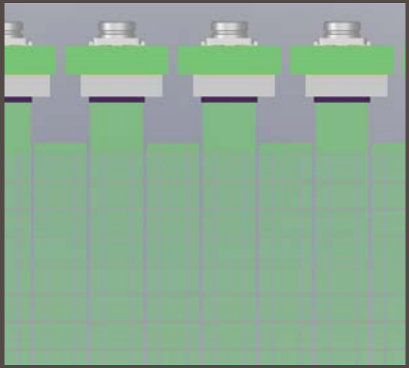
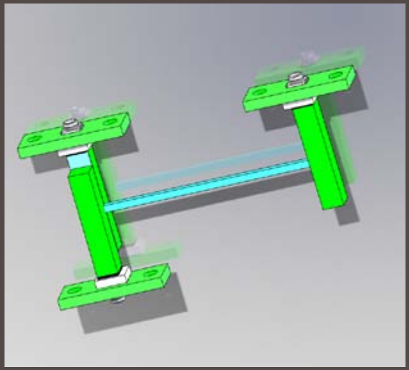
TRIUMF

Canada's national laboratory for particle and nuclear physics
Laboratoire national canadien pour la recherche en physique nucléaire et en physique des particules





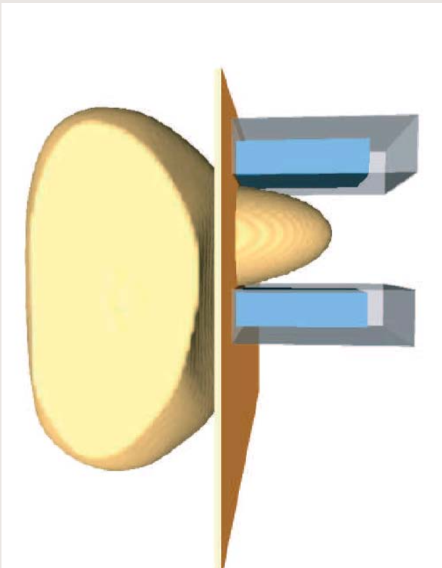
A low cost high performance planar detector for Positron Emission Tomography

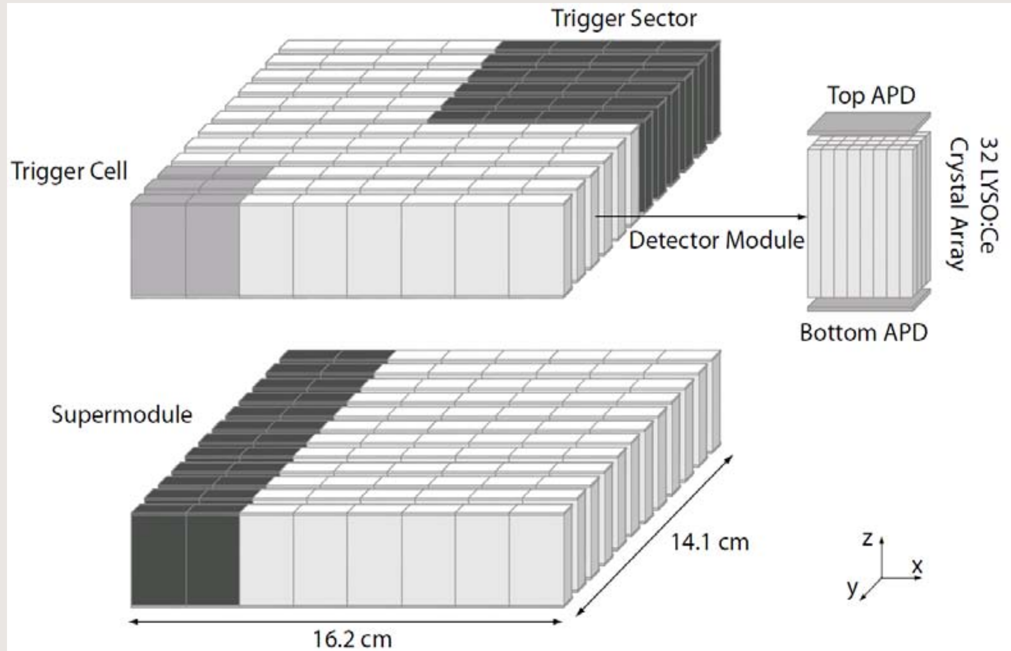
P-A. Amaudruz (DAQ) ,D. Bishop (electronics), K. Boone (undergrad), C. Lim (mech tech), P. Gumplinger (GEANT4), F. Retiere, C. Southcott (undergrad), P. Vincent (mech tech)

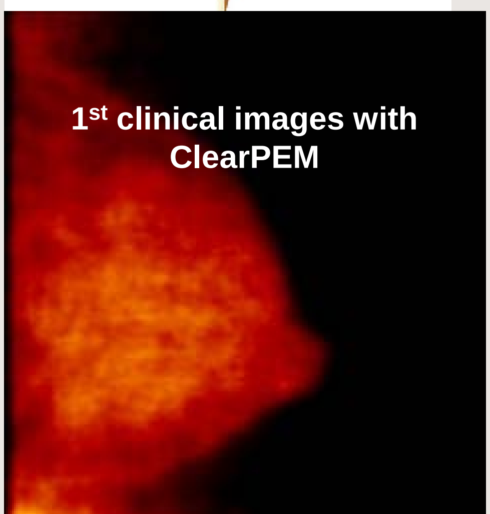
Organ dedicated PET and beyond

- Advantages of organ dedicated PET
  - Reduce scatter
  - Focus on region of interest
- Is it really better than full body PET
  - The jury is still out. Research is ongoing
- Nevertheless such application is interesting because of the simpler constraints
- And there may be applications beyond medical imaging
  - Plant research
  - Industrial process system
- The goal of this project is to build modular, low cost detector planes for PET

clearPEM
State of the art for PEM





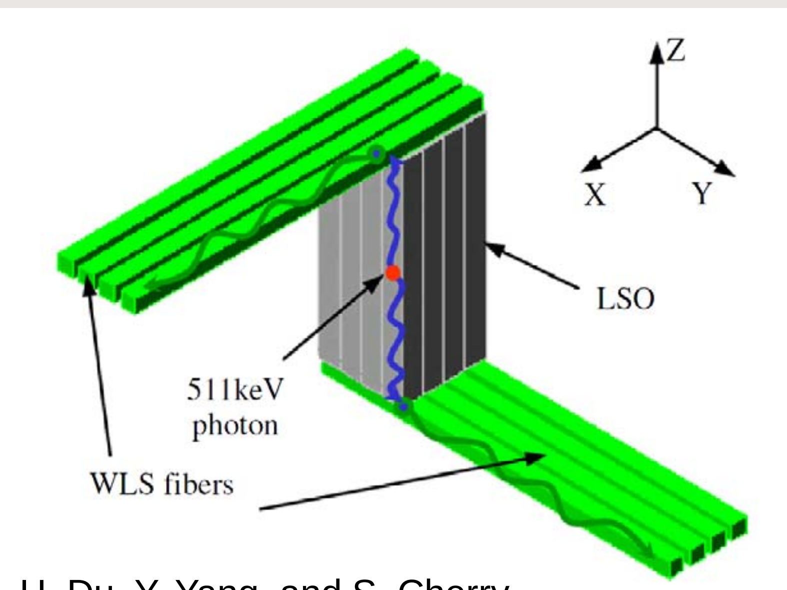


- ClearPEM: State of the art PEM
  - Very good 3D resolution
  - High sensitivity
  - Complex: 12,000 avalanche photodiodes and associated electronics

Nucl. Instrum. And meth. Volume 571, Issues 1-2, (2007), Pages 81-84

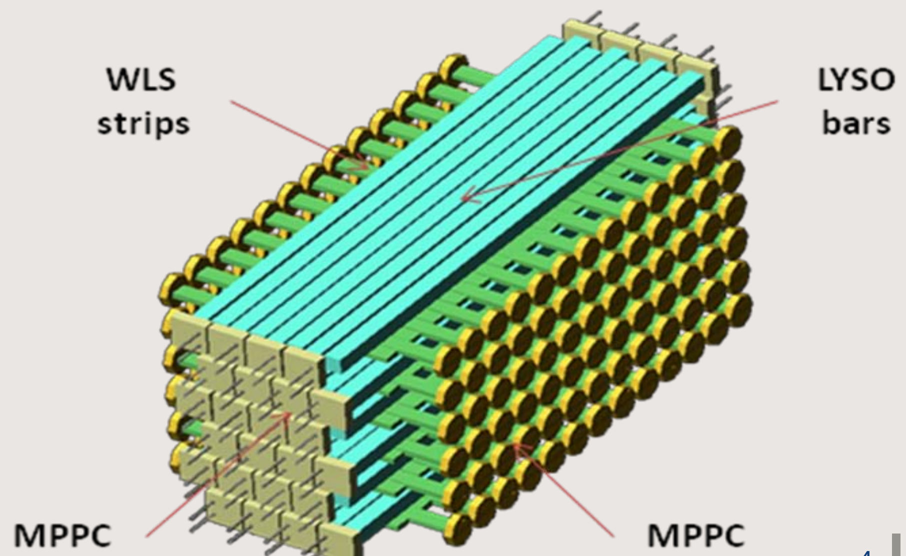
Reducing complexity by optical multiplexing

- R&D by UC Davis group using Wavelength shifting bars
  - $2 \times 2 \times 20$ mm^3 LYSO crystals
  - $2 \times 2 \times 20$ mm^3 WLS bars



H. Du, Y. Yang, and S. Cherry
Phys. Med. Biol. **53 (2008) 1829–1842**

- Large prototype by AXPET collaboration
  - $3 \times 3 \times 100$ mm^3 LYSO crystals
  - $0.9 \times 3 \times 40$ mm^3 WLS bars
  - Detector being tested

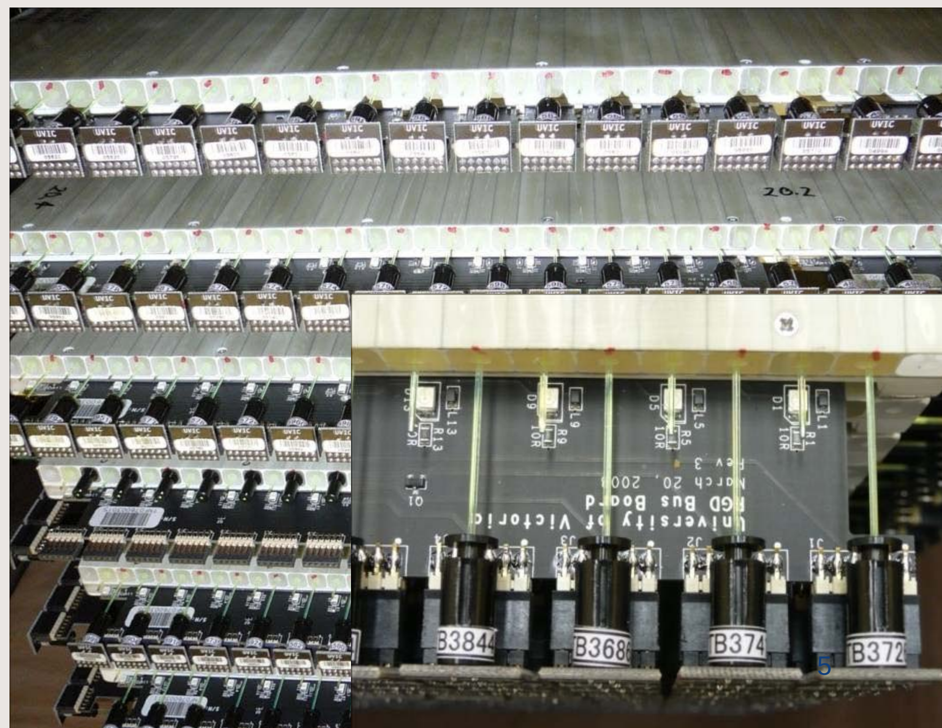


See previous talk

Where we are coming from

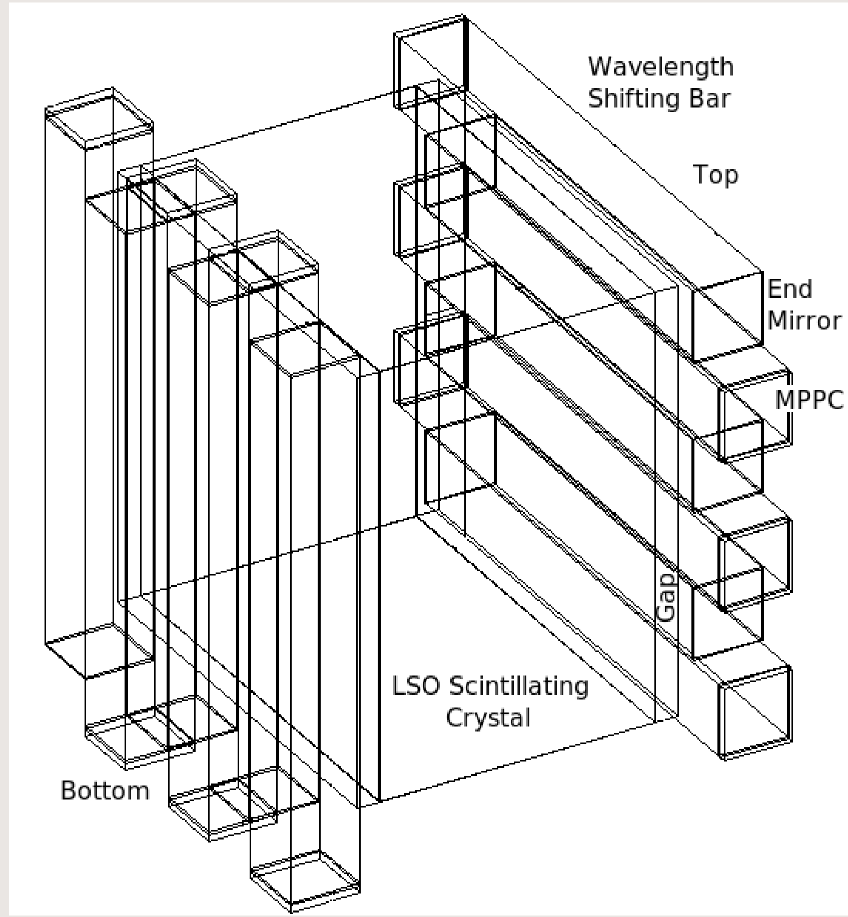
U. British Columbia, Kyoto U., U. Regina,
TRIUMF, U. of Victoria

- T2K Fine Grained Detector
  - 2x2x0.3 m3 detector
  - Plastic scintillator + wavelength shifters
  - Readout by 8448 1.3x1.3 mm2 MPPC

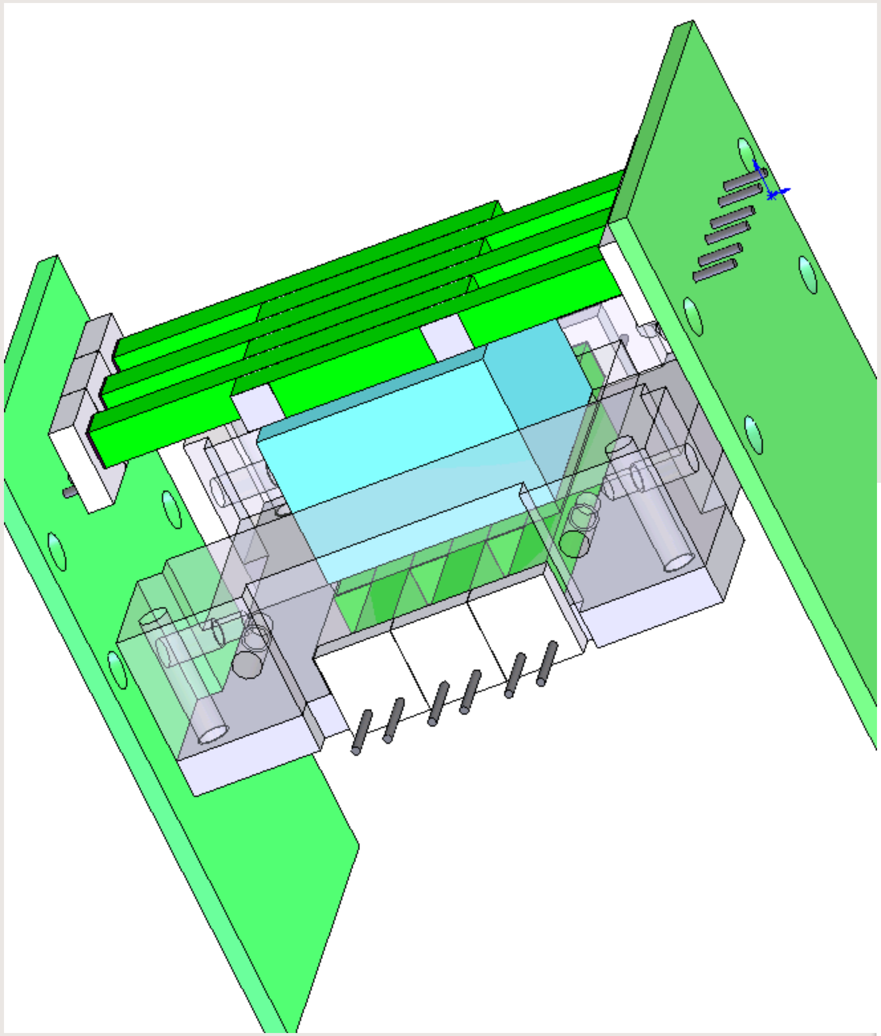


Optical multiplexing

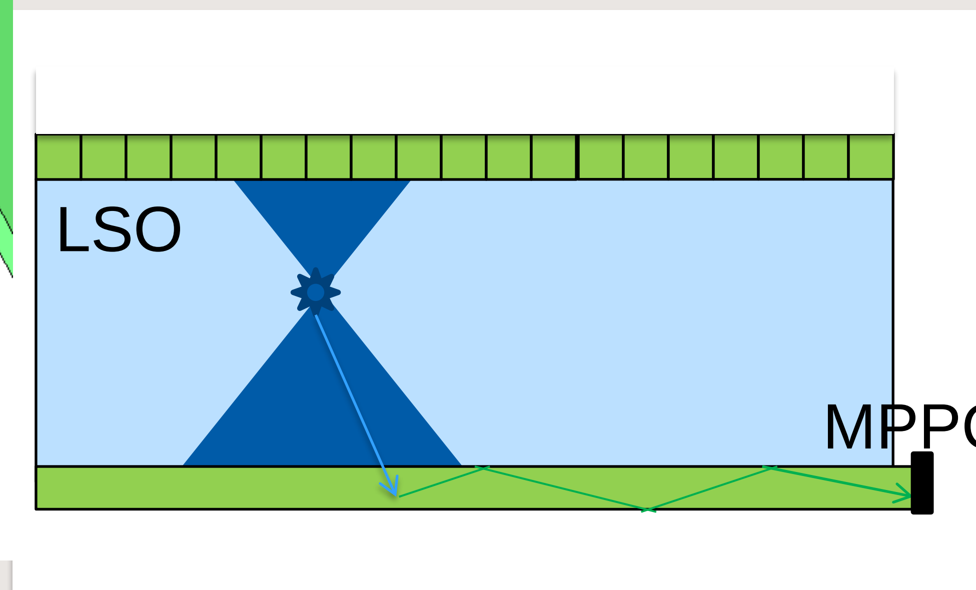
- Sandwich LSO/LYSO crystals between wavelength shifting bars readout by MPPCs
  - 3 × 3 mm^2 cross section WLS bar and MPPC
- Solution pays off for large area:
  - 12 channels for 18 × 18 mm^2 wide crystal
    - 27 mm^2/ch (49 mm^2/ch for multiplexed uPET)
  - 96 channels for 144 × 144 mm^2 wide crystal
    - 216 mm^2/ch



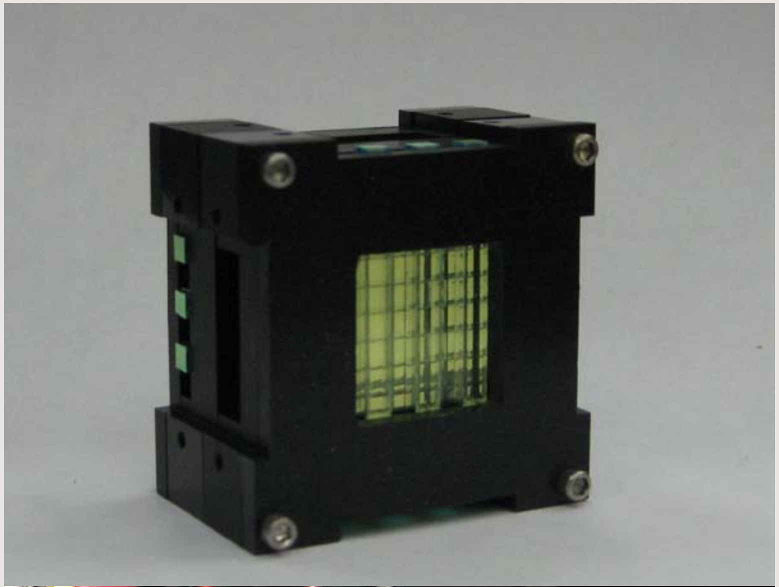
monoPET concept

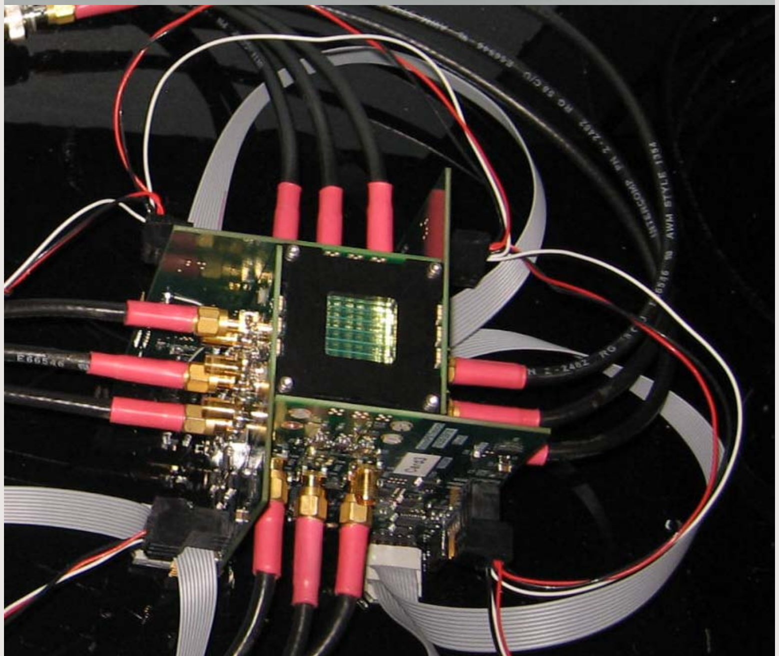


- Reconstruct 3D position by likelihood method
  - Based on pre-simulated points within a 1 mm spacing grid



monoPET prototype

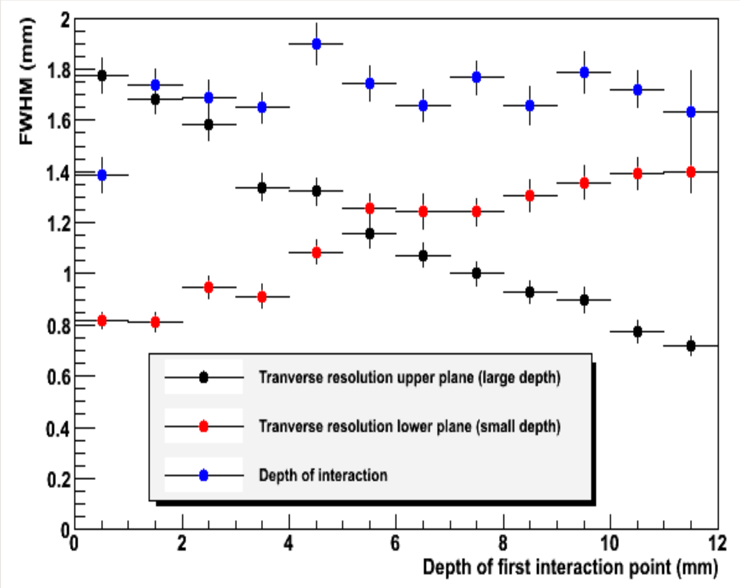


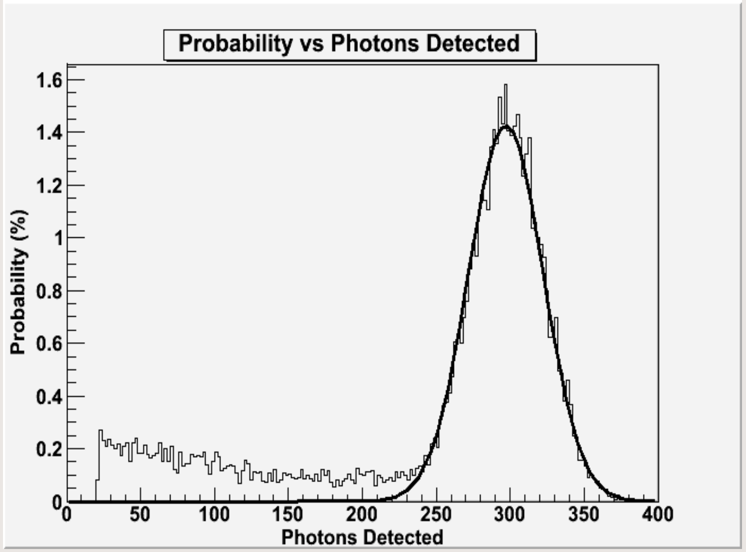


- 1 Monolithic LSO crystal, $18 \times 18 \times 12$ mm^3
- 6 WLS bars (BCF92) on each side, $3 \times 3 \times 25$ mm^3
- 12 MPPCs, 3×3 mm^2, 50 mm pitch
- Custom analog electronics
  - 1.6 GHz low noise differential amplifier
    - LTC6401-26
  - Slow control from T2K
    - On-board charge pump
    - Extensive control and monitoring
- Backend electronics, CAEN V1720, 250 MS/sec digitizer

monoPET simulations

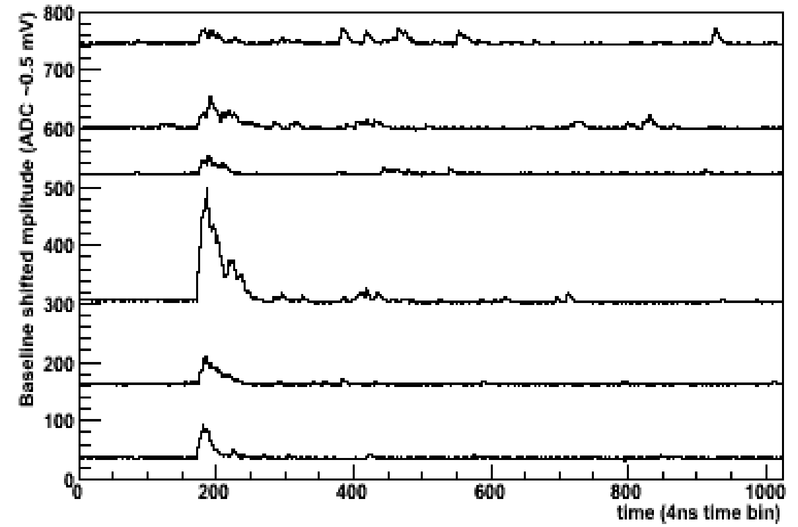
- Good photon collection expected
  - Ok energy resolution (20% FWHM)
- Develop algorithm for 3D position reconstruction
  - Based on matching expected charge pattern on the 12 bars with measured pattern
  - Position resolution < 2 mm
- However, resolution is limited by Compton scattering
  - Cannot resolve individual interactions

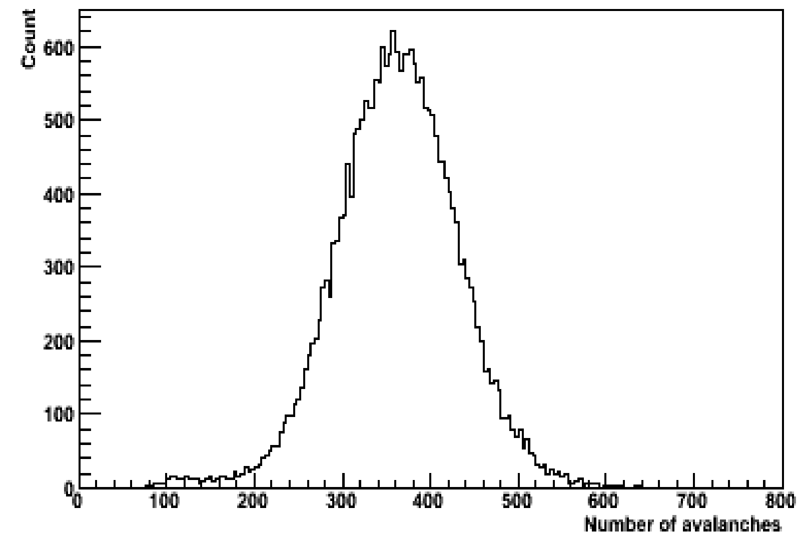




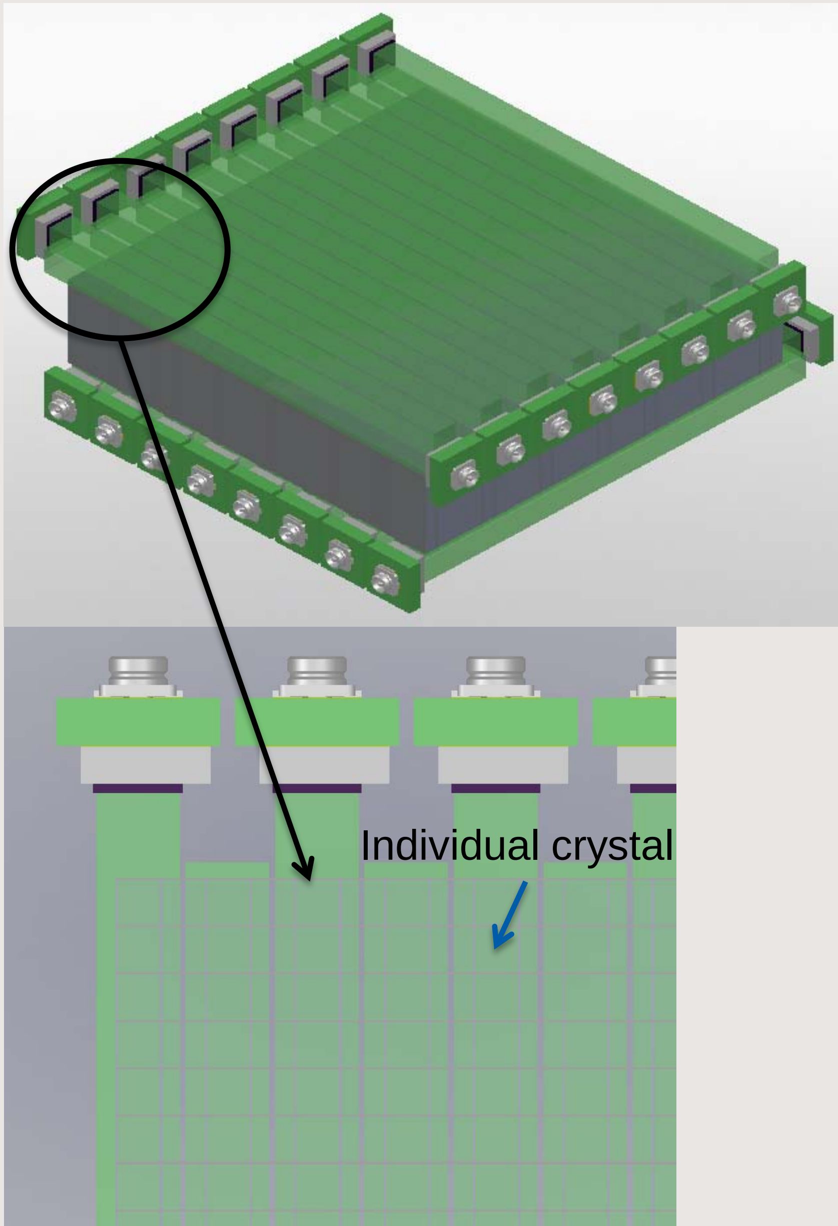
monoPET data

- Good photon collection
  - Match expectation from simulations
- However, large channel to channel variation in photon collection efficiency
  - Difficult to calibrate
    - Location of interaction unknown
    - Most of the bars fire for each events
  - Need a specific calibration system
    - E.g. Light injection

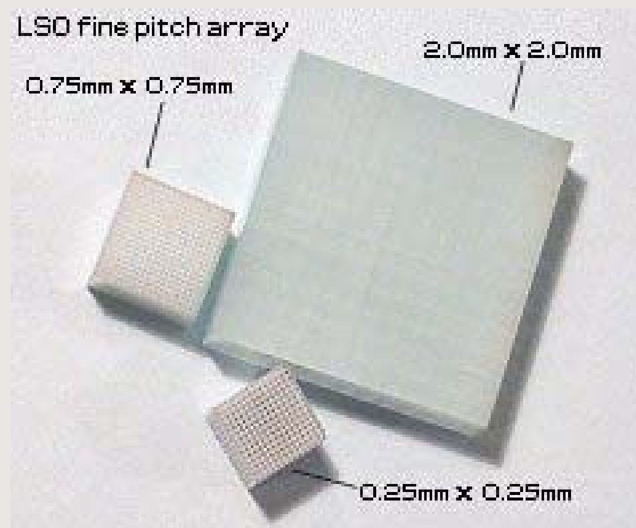




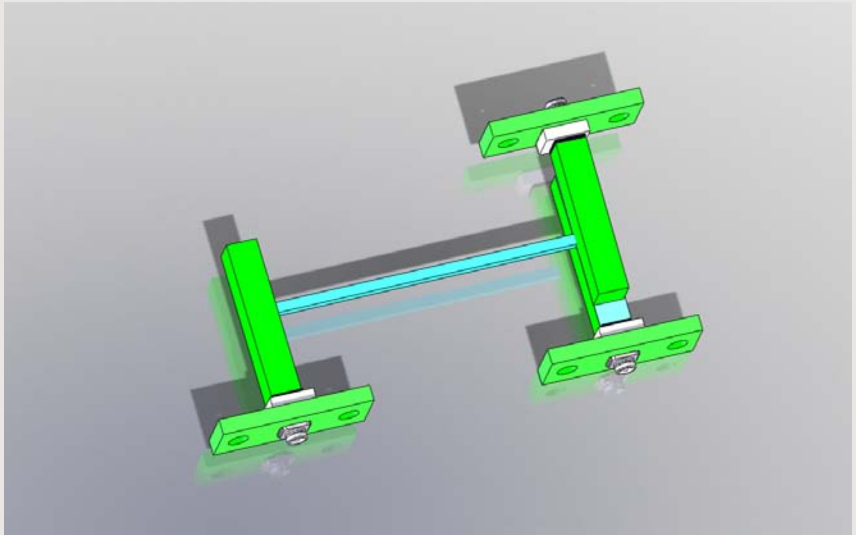
WavePET concept

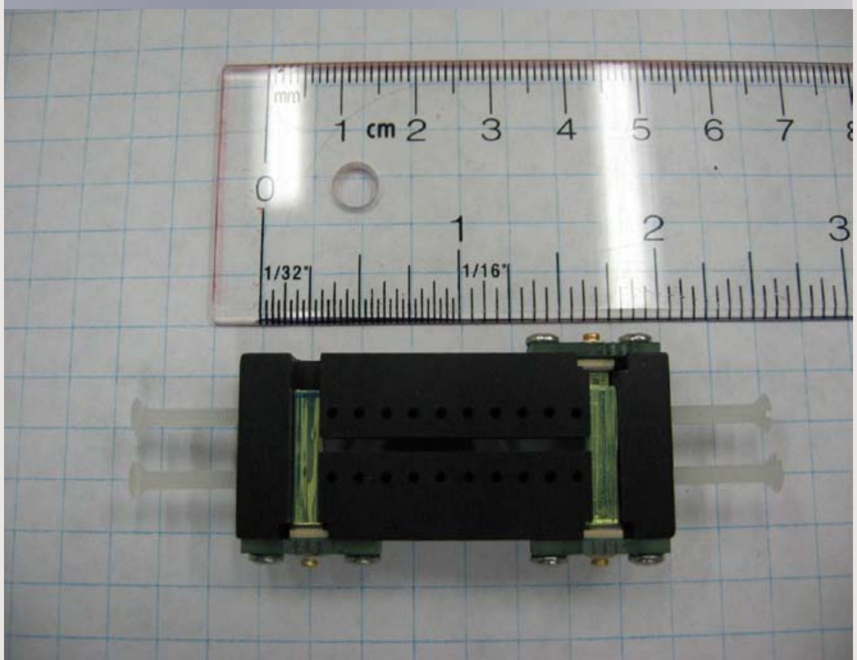


- 1.5 × 1.5 × 20 mm^3 crystals separated by reflective material
- On each side, light collected by 1 or 2 bars
  - Use 511 keV peak for light collection calibration
- Depth of interaction by comparing light measured on both sides
  - Require attenuation or redistribution of light in a way that depends on the DOI
  - Need R&D



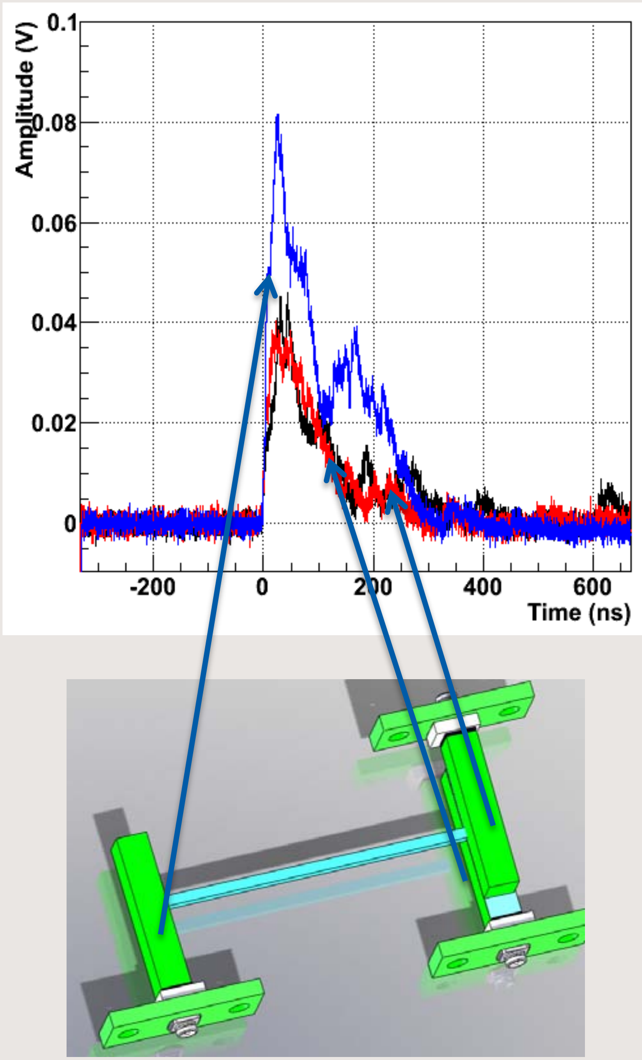
Testing wavePET concept

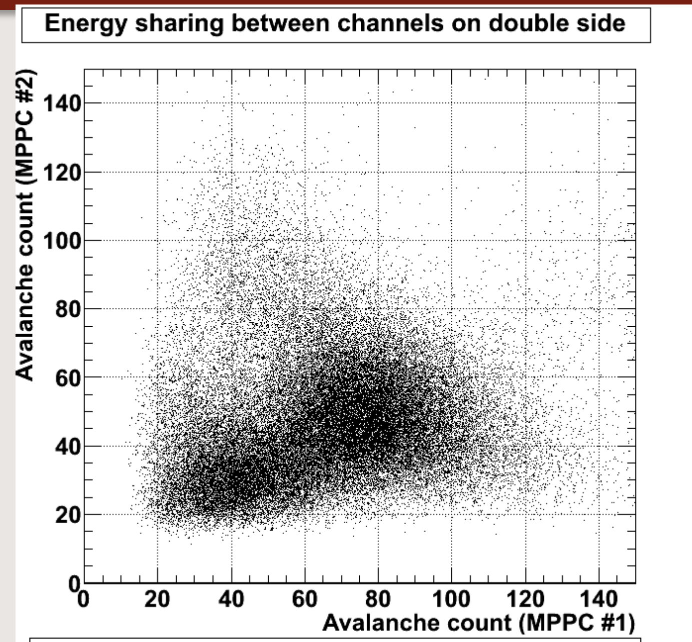


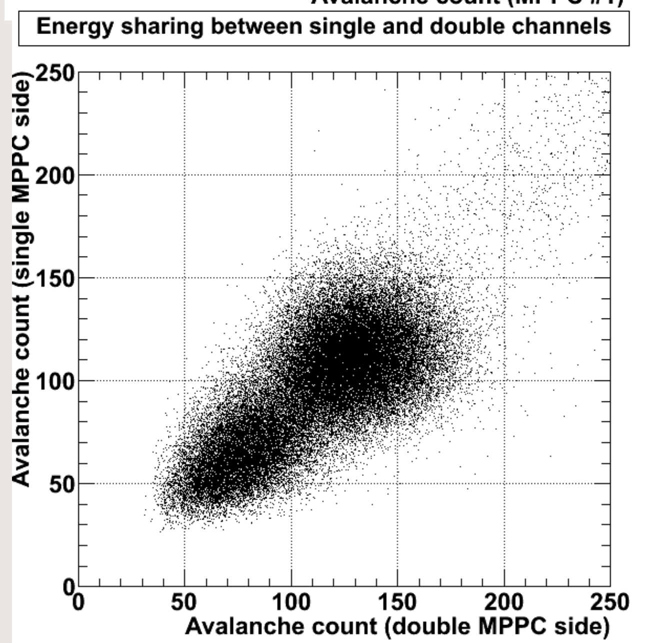


- $1.5 \times 1.5 \times 30$ mm^3 LSO
  - 1 side centered onto 1 WLS bar
  - Other side, crystal exactly in between 2 WLS bar
  - 30 mm is a bit long but that's what we had around
- Mating piece for trigger definition

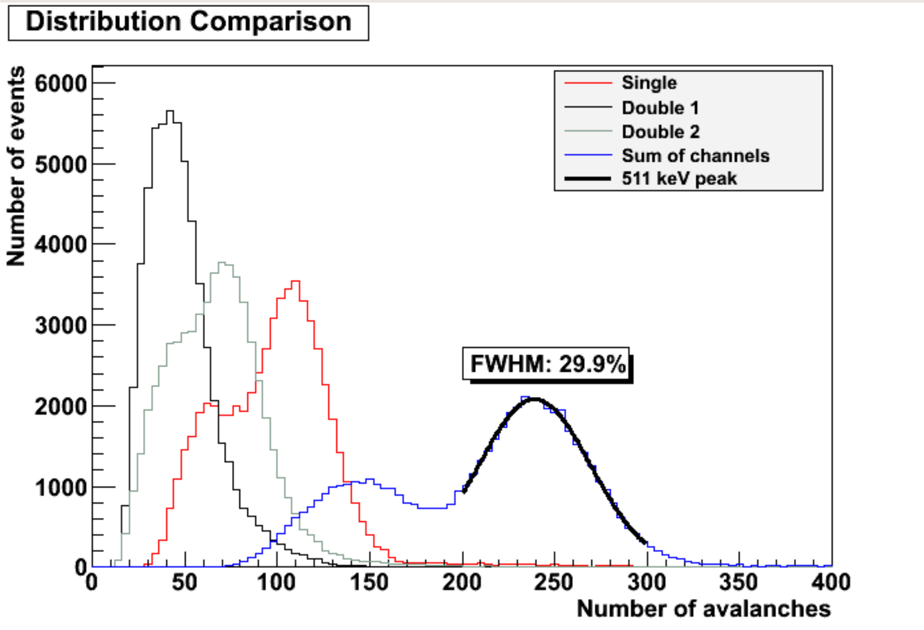
WavePET light collection





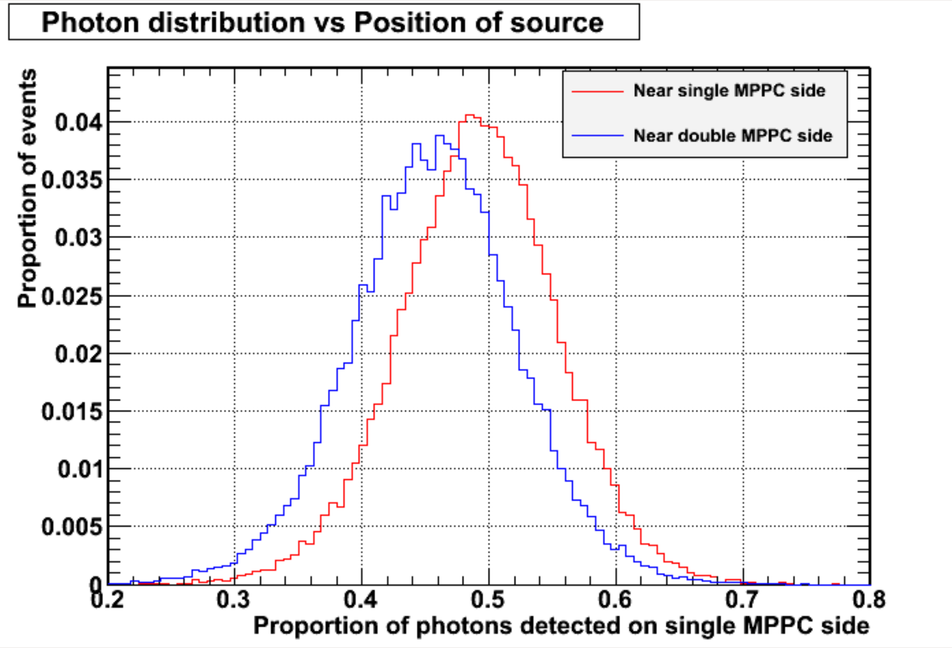


Energy resolution



- 511keV peak visible for the centered bar
  - Will be used for channel to channel calibration
- Why is the energy resolution so poor?
  - Should be significantly better
  - Large excess noise factor?
    - Need quantitative study

Depth of interaction and timing resolution



- Small variation of the light distribution between both sides
  - Expected because polished crystal
- Width of the distribution is large
  - Worrisome because it will drive the resolution
  - Need improvement in energy resolution
- Timing resolution better than 2 ns (sigma)
  - Work in progress

Next steps

- Improve photon collection in single crystal prototype
  - Improve alignment
- Understand what drive the energy resolution
  - Run full simulation GEANT4 + MPPC simulations
  - Current hypothesis, correlated noise (cross-talk and after-pulse) is significant
- Build a small scale detector (2011)
  - LSO Crystal $18 \times 18 \times 10$ mm^3 with 1.5 mm pitch elements
    - 3M ESR reflector. Expect poor DOI resolution but optimum photon collection
    - Toray diffusive reflector. Hoping to achieve a good compromise between DOI and energy resolution
  - Readout by $2.9 \times 2.9 \times 150$ mm^3 WLS bar (BCF92) and 3×3mm^2 MPPC
    - Test attenuation in long bars
- Build a $14.4 \times 14.4 \times 2$ cm^3 prototype in 2012
  - Estimated cost: 100k$ per plane

Summary

- Towards a lost cost planar detector using wavelength shifters
- Monolithic solutions
  - Pros:
    - Build in DOI
    - Cheapest solution
  - Cons:
    - very tight alignment or calibration requirement
    - Smearing due to Compton interaction
    - Edge effect
- Pixalized solution
  - Pros:
    - Build in calibration scheme
    - “transverse” resolution deifne by crystal size
  - Cons:
    - DOI not guaranteed
    - More expensive
- For both solution, must understand what drive resolutions

TRIUMF: Alberta | British Columbia | Calgary
Carleton | Guelph | Manitoba | McMaster
Montréal | Northern British Columbia
Queen's | Regina | Saint Mary's
Simon Fraser | Toronto | Victoria | York

Thank you!
Merci!