A Large Liquid Scintillator Detector

Ken Heller & Keith Ruddick + University of Minnesota group

Goals

Identify ν_e charged current events

Not neutral current

Not ν_μ charged current

Electron identification

π^o rejection

π^{+-} rejection

Muon identification

Cost of about $30M for a 20 kT detector

Inexpensive

active detector

material

electronics

structure

Why Liquid Scintillator

- **Inexpensive active detector**
  - **Mineral oil (tanker deliveries) $2.75/gallon**
  - **Pre-mixed fluors ($2300/55 gallon diluted @ 20:1 for BC517L) $2.09/gallon**
  - **Total is $5.75/gallon <u>$1.65M / kTon</u>**
- **Easy to fabricate**
  - **Mix**
  - **Pump into container at site**

Possible Designs

- Liquid scintillator, steel plates, air gaps
  - **Engineering design: Border et al, NIM A 463, 194-204 (2001)**
- Liquid scintillator and taconite
- Liquid scintillator and water
- All liquid scintillator
  - **Attenuation length 5 m**
  - **MiniBooNE**

Monte Carlo optimization studies to follow
Northwestern group

Example Design

- **Liquid scintillator + wavelength shifting fiber**
- **Signal into image intensifier tube (gain = 10^6, QE = 12%)**
- **Read out with digital TV camera**
- **Mass from water (15 cm between each scintillator plane, X_{rad} = 1/3)**
- **Water and scintillator held in PVC extrusions**

Mechanical design – MINOS engineering study
Scintillator/fiber design – MINOS engineering study
Readout design – updated DONUT

Scintillator Elements

30 wls fibers to a manifold ($ 1.5 /m)

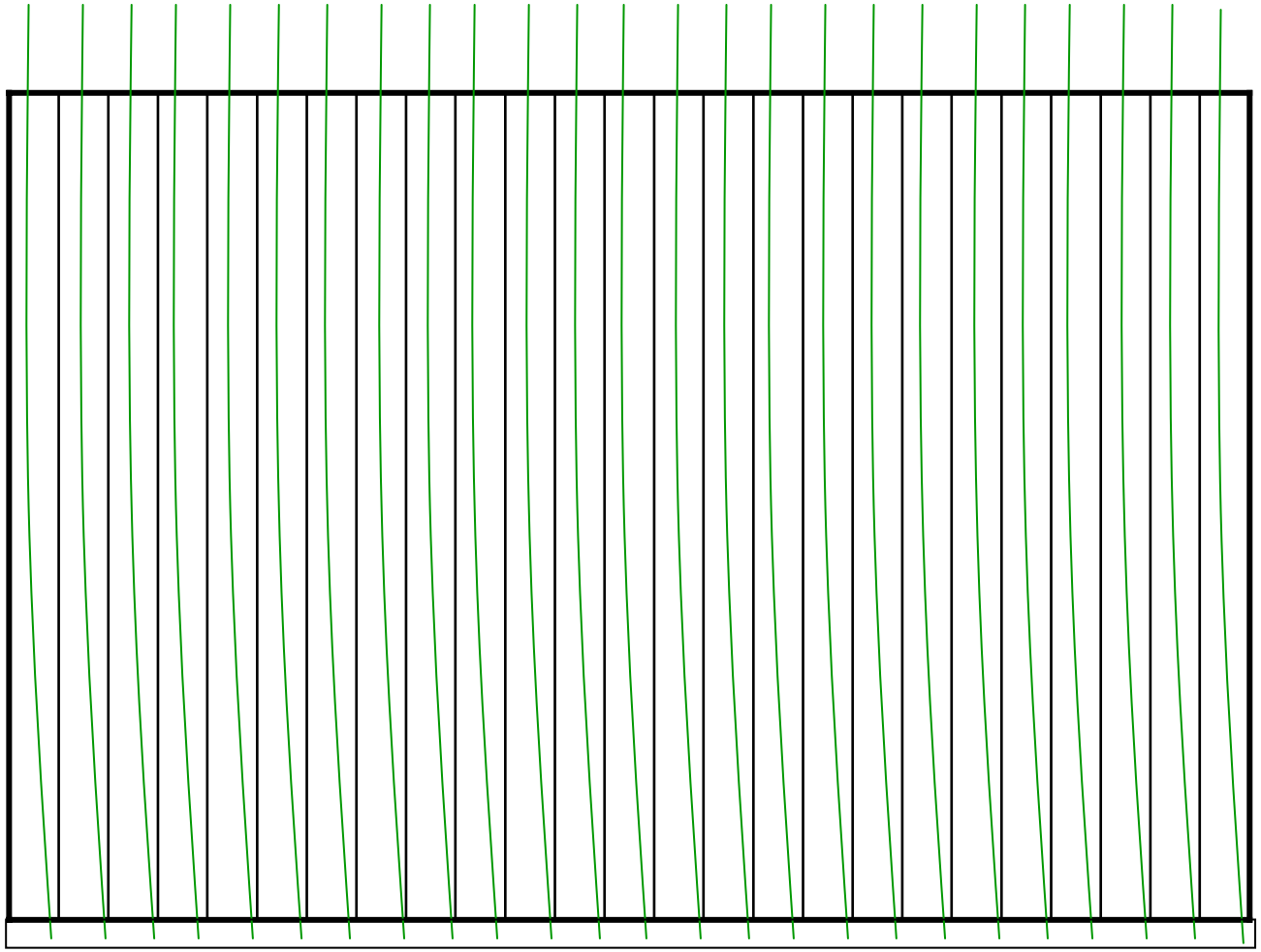
Extruded PVC

$0.41 M / kton
$0.20 /lb

Engineering designs exist

- **Extrusions**
- **Bottom seals**
- **Top manifolds**
- **Machines for fabrication**

2 Mechanical Engineering Masters Theses



10 m

3.3 cm

1 mm fiber gives 40 photons at far end for minimum ionizing particle

Detector

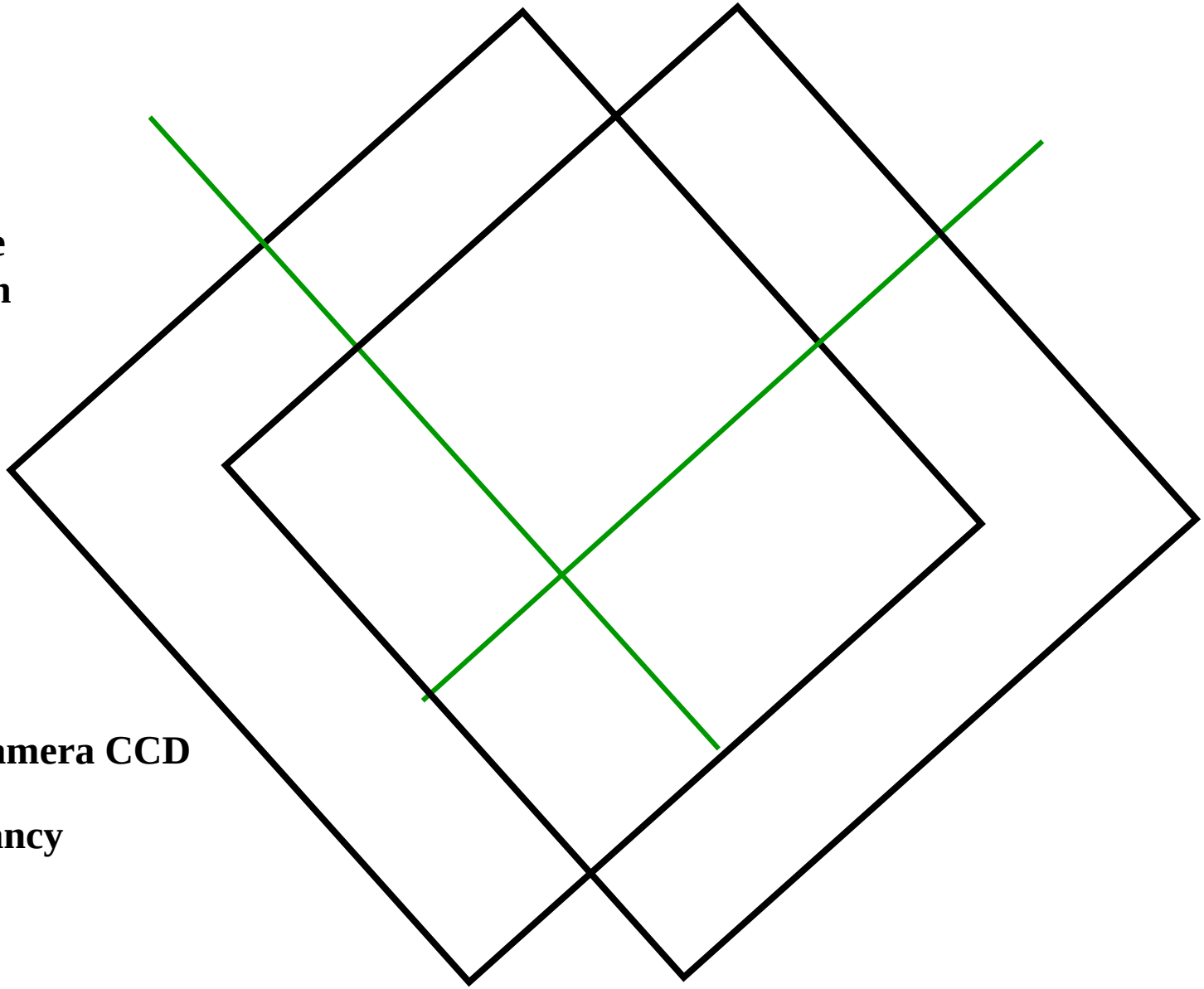
Alternate plane uv readout from top
300 cells/plane

2 planes into 1 Image Intensifier (600, 1mm fibers per 25mm II) ($4K/II including II, optics, CCD camera)

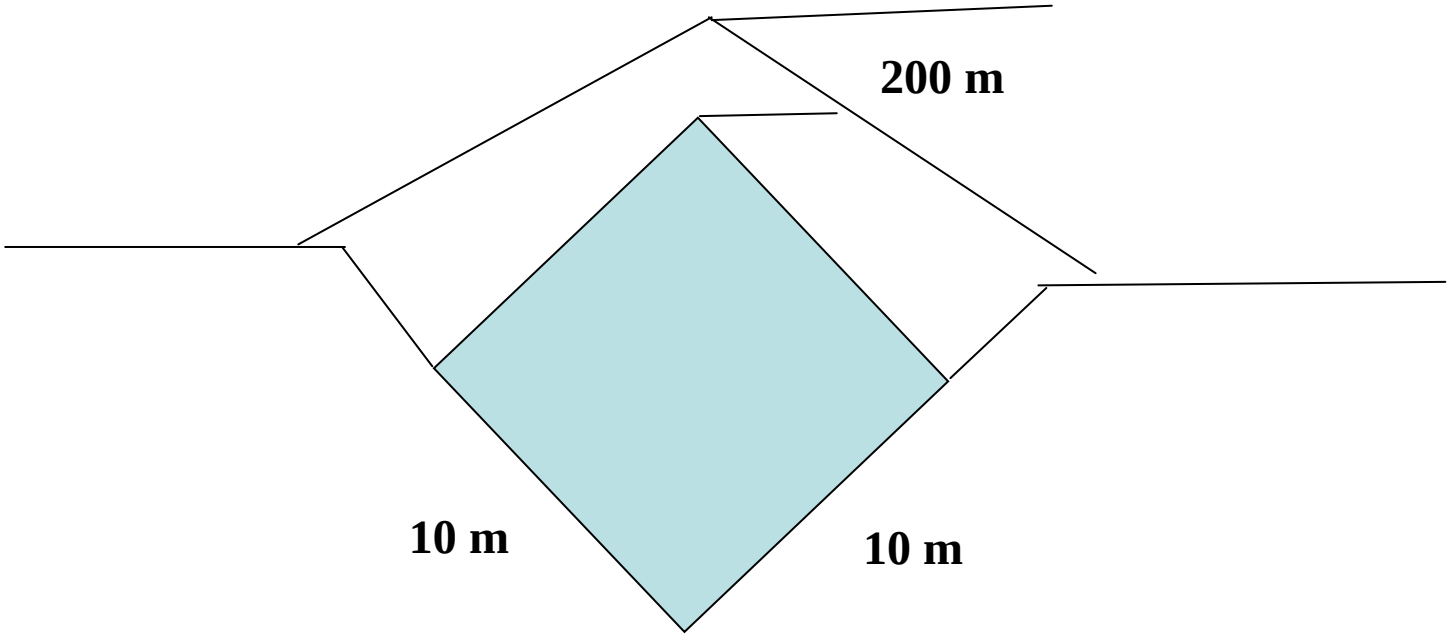
Cosmic ray rate
300 Hz/cell

100 μsec gate TV camera CCD

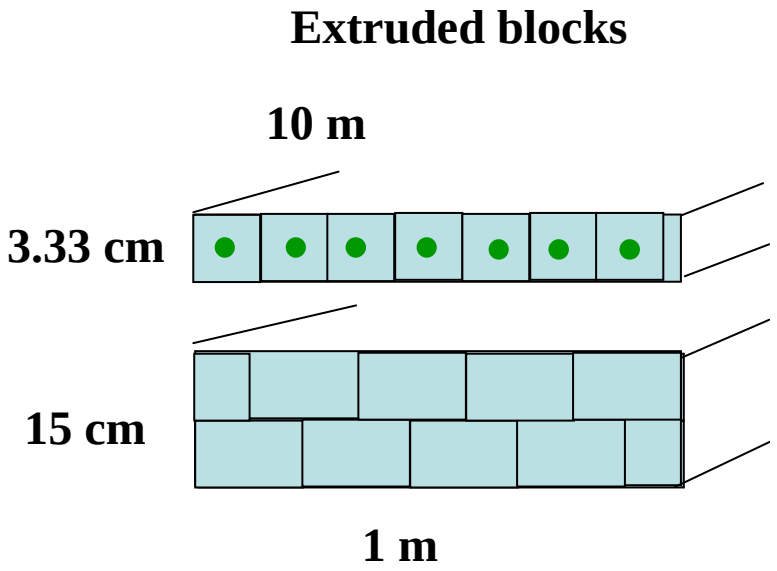
3% occupancy



Structure



- **On the surface, cut and cover**
  - **Handle Cosmic Ray rate**
  - **Can cover with fill**
- **Self supporting elements**
  - **Fill extrusions in place**



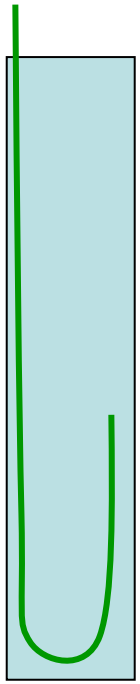
Costs – Scintillator + mass

- **4.4 kTon scintillator** **$7.3 M**
- **PVC extrusions** **$7.0 M**
- **WLS fibers** **(4×10^5)** **$6.0 M**
- **Manifolds** **(13333)** **$1.3 M**
- **Clear fibers & connectors** **$3.1 M**
- **Read out** **(1333 planes, $2K/plane)** **$4.5 M**
- **Water (or taconite)** **(15 cm H_2O = 0.3 X_{rad})** **$0**
- **Assembly** **(8 man hrs/plane)** **$2 M**
- **DAQ & electronics** **$0.3 M**

Total **$ 31.5 M + Structure**

Cost Savings Options

- **Reduce fiber diameter in half (0.5 mm)**
  - **Fiber cost goes as r^2**
  - **Image intensifier cost goes as r^2**
  - **Light goes as r**
- **Recover photons from far end with J (more uniform response but add 50% more fiber)**



• 4.4 kTon scintillator	$7.3 M
• PVC extrusions	$7.0 M
• WLS fibers (4×10^5)	$2.3 M
• Manifolds (13333)	$1.3 M
• Clear fibers & connectors	$1.5 M
• Read out (1333 planes, $0.5K/plane)	$1.3 M
• Water (or taconite) (15 cm H_2O = 0.3 X_{rad})	$ 0
• Assembly (8 man hrs/plane)	$2 M
• DAQ & electronics	$0.2 M
Total	**$ 23 M + Structure**

Summary

- **Liquid scintillator has the right properties for the off axis detector**
  - **Good energy resolution**
  - **Good time resolution**
  - **Easy to assemble**
  - **Known technology, stable operation**
  - **Simple electronics**
  - **Low cost**
  - **Flexible geometry**
  - **Ready for beam in 2005**

A cheap, low risk detector

Modern Photonics Options

- **Devices with 80% QE**
  - **Direct CCD readout**
  - **VLPCs**
  - **APDs**

Direct CCS readout

Noise (cooled) 15 electrons/pixel
Pixel size (off the shelf) 24μm

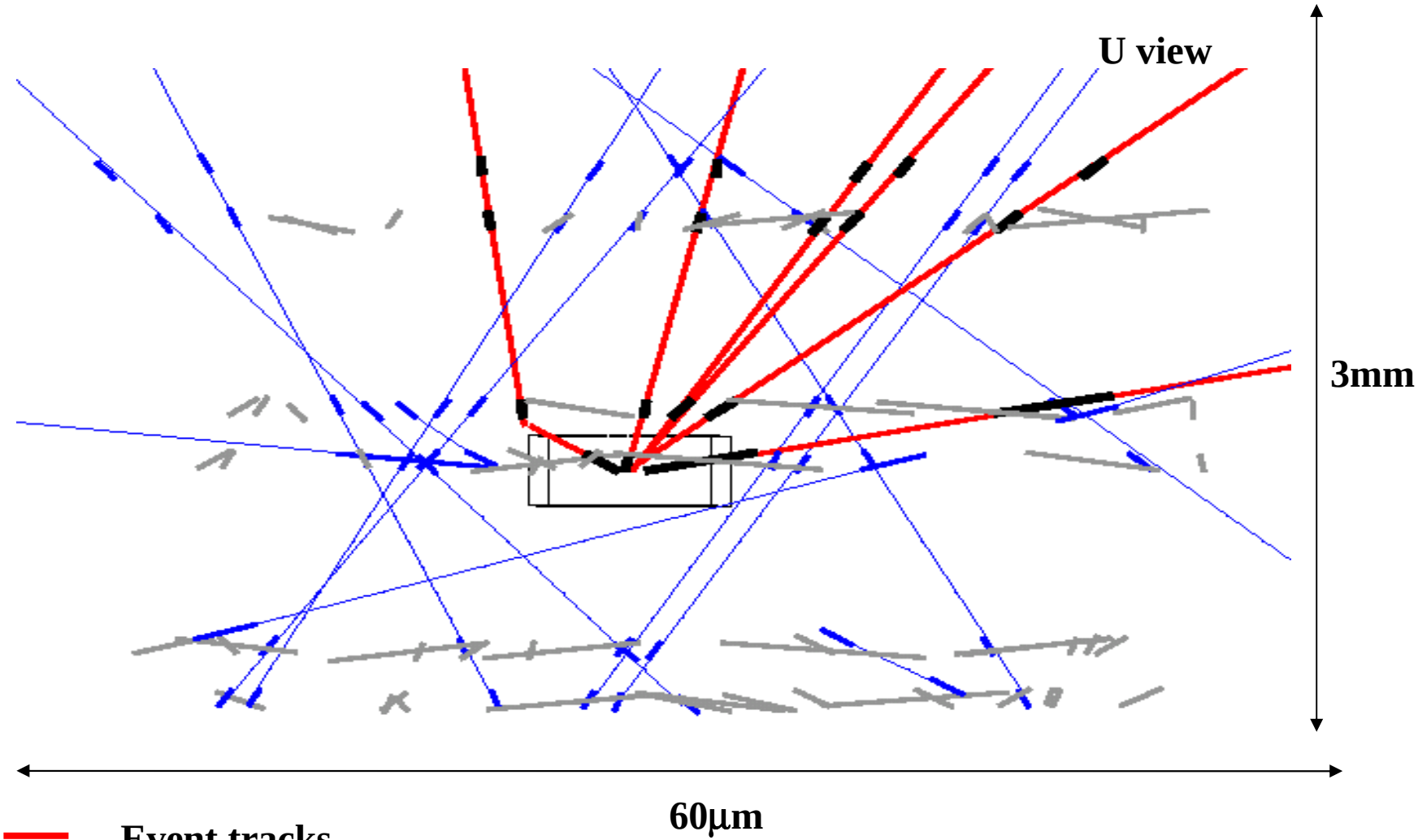
Photoelectrons from 1 mm fiber = 32 pe into (50 x50)
Get 2 x more photons/fiber end with U & reduce fiber radius by 4
250 μm fiber = 32 pe into (10 x 10)
Need optical demagnification by 10

A Far Out Option

A liquid scintillator “bubble chamber”

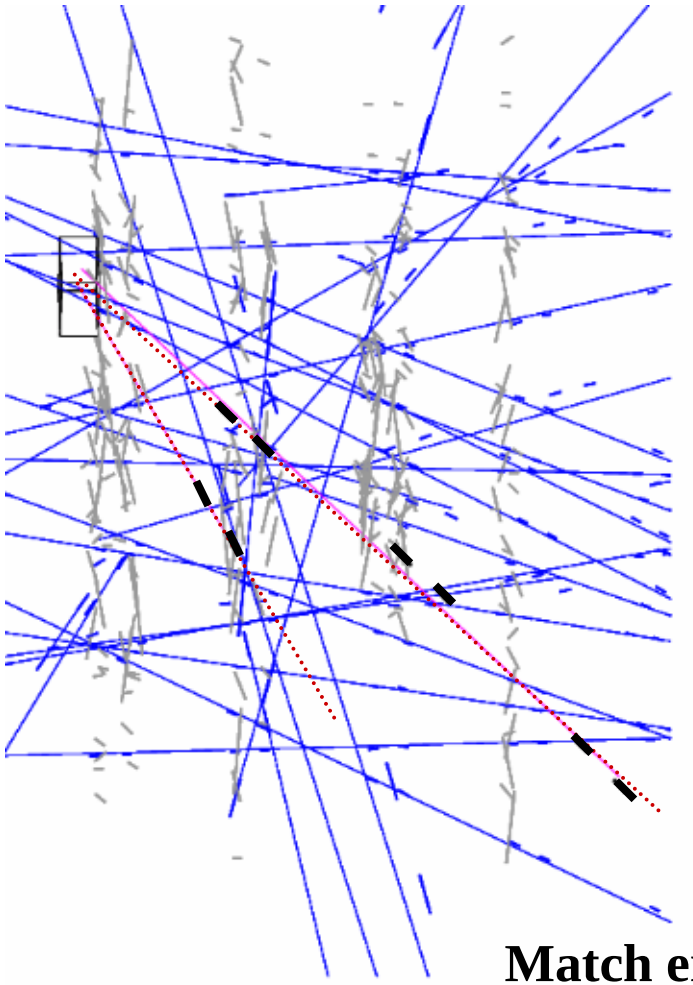
- **20 kTon of liquid scintillator ($33M)**
  - **Use PXE based for 2 x light**
- **Read out 3 – D image of event with optics and CCD cameras ($ 1M).**
- **Spherical container in the ground or several (MiniBooNE)**

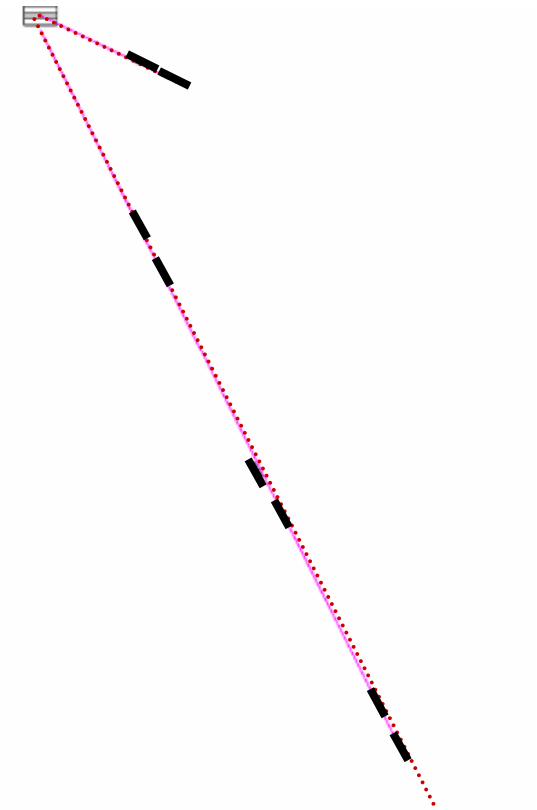
Finding Neutrino Events in High Occupancy – The Donut Experience



Event 3039-01910

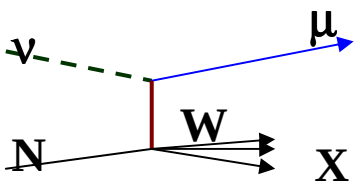
Simple Event

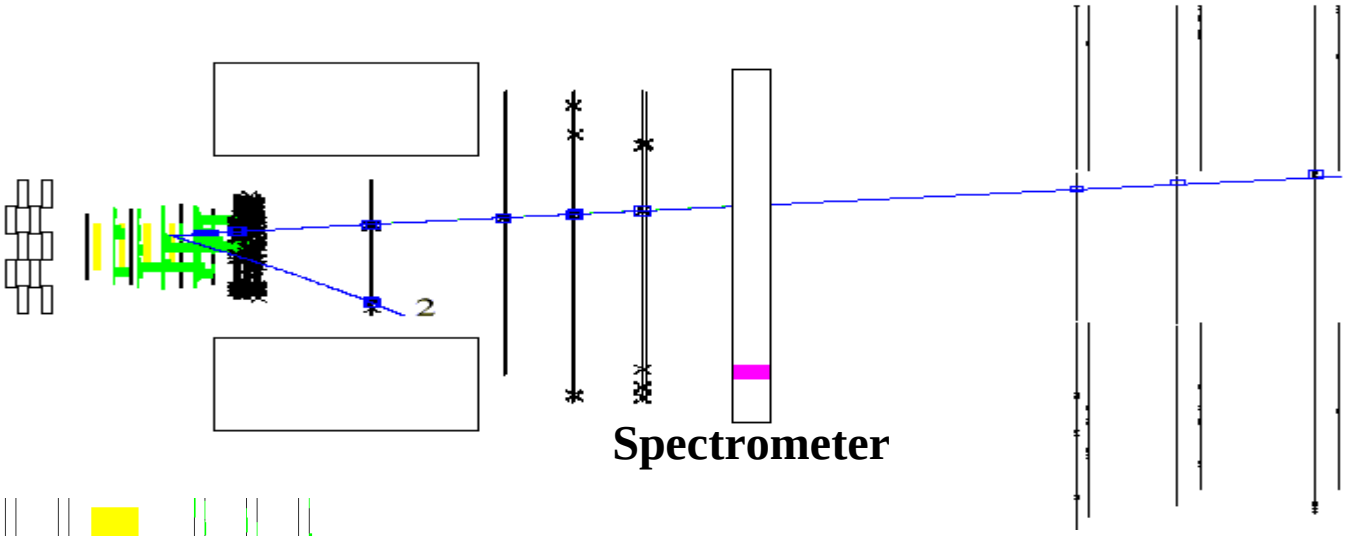




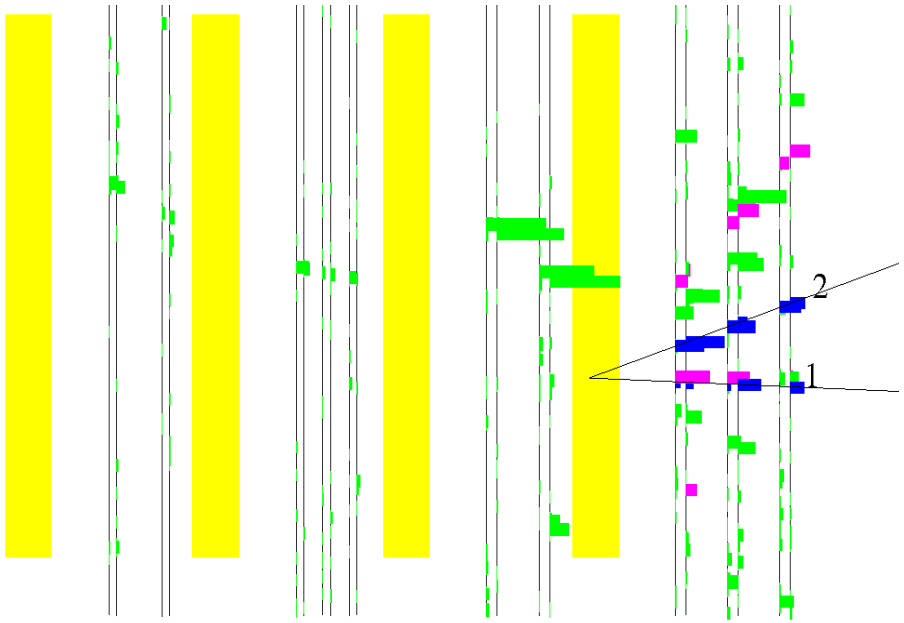
Match emulsion track in spectrometer

ν_μ Charged Current Interaction

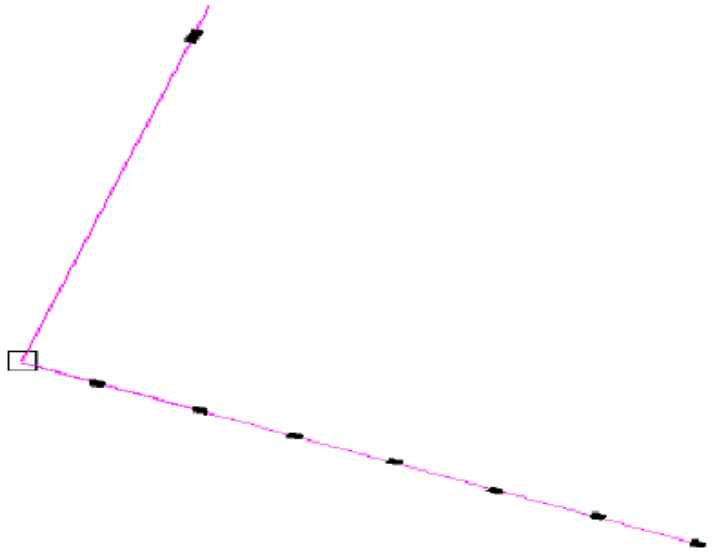




Spectrometer



Fiber tracker read out with image intensifier



In Emulsion

Conclusion

- **Liquid scintillator read out with wavelength shifting fiber into an image intensifier is an attractive candidate for a low cost 20 kTon fine grained calorimeter.**
  - **Well established technology**
  - **Stable operation**
  - **Easy to construct**
- **Cost is in range and cost savings may be possible.**