UV Detectors for POLLUX

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Outline

• Proposed detector technologies for POLLUX
• MCP UV Imager technologies
  • Photocathode choice and detector format
  • Large area MCP technology
  • ALD-MCP performance enhancement
  • Square format MCP detectors
• High speed readout techniques
  • Cross-strip
  • Centroiding Pixel Array
Proposed detector technologies for POLLUX

• FUV detector
  • 98-123 nm
  • Format (tbd) nominally 150 x 64.2 mm$^2$
  • Open-faced MCP coated with alkali halide photocathode

• MUV detector
  • 119-220 nm
  • Format (tbd) nominally 152 x 44.8 mm$^2$
  • Sealed tube MCP
  • Semi-transparent photocathode e.g. Cs$_2$Te – solar blind

• NUV detector
  • 210-390 nm
  • Format (tbd) nominally 90.5 x 44.9 mm$^2$
  • CCD or sCMOS 4k x 4k pixel$^2$ format, 13 µm pixel
  • Enhancement using graded AR coating, or scintillator coating?
MCP UV Imager technologies
FUV Photocathode & Detector

- Alkali halide deposited on MCP
  - Typically CsI or KBr
  - Much space heritage
  - Sensitive to incident angle
    - Choose MCP bias to match optical design
- Open tube configuration
  - Requires door mechanism
  - Higher mass, complexity, cost
  - Performance trade-off:
    - Repeller grid enhances QE at expense of spatial resolution


N.B. not coated MCPs
MUV Photocathode & Detector

• Solar-blind Cs$_2$Te
  • QE: 34% at 254 nm
    • cf. HST-STIS QE: 9%
  • Optical wavelength rejection
    • two orders of mag. >350 nm
    • zero red leak
  • Cut-off wavelength can be tuned
  • Short wavelength performance needs characterization

• Sealed tube
  • No door mechanism or contamination
  • Lower mass, complexity, cost
  • Downside: MgF$_2$ window cut-off
MCP UV Imager technologies

- New technology developed for Large Area Picosecond Detector (LAPPD)
  - LAPPD collaboration – instigated by Frisch, Chicago
  - LAPPD – primarily developed for HEP apps
- Glass capillary array
  - Developed by Incom – fibre optic heritage
  - Borosilicate construction – up to 200 x 200 mm$^2$
- ALD technology originally developed for Si-MCP
  - Arradiance Inc. Nanofilm technology
  - Provides resistive and emissive layers
  - Order of magnitude improvement in detector lifetime
MCP UV Imager technologies

- **Glass Capillary Arrays**
  - Borosilicate glass – more durable than lead-glass MCPs
    - e.g. similar to Pyrex
  - Manufactured by hollow core draw – no etching
  - Stronger, less warpage
    - Allows MCPs > 100 mm – limited by lead-glass fragility
  - No lead content, reduced Potassium, Rubidium
    - Lower gamma ray x-section and intrinsic background

- **Atomic Layer Deposition**
  - Resistive layer for continuous dynode
  - Emissive layer for electron gain
  - No leaching of hydrogen cf. lead-glass MCP
    - Reduced photocathode ageing and MCP gain sag
    - Longer detector lifetime
Important issues from LAPPD

20 µm pore size – limits resolution

Dead area due to support bars

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Recent Functional LAPPDs

LAPPD 9
LAPPD 10
LAPPD 12
LAPPD 13

Craven - Large Area Micro-Channel Plates for LAPPD, 2014
Large area detector issues

• 20 µm resolution – requires smaller (10 µm) pore φ
  • LAPPD only down to 20 µm pores so far
  • Rocket flight will only prove 40 µm pore technology
• Typical L/d of 60:1 → 1.2 mm thickness
  • 10 µm pore MCPs will be 600 µm thick!
  • Practical limit to size/thickness ratio – when will it be reached?
  • If feasible, likely to need even more internal support
• Inherent dead-space due to support bars
  • alternative would be to mosaic smaller detectors
  • Added advantage of redundancy
• Semi-transparent photocathodes
  • Proximity focussing gap limits resolution – especially in the UV
  • Typically scales with detector size due to practicalities
  • Spatial resolution limited by transverse photoelectron momentum
• BUT – there is time and people have inclination to develop this technology
ALD enhanced MCPs

- ALD coated conventional MCPs
- Enhanced secondary electron emission
  - Higher QE due to higher photoelectron detection efficiency
  - Lower operating voltage due to higher gain per bounce
- Increased detector lifetime due to reduced MCP outgassing
  - ALD seals in MCP adsorbates
  - Reduces ion feedback events
  - Reduces photocathode QE fatigue
  - Reduces MCP gain loss
Square format MCP detector

- Thin-walled square tube MCP detector for LHC
- TORCH-Cherenkov detector element of LHCb upgrade
- Thin wall (3.5 mm) allows close packing of tube arrays
- Minimal dead space between active regions
- LHCb programme has enhanced to TRL6
- 64 x 64 pixel\(^2\) multilayer ceramic
- 60 x 60 mm\(^2\) with 57 x 57 mm\(^2\) active area

64 x 64 pixel\(^2\) multilayer ceramic readout
High speed readout techniques
Cross-strip – Siegmund, Berkeley

- Parallel cross strip (PXS) readout
- < 20 μm FWHM spatial resolution
- count rates ~2 MHz
- Lower gain requirement
- temporal resolution of ~ 1ns
- TRL 6 by using custom ASICs
- lower the power, mass and volume
- "standard" 50mm square active area MCP detector
- qualified for flight (temperature, vacuum, vibration)
- new 50 x 50 mm XS detector (2014)
Centroiding Pixel Array

- Square electrode array using “Image Charge”
- Event spread over small number of localised electrodes
- 40 mm CPA prototype at Leicester
- 32 x 32 pixel$^2$ multilayer ceramic
- Currently optimised for timing electronics
- PetSYS 256-channel event timing ASIC-based system (TOFPET)

- Time over threshold $\rightarrow$ pulse amplitude for sub-pixel centroiding
- Combined imaging and event timing $\leq$ 100ps, 600k event/s/channel

- Investigating fast, lower noise multichannel ASICs
  - E.g. TARGET, DRS4 digitizers
  $\rightarrow$ Higher precision centroiding at high event rate
Image Charge technique

- CPA uses Image Charge capacitive induction
- Eliminates secondary electron redistribution on anode
- cf. electronic readouts with direct charge collection
- Stable geometric charge footprint
- Reduced susceptibility to fixed pattern noise
- Flexible choice of detector input voltage
  - anode always at ground
- 2D electrode array
  - Very low capacitance and thus low noise due to small electrode size
  - Cf. distributed and overlapping strips across extent of cross-strip readout
- Flexible choice of electrode array geometry
  -TORCH readout highly assymetric
- Event deadtime paralysis applies to local event area only
  - Cf. cross-stripe with area of paralysis a cruciform as big as the readout
- Simple 3D interconnection technique developed to connect readout to front end electronics

N.B. Diagram show a different readout to CPA
Conclusions

• New glass capillary array + ALD MCP technologies important irrespective of MCP size
• Large MCPs (>100x100 mm$^2$) will become available, but how useful given their intrinsic dead-space?
• Long but narrow detectors (e.g. 150x60 mm$^2$) may escape this issue
• Mosaiced detectors could be a competitive solution
• Mosaiced detectors also provide levels of redundancy
• MCP electronic readouts with multichannel ASICs suitable for large readouts
• Offer improved local count rates and dynamic range cf. alternatives e.g. iCMOS, iCCD