NuMI

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# Experience with the NuMI Target



Target took beam for over a year, 820 MWhr integrated beam power. Two problems:

1) water leak soon after turn-on
2) target motion drive shaft froze up after year of operation

| | Max. Proton/spill | Max. Beam Power | Integrated Protons on Target |
|---|---|---|---|
| Target Design | 40e12 p.p.p. | 400 kW | 370 e18 p.o.t. lifetime |
| Experience: | | | |
| Before leak | 25e12 p.p.p. *11e12 day before leak* | 69 kW | 0.7 e18 p.o.t. |
| After leak | 30e12 p.p.p. | 270 kW | 158 e18 p.o.t. |

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# NuMI Target

*long, thin, slides into horn without touching*



Graphite Fin Core, 2 int. len.

( *6.4 mm x 15 mm x 20 mm* ) *x 47*

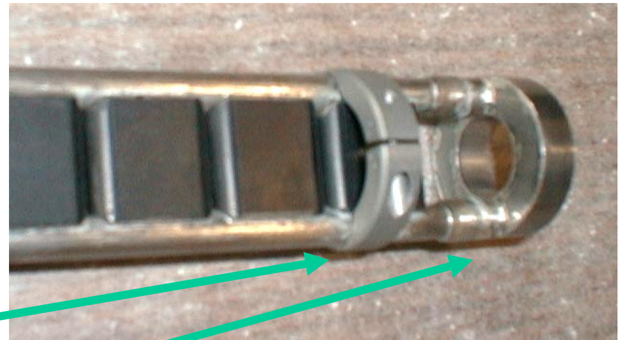
Water cooling tube also provides mech. support

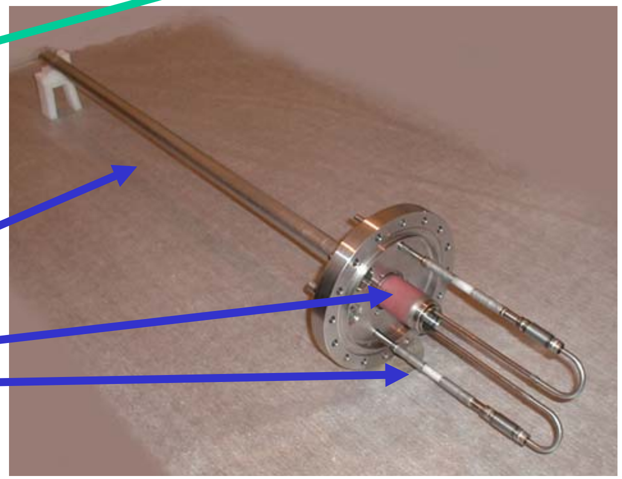
Anodized Al spacer (electrical insulation)

Water turn-around at end of target

0.4 mm thick Aluminum vacuum/Helium tube

Ceramic electrical isolation



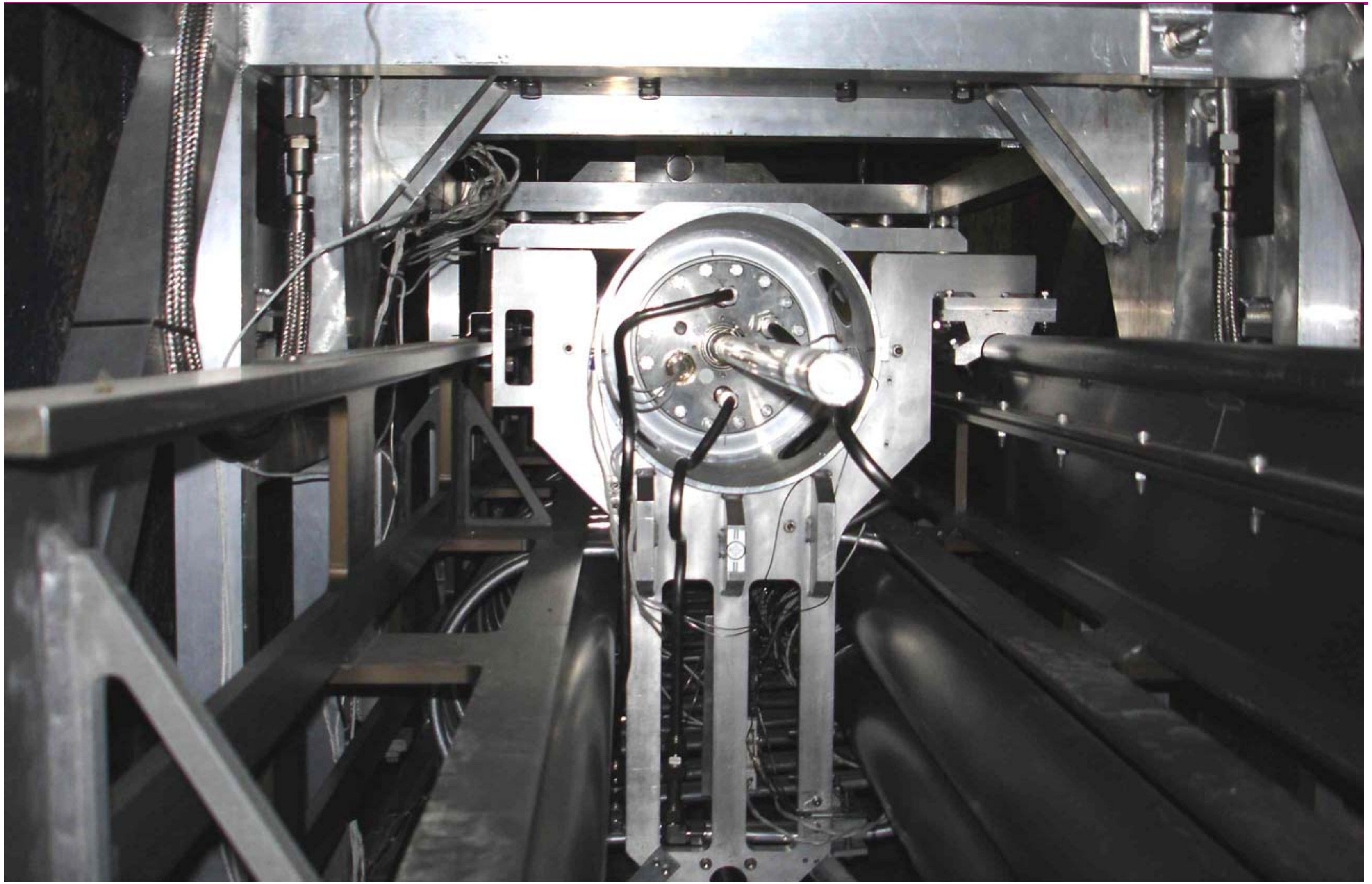


# Target water line



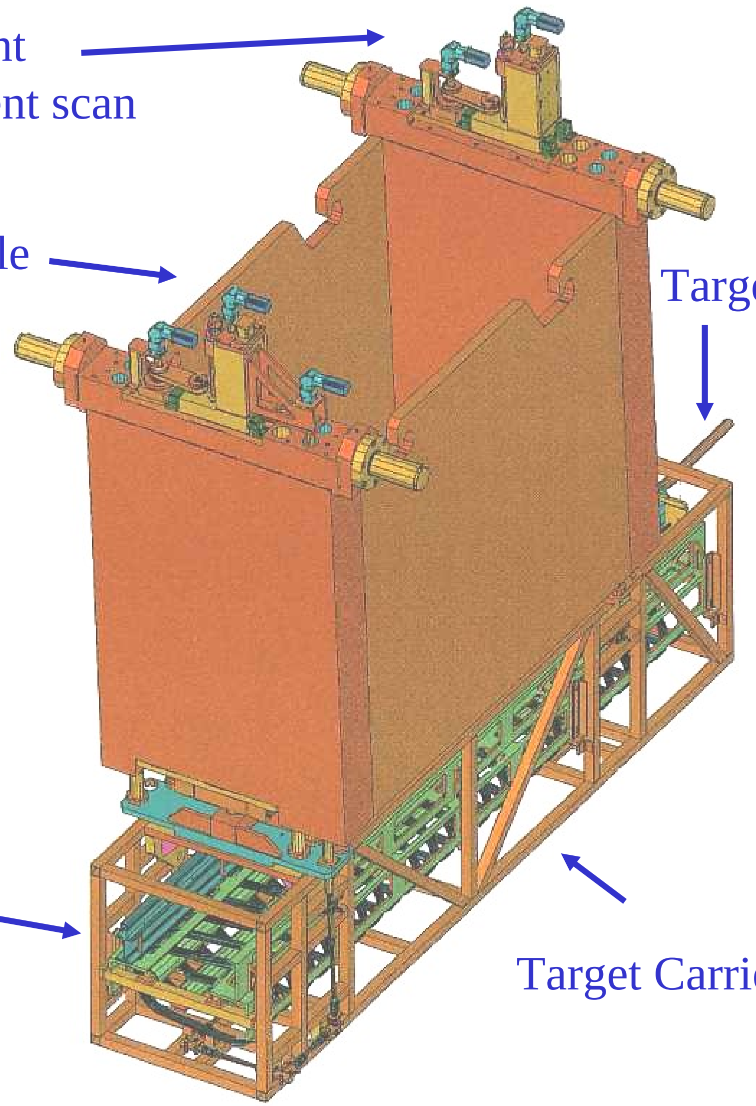
# Target
## mounted on carrier





# Target system





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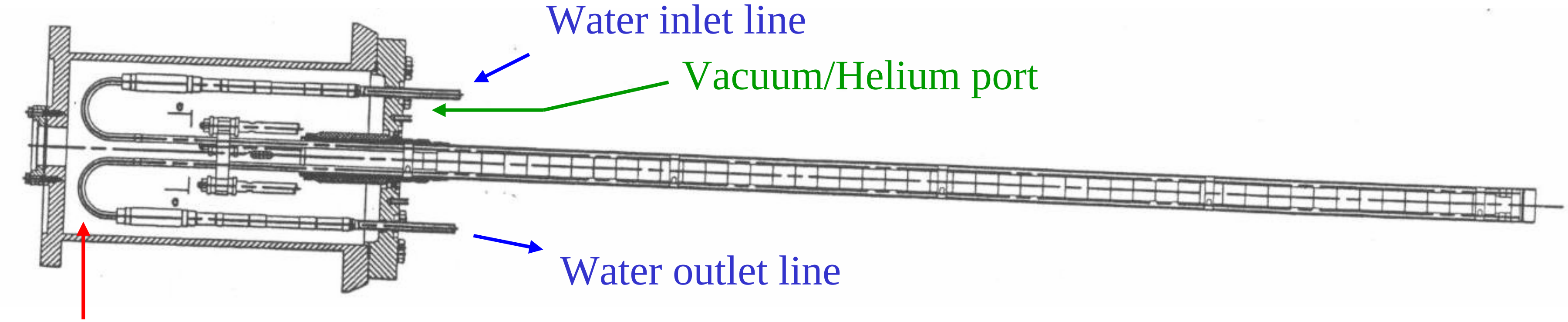
# Target water leak



On March 23, 2005 water leaked from cooling line into vacuum can, flooding target.




After draining target, we pressurized the can with 23 psig helium
(was planning to use helium for high power running anyway)

Helium bubbled through leak to water line, keeping water out of target.

# Didn't plug leak, but changed pressures, so helium leaks into water system instead of water into target



Helium bottle

Initially used 0.2 lpm,
now bubbling 0.8 lpm helium into water.

No sign of water getting into target during 15 months!

Expansion tank

Pump

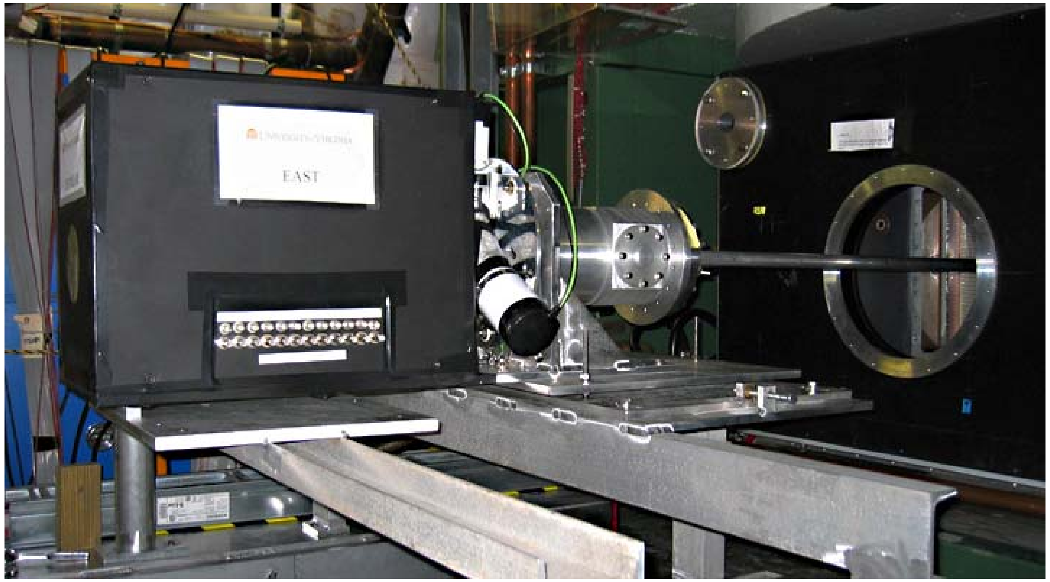
Leak from He to cooling water loop

Target

# NuMI target spare



Target #2
used in MIPP E907 experiment
to measure hadron production →




Modifications:

1) clamped the bellows
(on suspicion that hydraulic shock might cause problem)

2) routed Helium port lower, making it easier to drain water through that line

3) will run Helium back-pressure system from day #1 just in case it starts to leak

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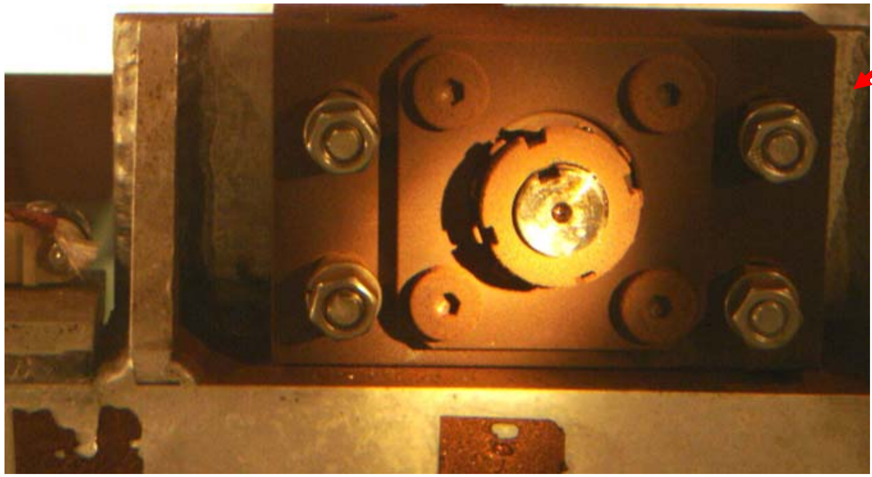
# Frozen drive shaft

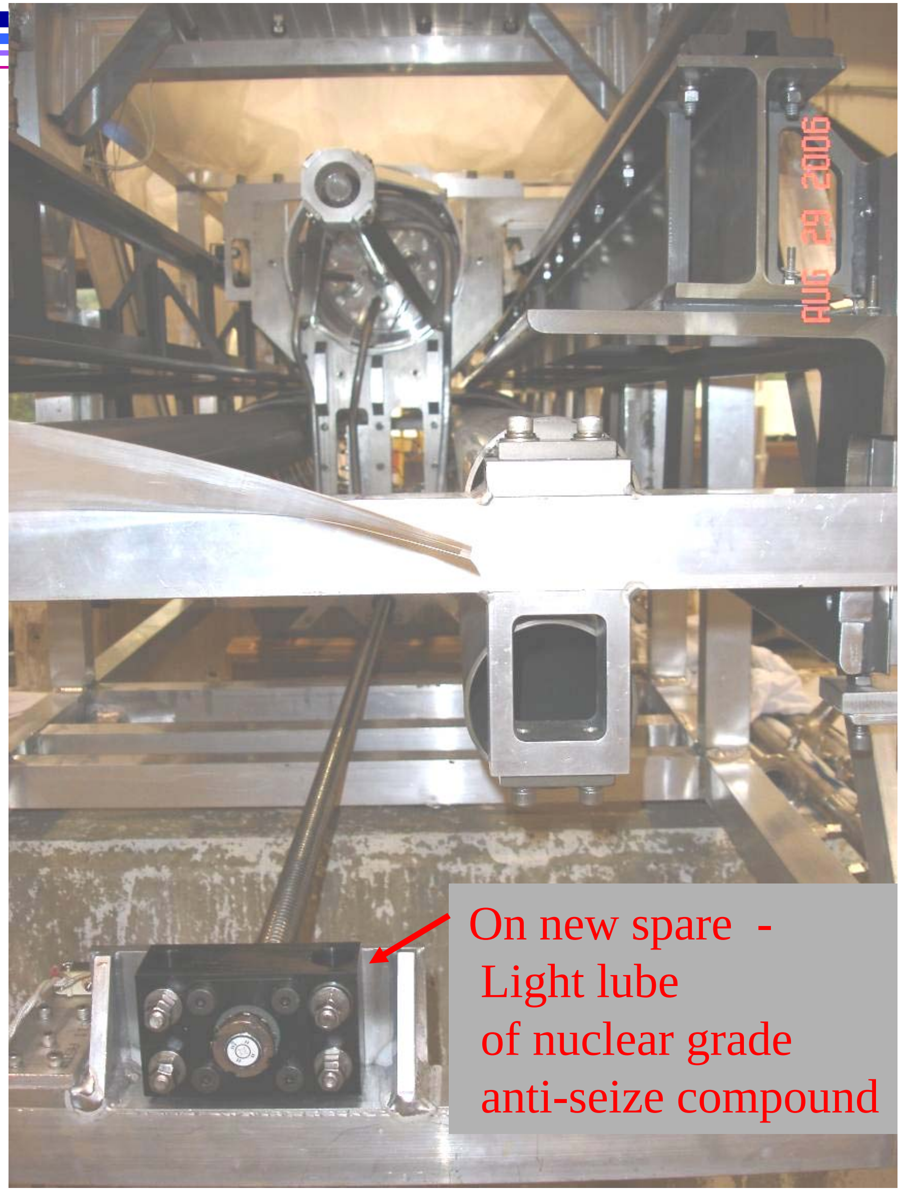
After month-long test in High Energy position
drive shaft will not rotate to move target
into Low Energy position

Now changing to spare target + carrier;
expect to finish end of this week

On future target carrier, probably change to
Graphalloy bushing

Old jammed pillow-block






On new spare -
Light lube
of nuclear grade
anti-seize compound

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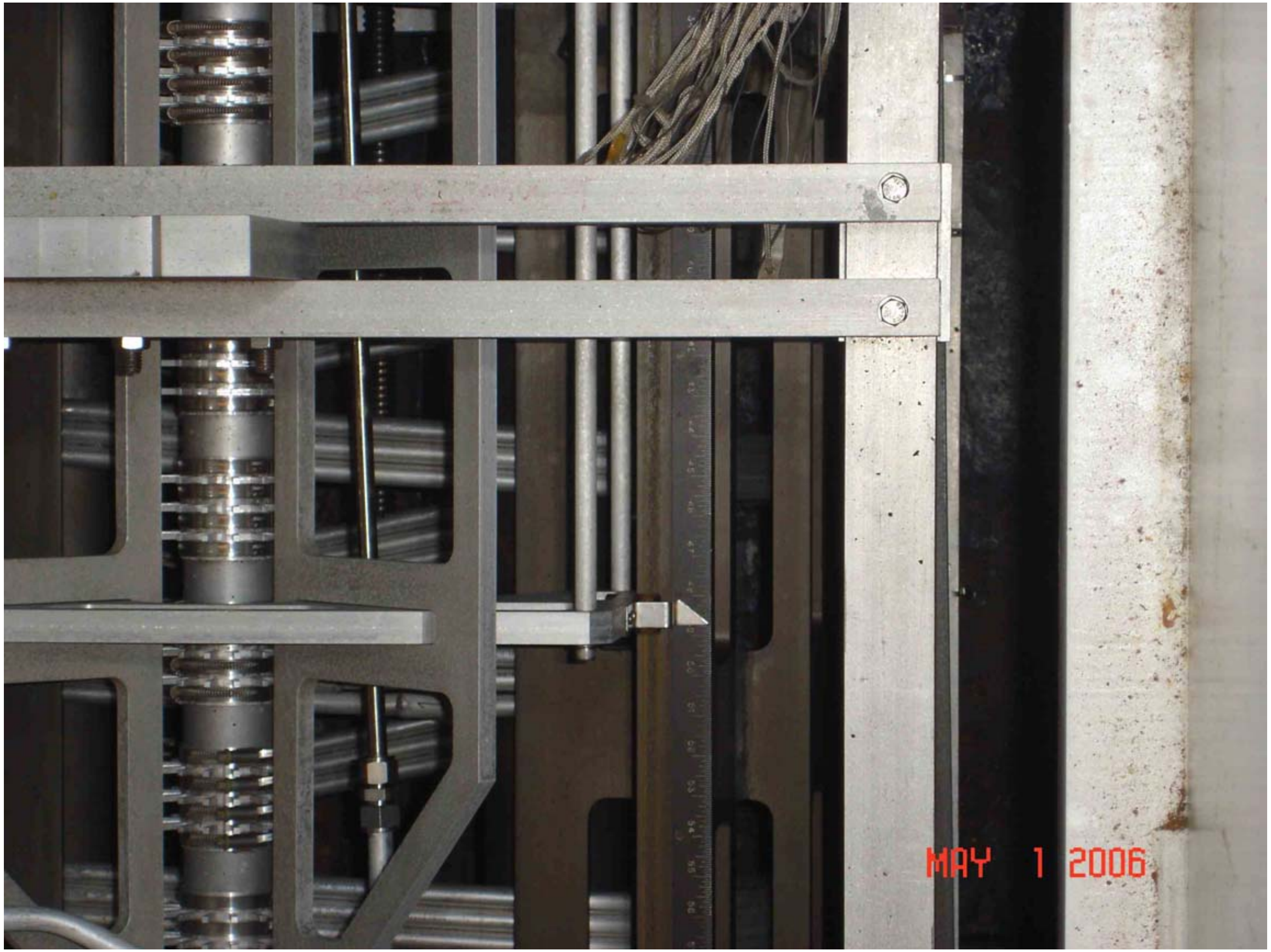
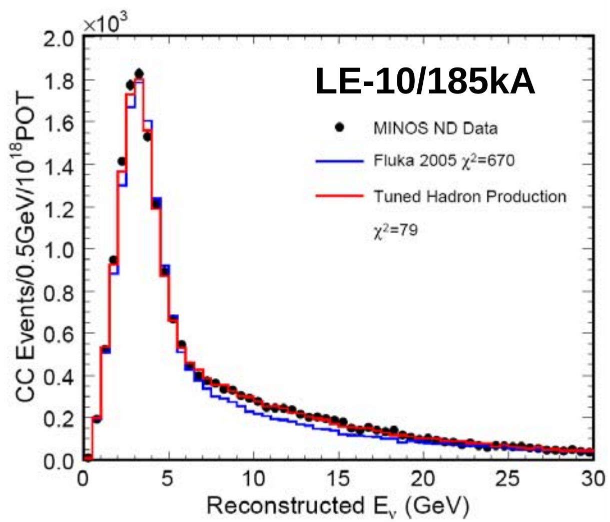
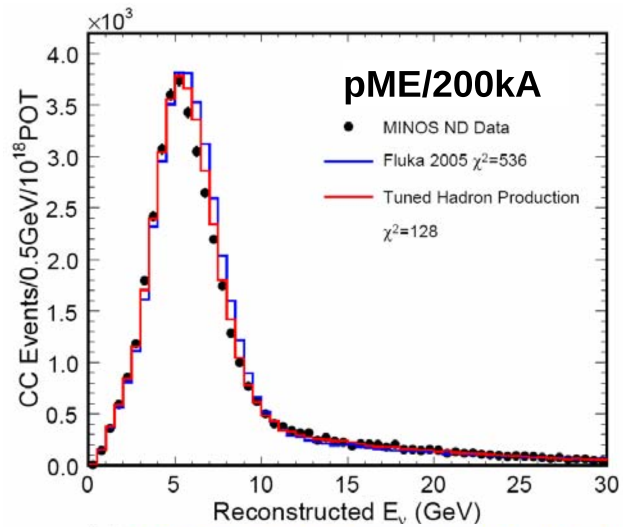
# When drive was sticking, used visual (camera) check of target location

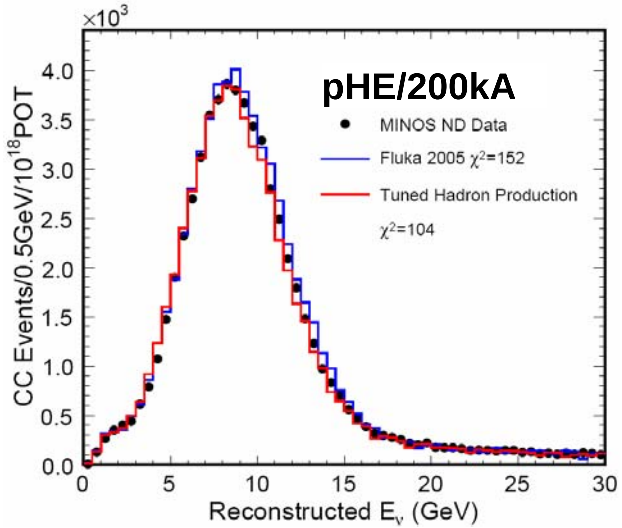


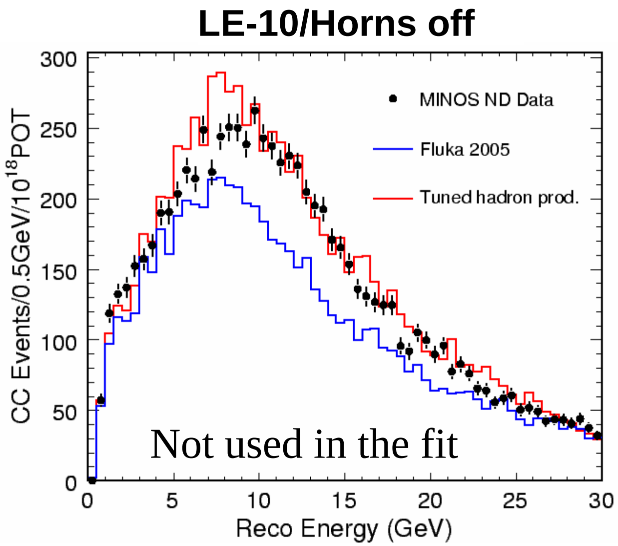


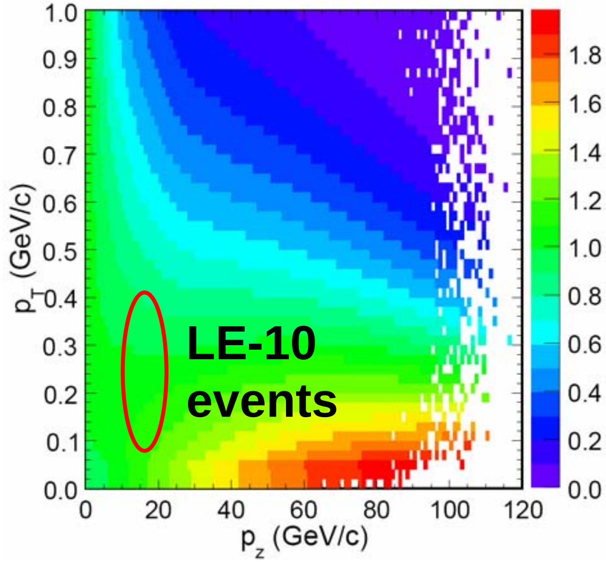
# Remote target drive capability was used for MINOS systematics studies



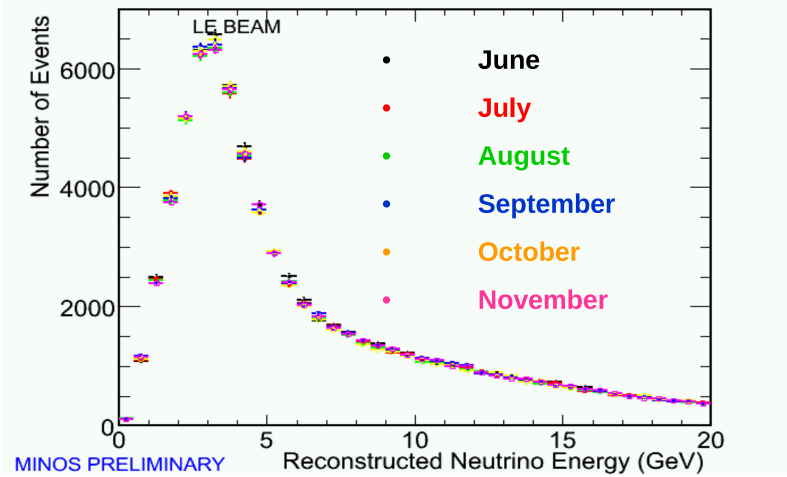

Weights applied as a function of hadronic $x_F$ and $p_T$.

Reasonable agreement between data and Fluka05, but tuning hadronic $x_F$ and $p_T$, simultaneously improves all distributions

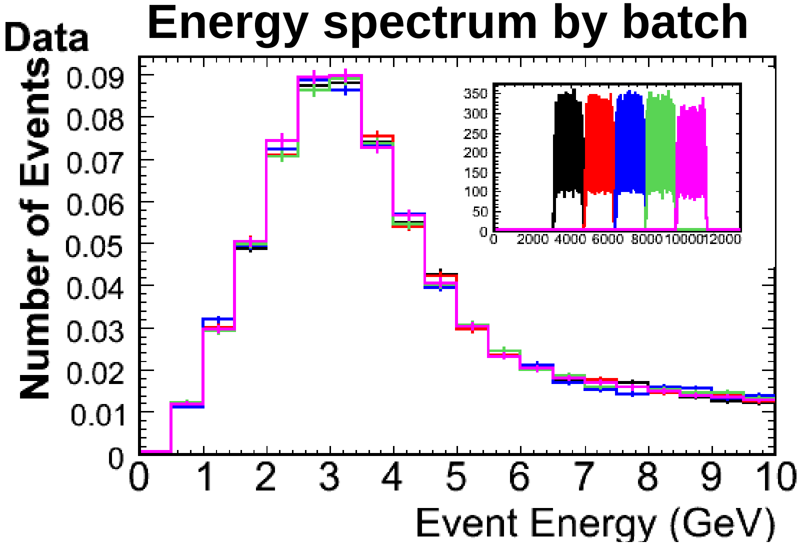
# Stability of the neutrino energy spectrum is indication that target did not deteriorate

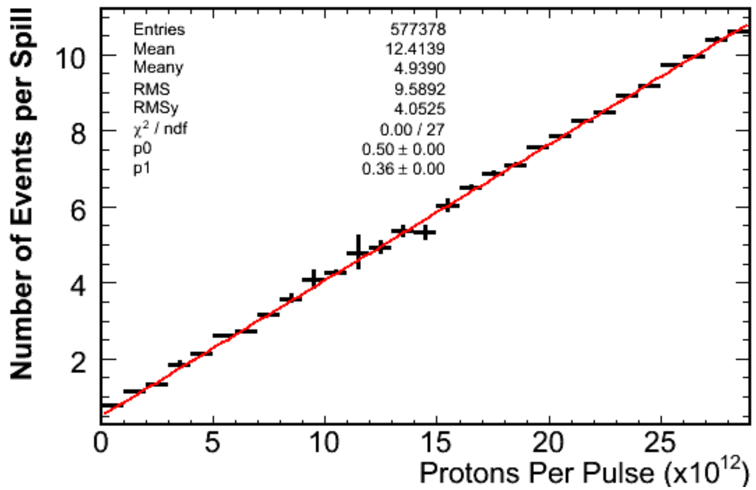


## Energy spectrum by Month




## Energy spectrum by batch




- Reconstructed energy distributions agree to within statistical uncertainties (~1-3%)
- Beam is very stable and there are no significant intensity-dependent biases in event reconstruction.

# Acknowledgement



The target design has proved itself through a year of operation.

A lot of credit should go to Valeri Garkusha's group at IHEP Protvino, who did most of the design and construction of the target!

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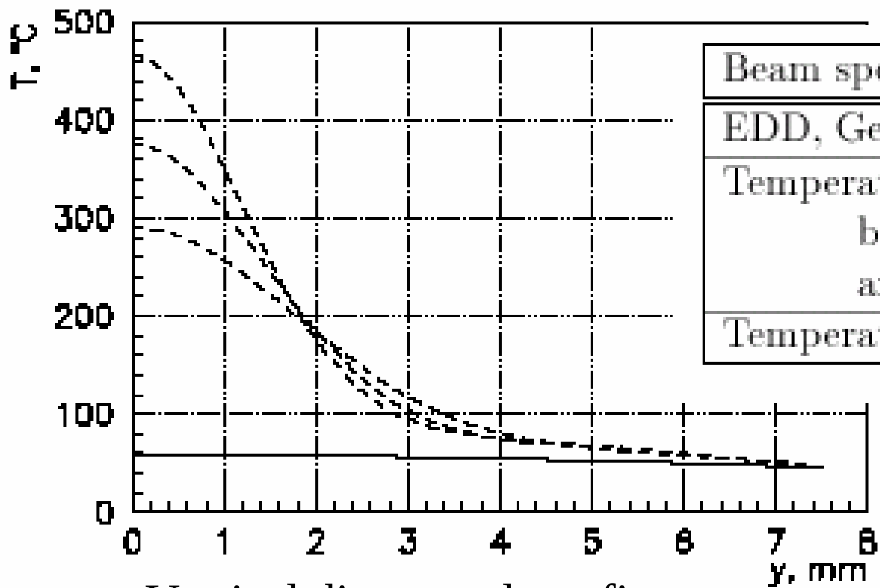
# Target calculations for Main Injector slip-stack mode



If Main Injector starts to run slip-stack mode for NuMI, then design conditions change:

| | Proton/pulse | Repetition rate | Beam power |
|---|---|---|---|
| Orig. Design | $4.0 \times 10^{13}$ | 1.87 second | 400 kW |
| Slip-stack (max.) | $5.5 \times 10^{13}$ | 2.2 second | 480 kW |




Vertical distance along fin

| Beam spot size ($\sigma$), mm | 1.0 | 1.2 | 1.5 |
|---|---|---|---|
| EDD, GeV/cm$^3$/proton | 0.118 | 0.085 | 0.058 |
| Temperature, °C | | | |
| before the beam pulse | 59 | 58 | 56 |
| after the beam pulse | 468 | 376 | 291 |
| Temperature rise, °C | 409 | 318 | 235 |

*Temperature for slip-stack mode*

# Target calculations for Main Injector slip-stack mode



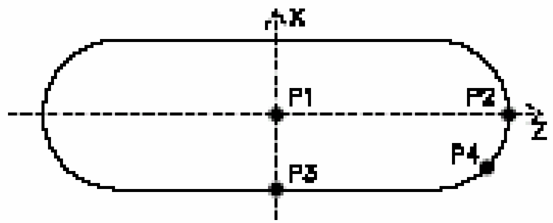



Figure 7: Position of points P1÷P4 in the median (beam axis) plane of the target segment.

| Proton beam intensity, ppp | $4.0\times10^{13}$ | $5.5\times10^{13}$ | | |
|---|---|---|---|---|
| Beam spot size ($\sigma$), mm | 1.0 | 1.0 | 1.2 | 1.5 |
| $P1$ | 2.2 | 1.7 | 2.4 | 3.5 |
| $P2$ | 1.8 | 1.4 | 1.7 | 2.0 |
| $P3$ | 2.2 | 1.7 | 1.9 | 2.3 |
| $P4$ | 1.4 | 1.0 | 1.3 | 1.6 |

(V.Garkusha et al., IHEP)

Can regain original stress safety-factor for graphite fin by increasing beam spot size from 1.0 mm RMS to 1.3 mm RMS

Have concern about water hydraulic shock, estimated as 30 atm. Considering injecting gas into cooling water to alleviate stress.

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# Conclusion

## After scary initial water leak, NuMI target functioned well
## Now looking forward to lots more beam !