PLASTIC SCINTILLATOR DEVELOPMENTS: PAST, PRESENT AND FUTURE

Anna Pla-Dalmau and Alan D. Bross

PPD Mini-Review

October 6, 2009

OUTLINE

- Review of our early work in plastic scintillators
  - This phase was dominated by R&D work.
- Extruded plastic scintillators
  - FNAL-NICADD extrusion line – impact to the physics community
  - This phase is dominated by service work.
- Next generation → back to R&D:
  - What would be beneficial to have in plastic scintillators?

THE EARLY DAYS...

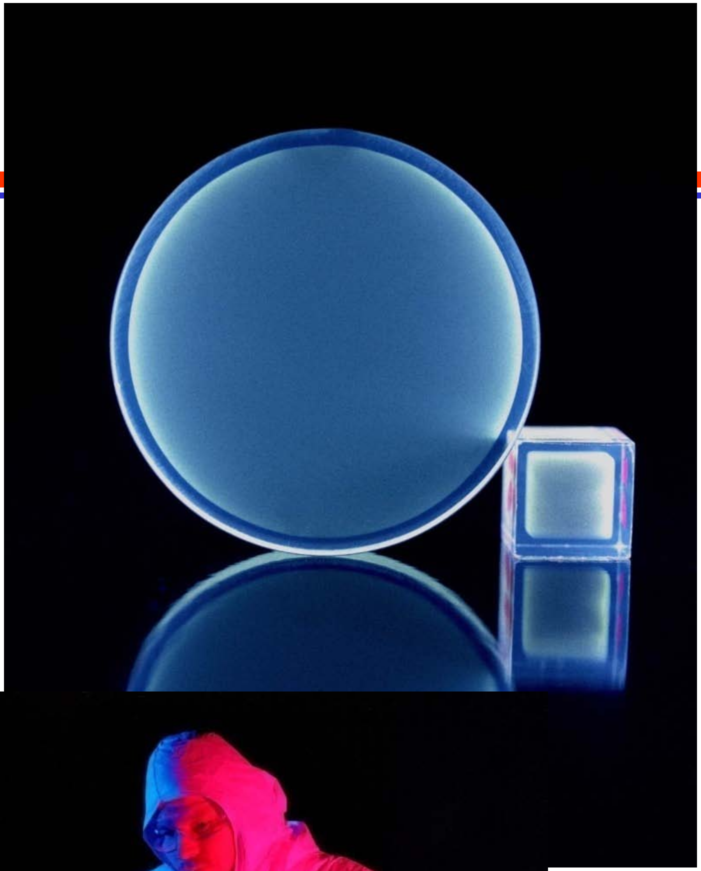
- Fermilab has a long history of work in plastic scintillators.

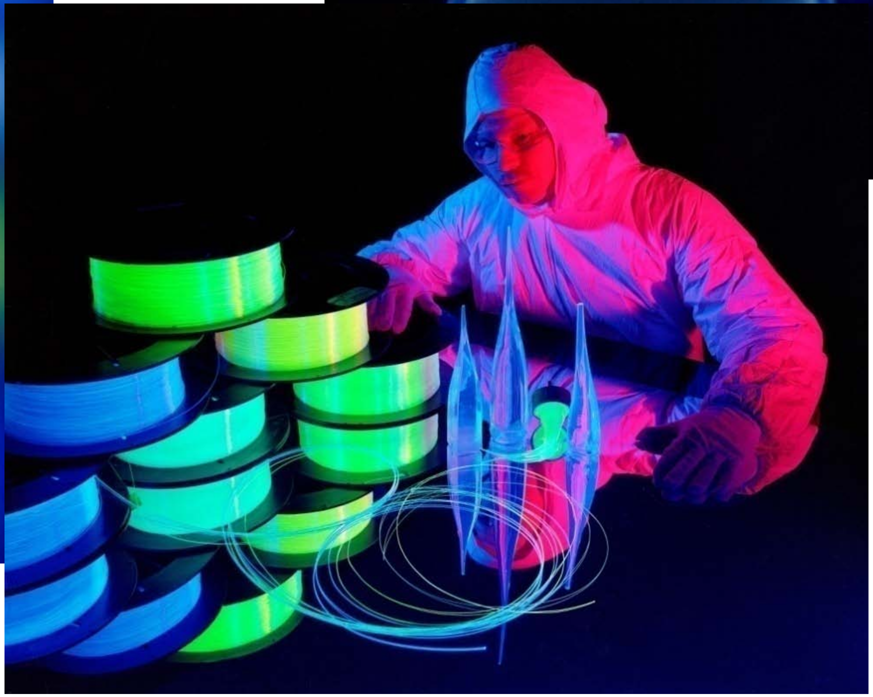
- Late 80’s and early 90’s:
  - Scintillating and WLS plastic optical fibers.
  - Scintillating tile and WLS fiber arrangements
  - Radiation damage studies
  - New fast, green dopants

SCINTILLATOR SUPPORT FACILITIES

- Plastic Scintillator has driven the development of significant infrastructure at Fermilab:
  - Thin-Film facility
    - Mirroring and coatings, photocathode work
  - CNC Routing
    - Tile-fiber detectors
  - Machine Development
    - Diamond polishing, optical connectors and VLPC packaging
  - Scintillation Detector Development (SDD) Laboratory
    - Plastic Scintillator R&D
    - Fiber production, characterization, and test
    - Extruded scintillator

THE EARLY DAYS…





WORK IN THE 90'S…

…was dominated by the economic concern that plastic scintillators were too expensive for large detectors – neutrino detectors:

➔OBJECTIVE:

USE LOW COST SCINTILLATOR

➔APPROACH:

NEW TECHNIQUE $\rightarrow$ EXTRUSION

EXTRUDED PLASTIC SCINTILLATOR

ADVANTAGES:

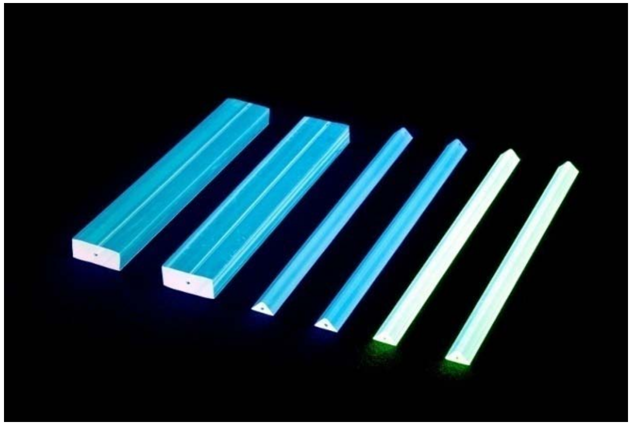
- Use commercial polystyrene (PS) pellets
  - No monomer purification problems
- Processing flexibility
  - Manufacture of essentially any shape

DISADVANTAGES:

- Poorer optical quality
  - Particulate matter in PS pellets
  - Additives in PS pellets

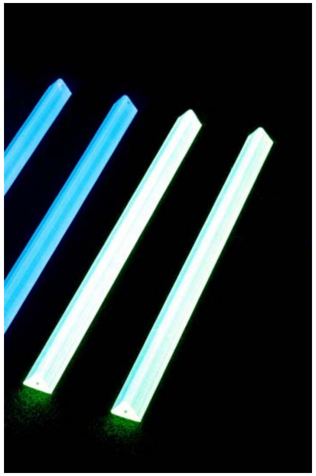
SOLUTION:

- **Use a WLS fiber**

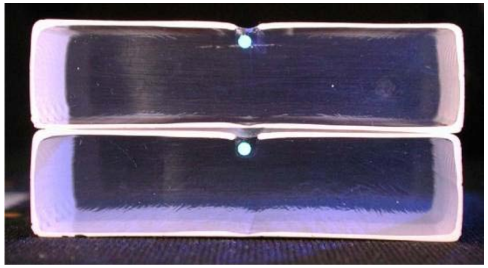


EARLY PROJECTS

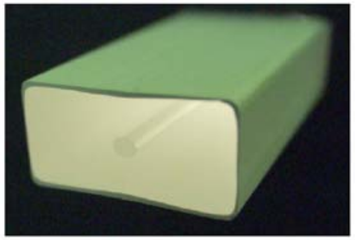
- D0 preshower detectors



- MINOS

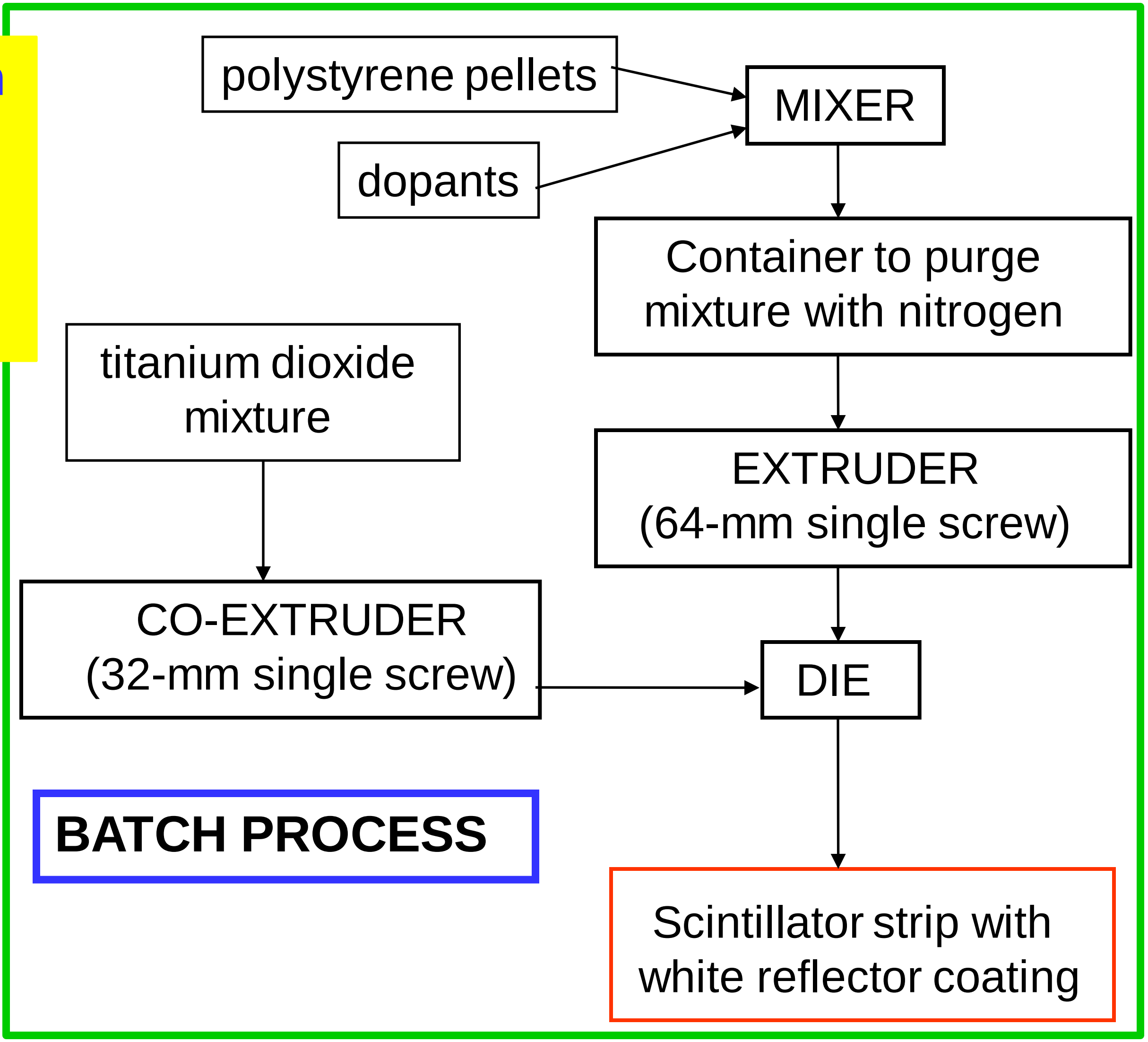


- SciBar – K2K/SciBoone
- Star
- Mayan Pyramid Mapping
  - UT-Austin



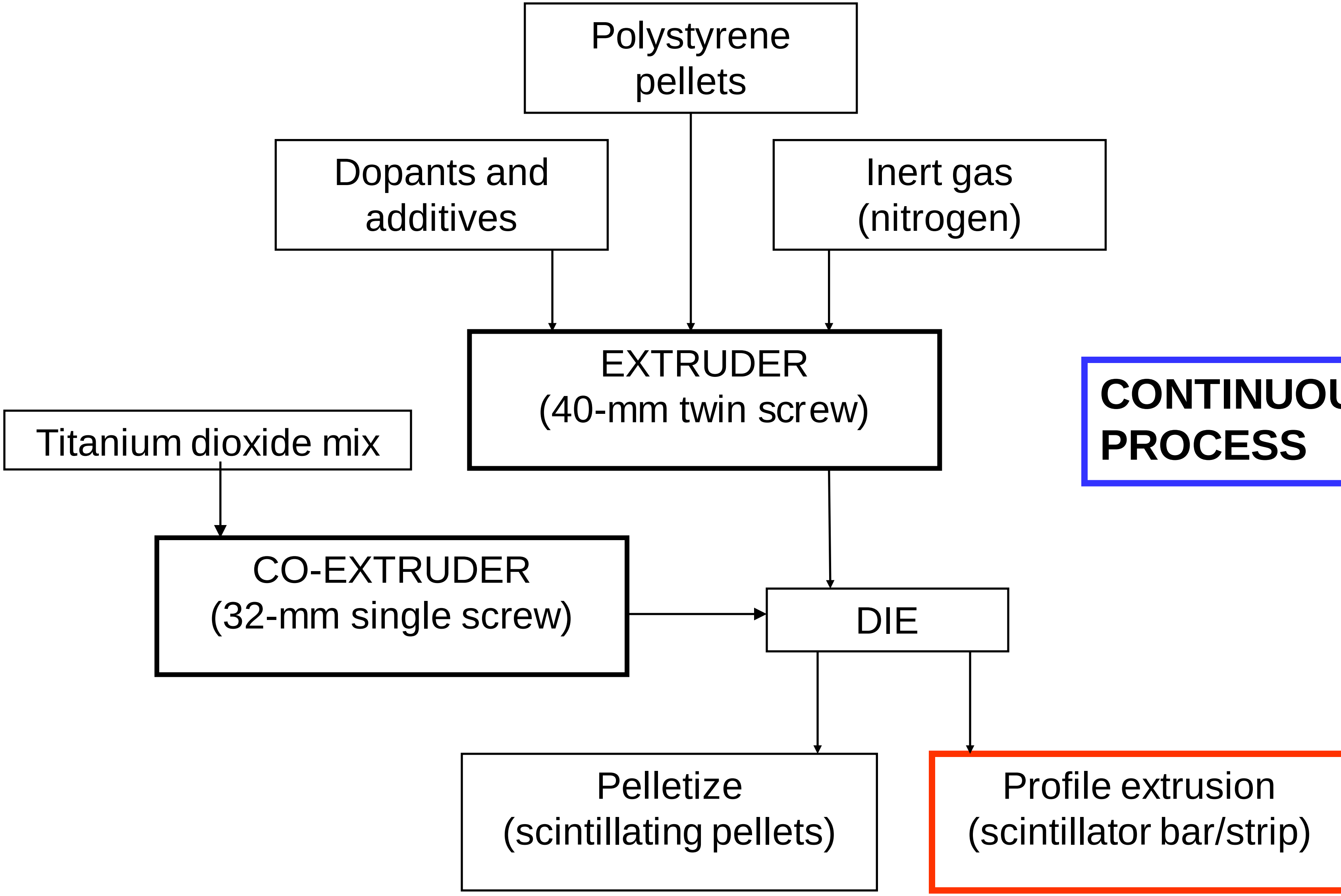
EXTRUSION NOT AT FERMILAB: MINOS, STAR, K2K… 1999 – 2003

Facilities/production techniques were not optimized for high quality scintillator production.



EXTRUSION AT ITASCA PLASTICS: PURGING STAGE, BATCH PRODUCTION

GOAL SINCE 1999: IN-LINE EXTRUSION



CONTINUOUS PROCESS

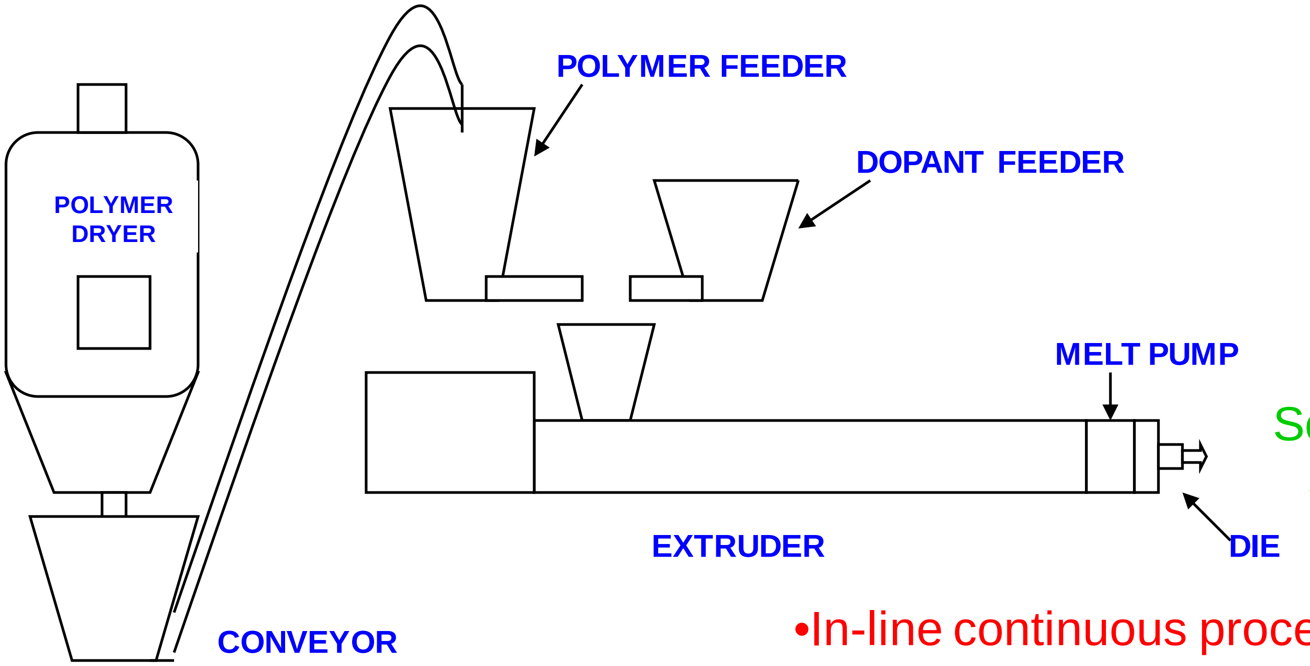
FNAL-NICADD EXTRUSION FACILITY

SINCE 2003

FNAL-NICADD EXTRUSION FACILITY

FNAL-NICADD EXTRUSION FACILITY

FNAL-NICADD EXTRUSION FACILITY



OUTPUT:

Scintillating pellets
Scintillator bars

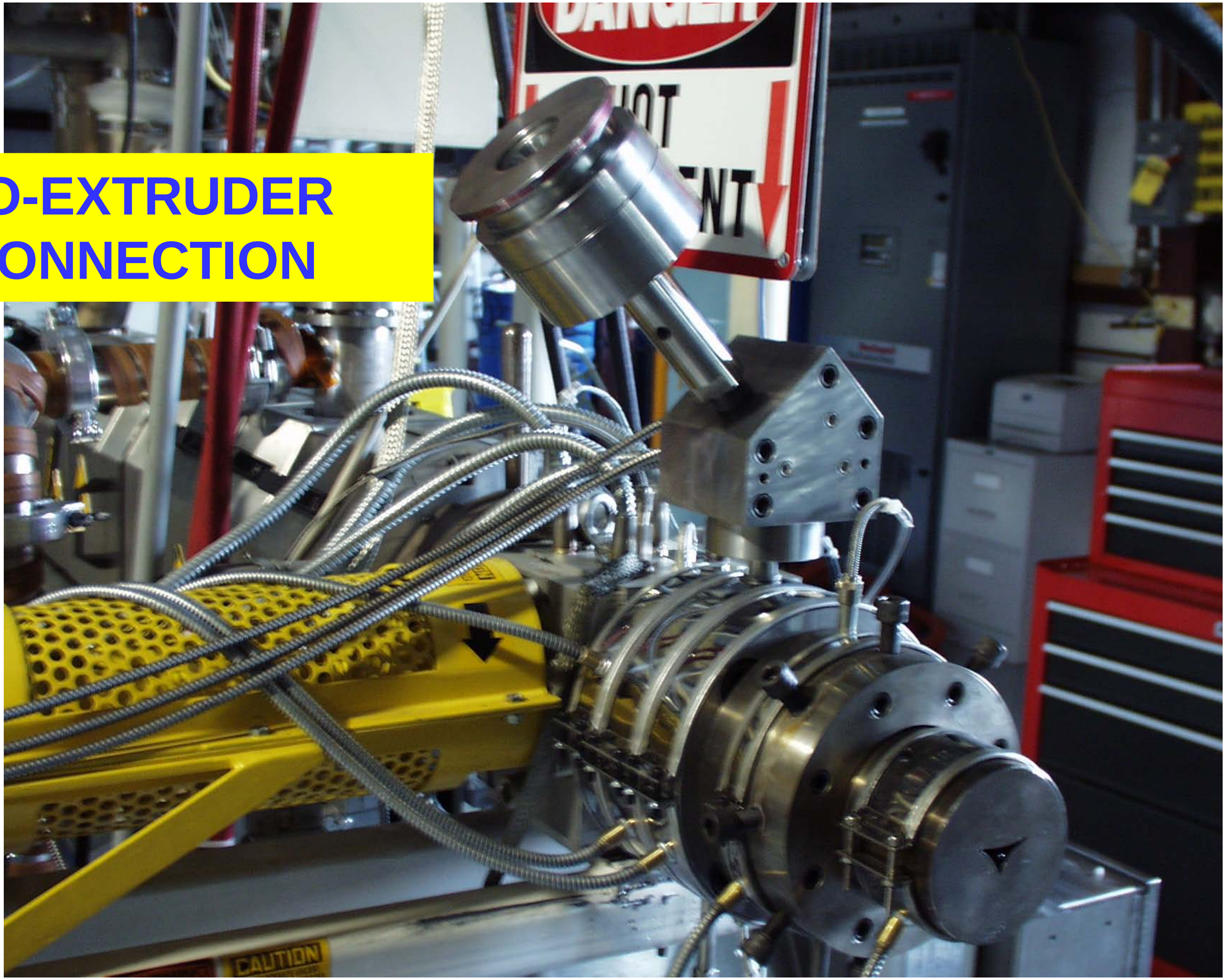
- In-line continuous process:
  - Less handling of raw materials
  - Precise metering of feeders
  - Twin-screw extruder (better mixing)
  - Melt pump offers steady output
  - Control instrumentation
- Line under nitrogen atmosphere:
  - Drying under nitrogen
  - Each piece of equipment is purged

FNAL-NICADD EXTRUSION FACILITY

CO-EXTRUDER PURCHASED IN 2005

FNAL/NICADD EXTRUSION FACILITY

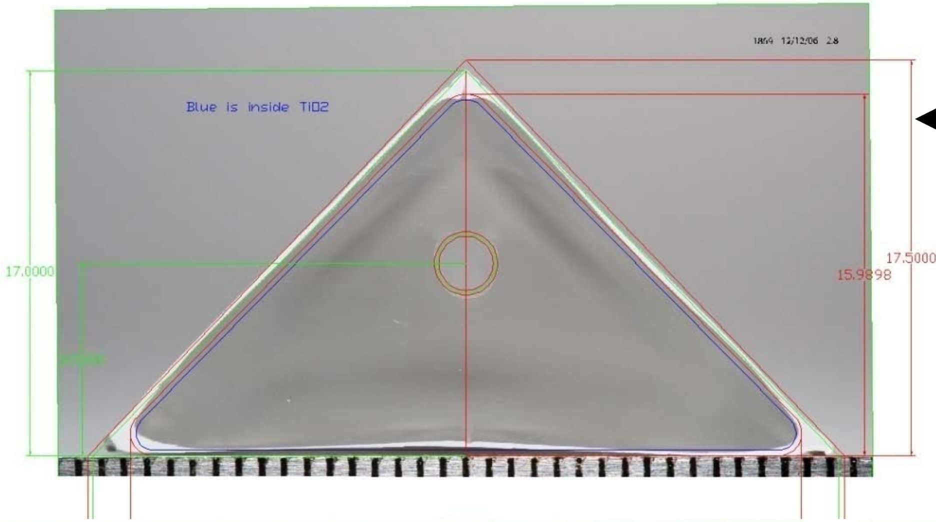
CO-EXTRUDER CONNECTION



PROJECTS - 20 – 25 TONS

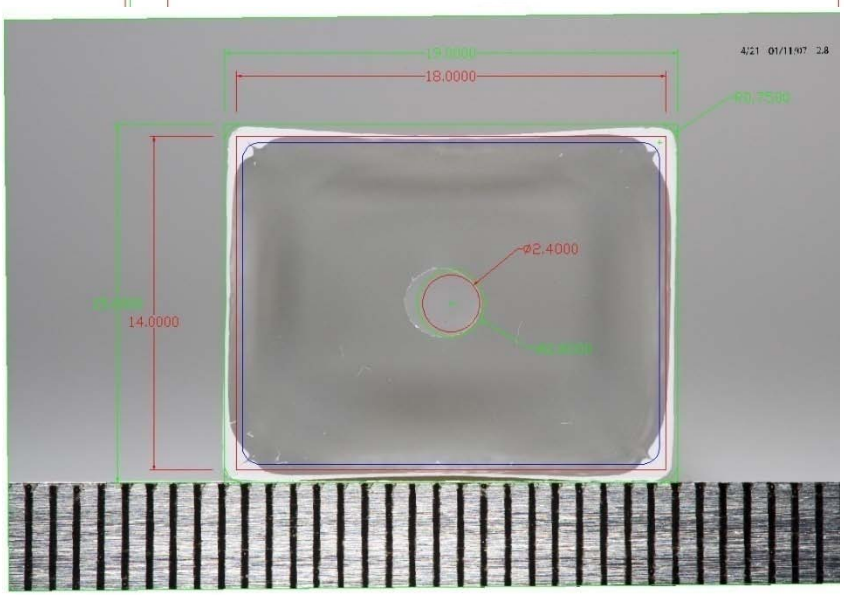
- Minerva – First project
  - Extruder operation, lots of R&D, production
- Hall B – JLAB → 3 grooves! – still developing
- T2K – ND280 – Productions
  - Rochester – MINERvA's triangle
  - Lancaster – 40 mm x 10 mm – 1 hole
  - Kyoto (Ingrid) – 50 mm x 10 mm – 1 hole
- Double-Chooz – Biggest production
  - 50 mm x 10 mm – 1 hole
- Amiga – Pierre Auger → near future

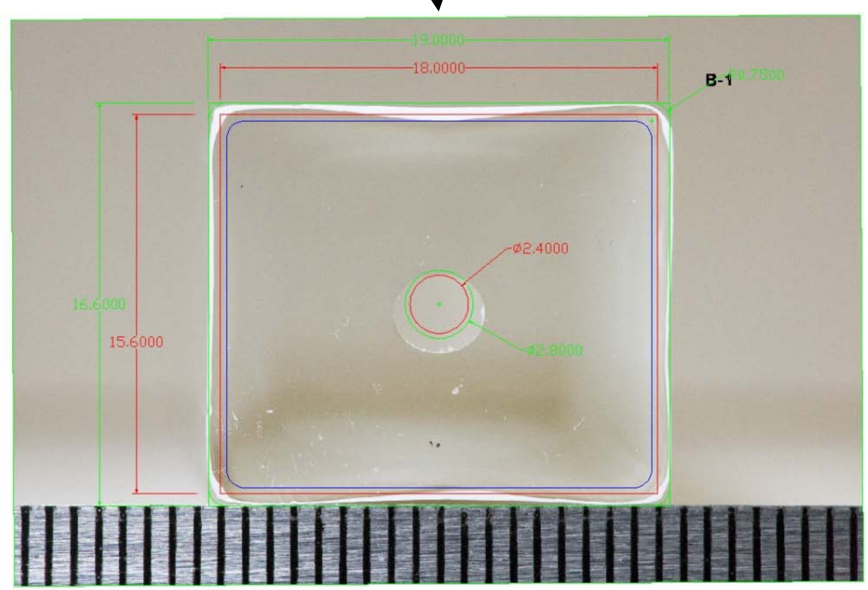
MINERVA SCINTILLATOR:



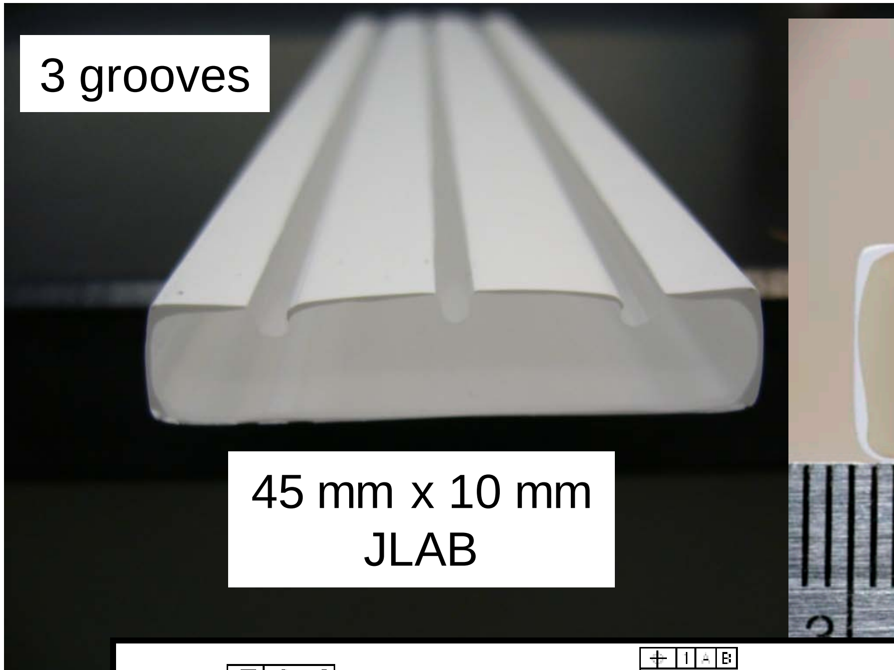
- DONE
- 13,850 STRIPS - 3.5 m long

- DONE
- 3,020 STRIPS - 3.2 m long



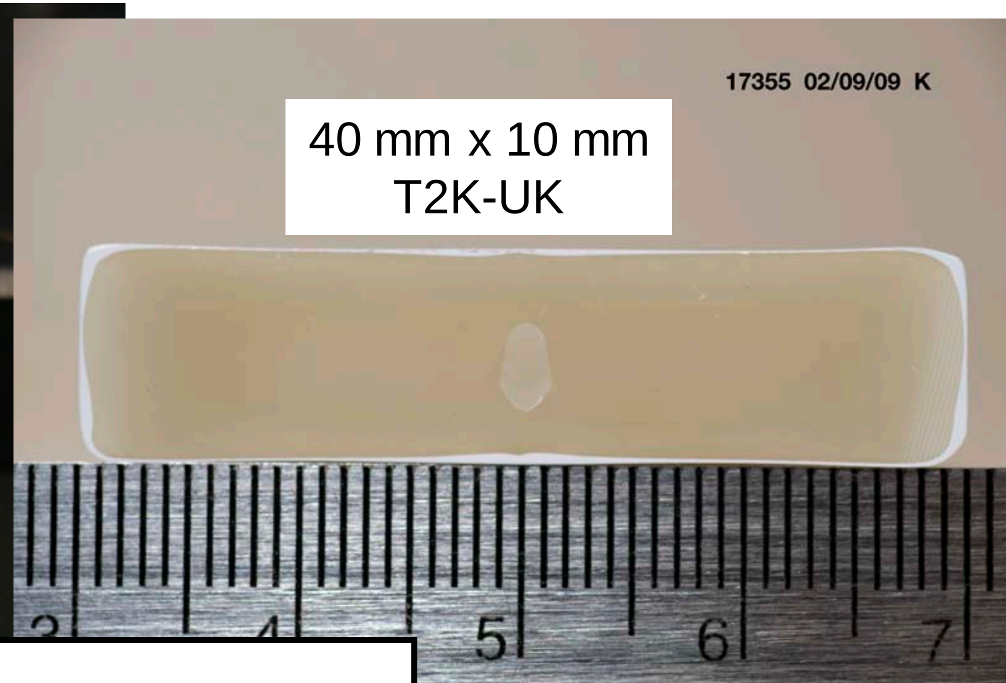


OTHER SCINTILLATOR SHAPES

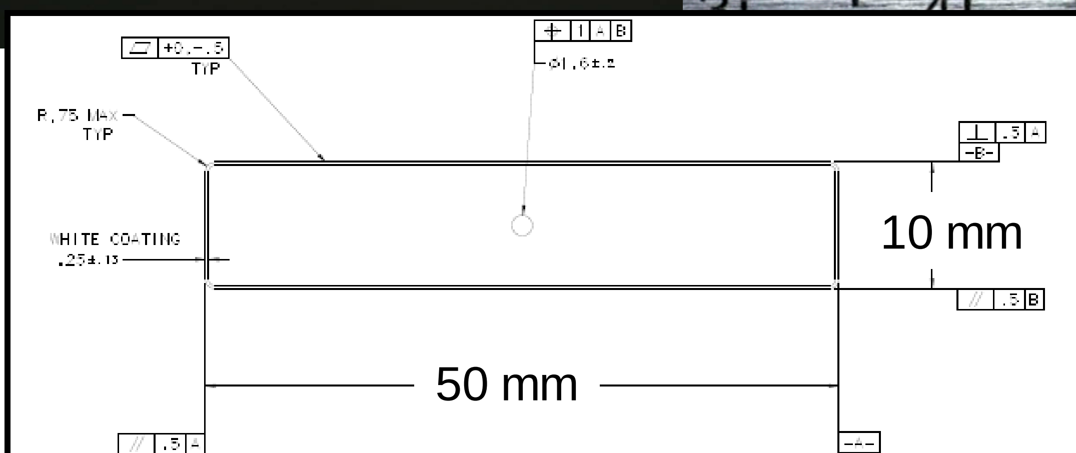


3 grooves

45 mm x 10 mm
JLAB



40 mm x 10 mm
T2K-UK



1 hole
DCHOOZ

PAST AND FUTURE R&D AT THE FNAL/NICADD FACILITY

- PAST – Improve die design:
  - Study and test new dies designed with Computational Fluid Dynamics simulations:
    - Past: collaboration with university
    - Recently: purchased from die industry using these tools

- FUTURE – Potential Process Modifications
  - Run multiple threads
    - Maximizes throughput of machine
    - Stability/Cooling issues
  - Co-extrude Kuraray fiber with the scintillator profile
    - Reduce handling of WLS
    - Processing temperature issues

SCINTILLATOR/FIBER CO-EXTRUSION

- Extruded scintillator profiles use readout with WLS Fiber.

- Logical next step in extruded scintillator.

- Advantages of co-extrusion
  - Almost no fiber handling, yielding significant manpower cost reduction
  - Almost perfect scintillator-fiber optical coupling
    - Greater uniformity with respect to light coupling between the scintillator and WLS fiber

NEXT STEP IN R&D

- Co-extrusion of scintillator and fiber:
  - Fiber needs to survive heat from thick scintillator layer
  - Preliminary tests performed about 8 years ago
  - Post-clad Kuraray fiber with a thin plastic layer:
    - Polyethylene
    - Kynar
    - Teflon
    - Thin 100-300 μm coatings
  - No fiber degradation was observed:
    - No losses in attenuation length
    - WLS fiber did see large heat excursion

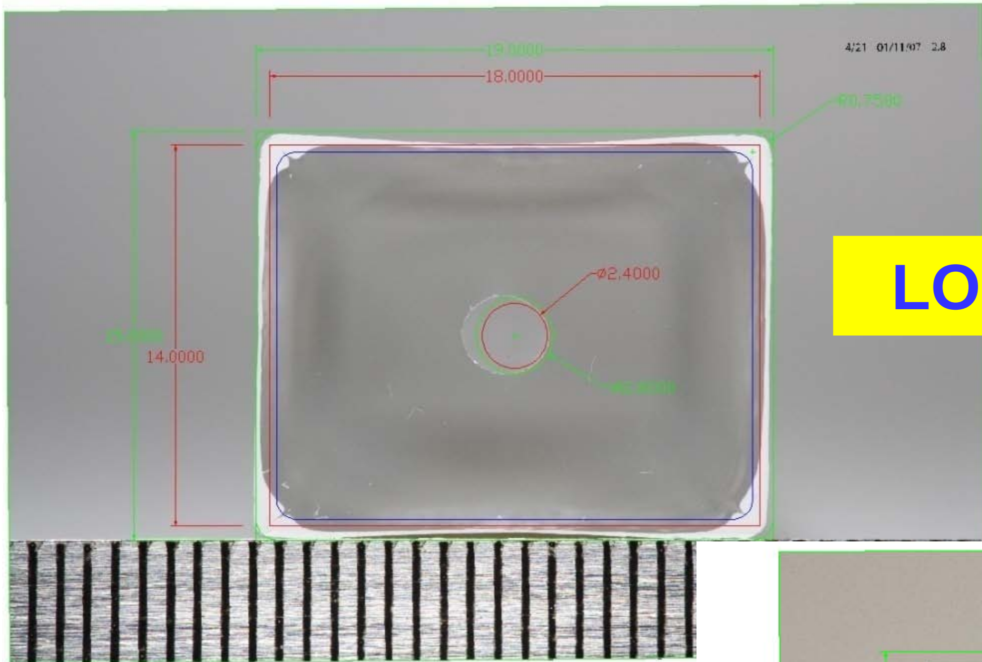
PROPOSAL

- Develop Co-Extrusion Die Tooling with ISO-9000 qualified Vendor - Guill Tool
  - Guill has experience with this type of die.
    - Developed tooling for co-extrusion applications that involve polymers with different melt characteristics which required pre-cooling of one or more of the components in the extrusion.
- Concerns:
  - Melt temperature for scintillator extrusions is above the glass transition temperature of the fiber.
  - Much larger heat soak than in our previous tests.

GUILL TOOLING

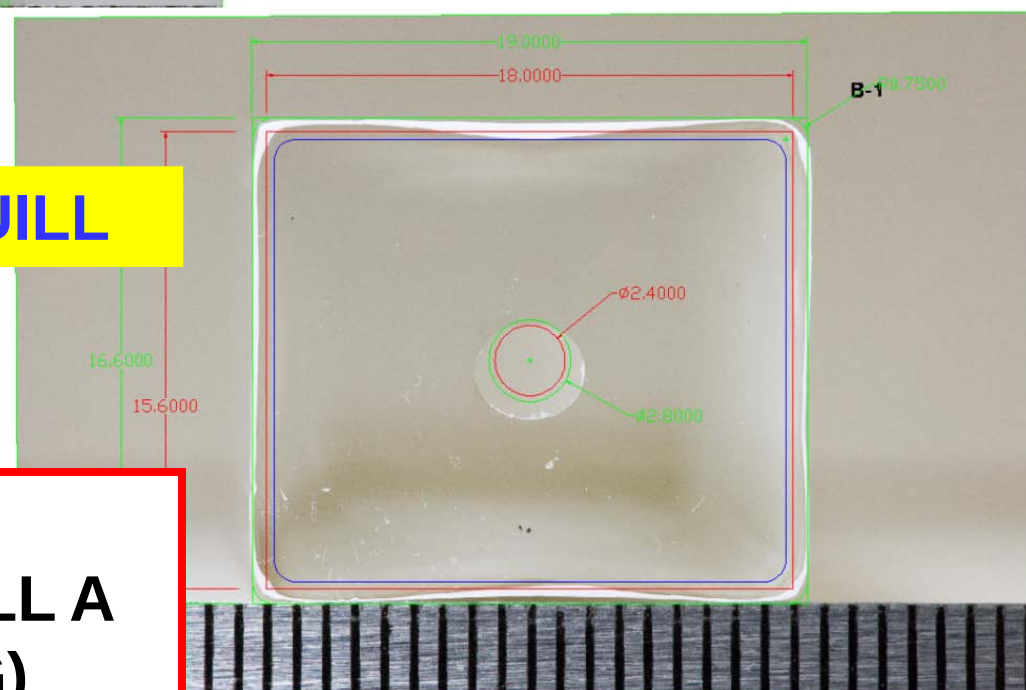
- Talk to them at extrusion show
- Visited factory in Providence, RI
- Company includes full engineering and manufacturing capabilities
- Dies are more expensive
- 12 weeks for order delivery

NEW DIE MANUFACTURER



LOCAL VENDOR

GUILL



BETTER CAPSTOCKING DISTRIBUTION BUT STILL A LARGE HOLE (PENDING)

COST ESTIMATE – MATERIALS

May-08

YEAR 1	Estimated Materials and Services Cost ($)
Material*	
Polystyrene pellets** (3 gaylords, 2220 Kg @ $2.60 each)	$5,772.00
Dopants** (48 units @ $165 each)	$7,920.00
Co-extrusion die***	$52,000.00
Fiber feeding system****	$15,000.00
Estimated Direct Cost	$80,692.00

*These expenses will be incurred in the purchase of both the die-fiber delivery assembly and the raw materials (polystyrene and dopants) needed for testing this new die.

**Price based on recently purchased materials.

***Budgetary quotation from Guill Tool & Engineering Co., Inc. number 19522 plus 25% contingency.

****This is an estimate after discussions with a Fermilab designer.

LABOR ESTIMATE

Extrusion line will need to be reconfigured.

Extrusion crew – 3 months:

- 2 Mechanical technicians – full time
  - 1 person started phased-retirement!
- 1 QC technician – full time
- 1 Engineering physicist – full time

NOTE: WE COULD USE CO-OP STUDENTS!!

We had a great co-op program with 4 to 5 students cycling through the year.

CONCLUSION

Scintillator/fiber co-extrusion is not a trivial endeavor:

- **A few important technical challenges**
- **Some economic hurdles**

- **For future experiments it has the potential to yield an overall better product and save money in handling and assembly costs.**