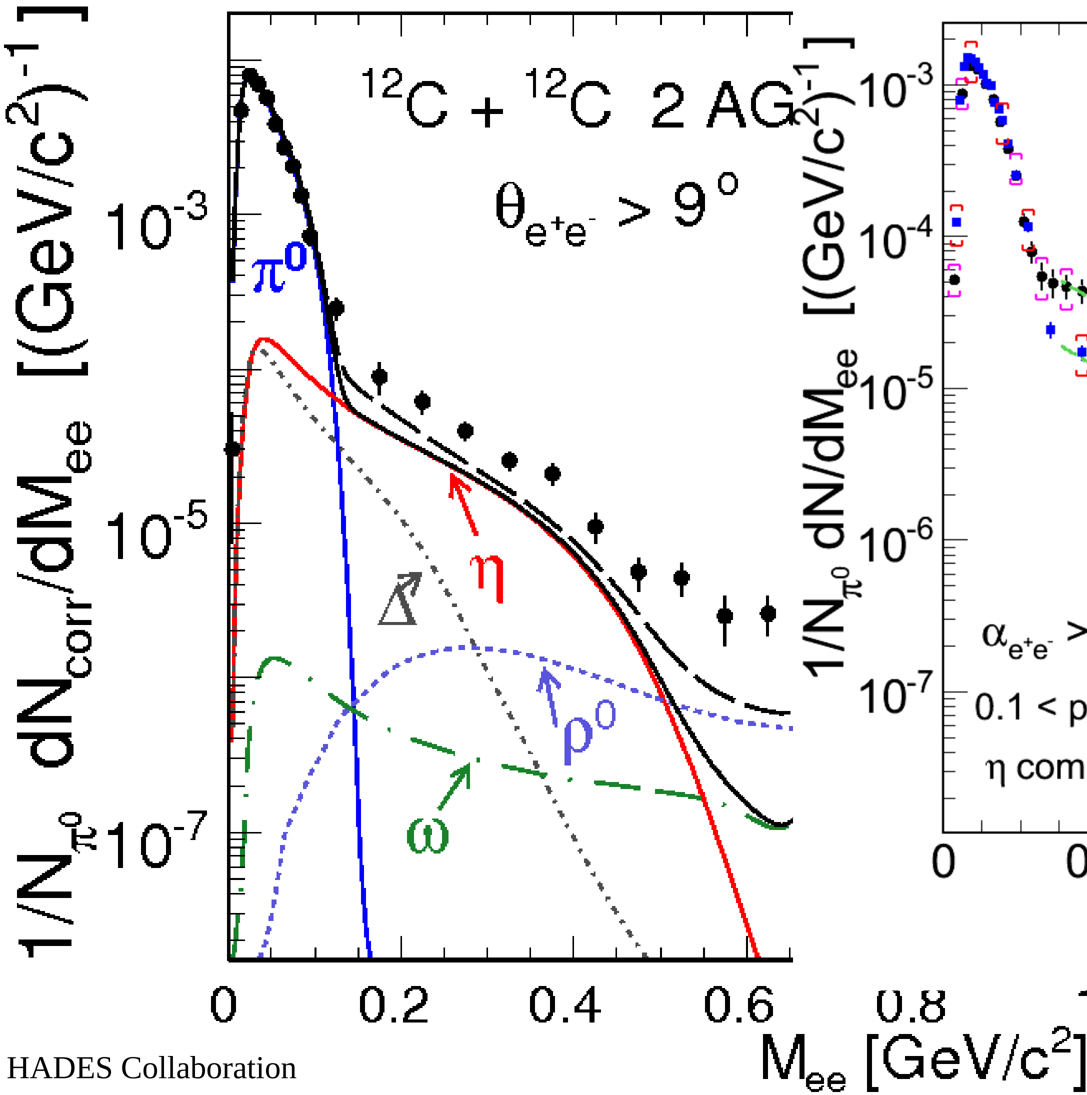
# Perspectives

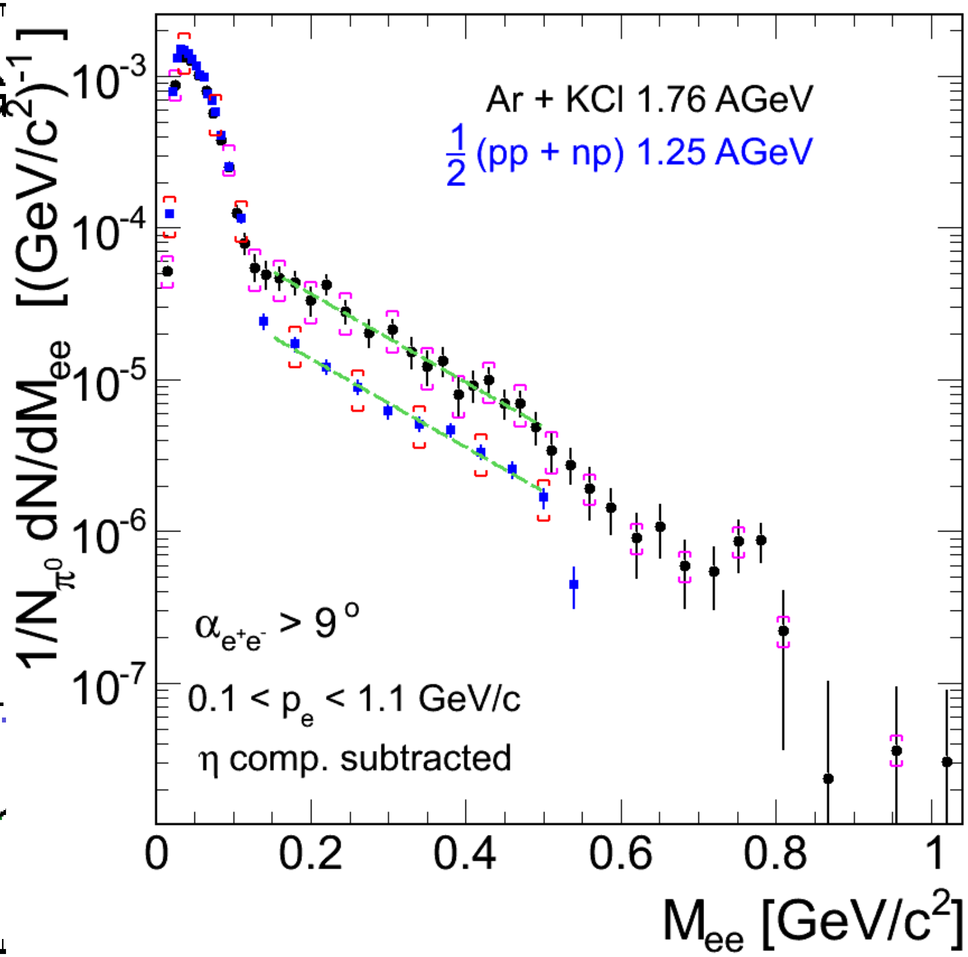
MPC → MAPMT

$C_4F_{10}$ → $C_4H_{10}$

| @ 20 °C, 1013 hPa | $C_4F_{10}$ | $C_4H_{10}$ |
|---|---|---|
| ρ [g/cm³] | 9,9 | 2,4 |
| $T_{boil}$ [ °C] | - 1,7 | -11,7 |
| P [hPa] | 2600 | 3019 |
| n-1 [@ 300 nm] | $1,3 \cdot 10^{-3}$ | $1,2 \cdot 10^{-3}$ |
| $\Gamma_{thresh}$ | 18,2 | 19,5 |
| $N_{ph}$ (Scint.) [MeV⁻¹] | 25 - 30 | 2 |

# Dielectron spectra $C + C$

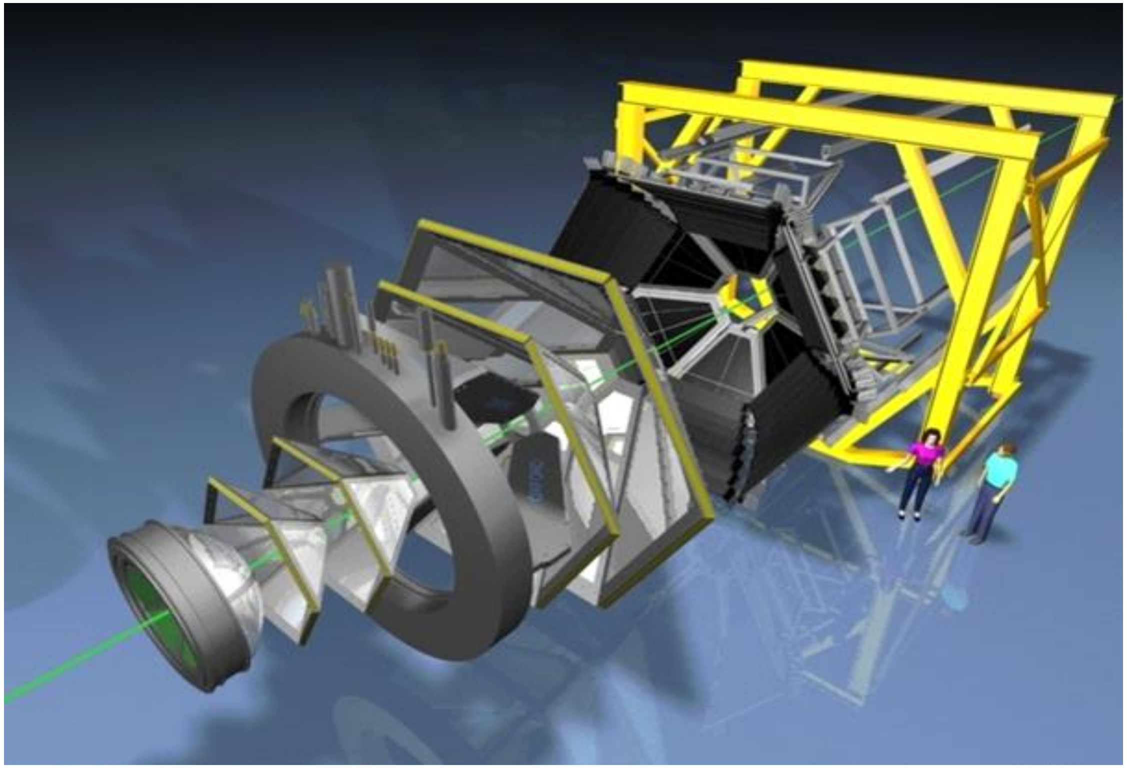



HADES Collaboration

# Schematic picture of the High-Acceptance DiElectron Spectrometer

**HADES is used for the systematic study of in-medium properties of light vector mesons $\rho$, $\omega$ and $\phi$.**



Components:

- **R**ing **I**maging **Ch**erenkov (RICH)
- **M**ini-**D**rift **C**hambers (MDC I-IV)
- Superconducting magnet
- **T**ime-**o**f-**f**light walls (TOF and RPC)

=> clean signal from decay into $e^+/e^-$ pairs

Stretched view, beam enters from the left [gsi.de]