

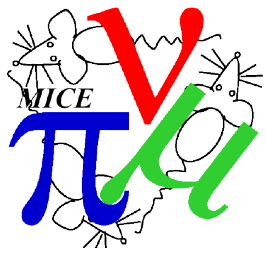
ILLINOIS INSTITUTE
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Solid Absorber Program for Step IV

Pavel Snopok

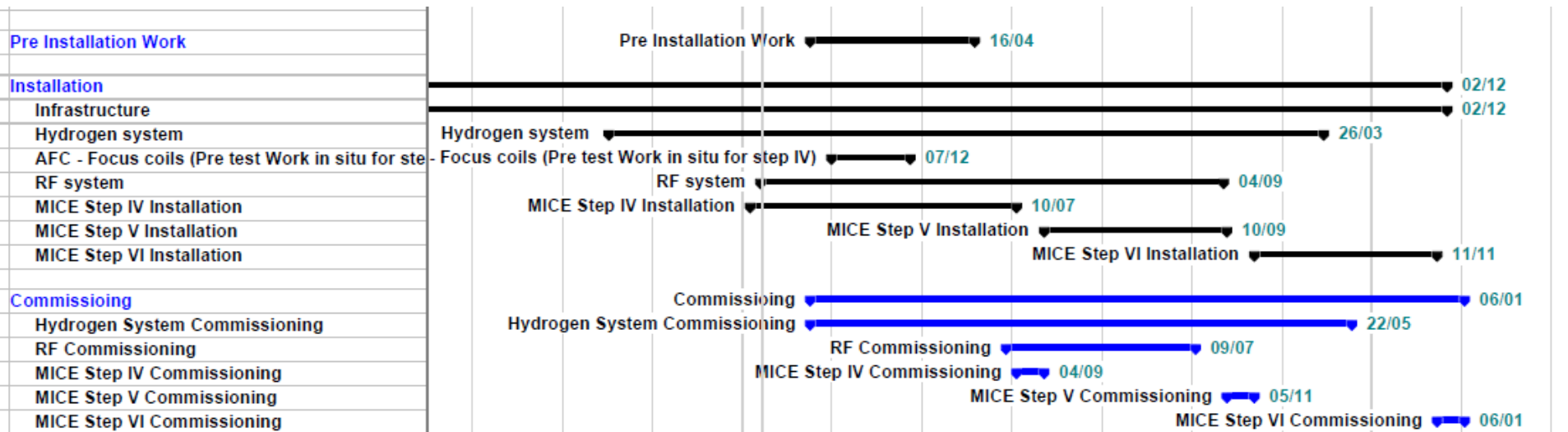
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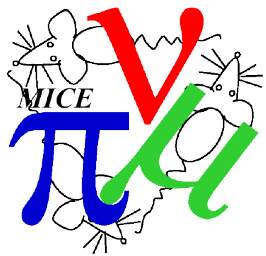


Current MICE Schedule

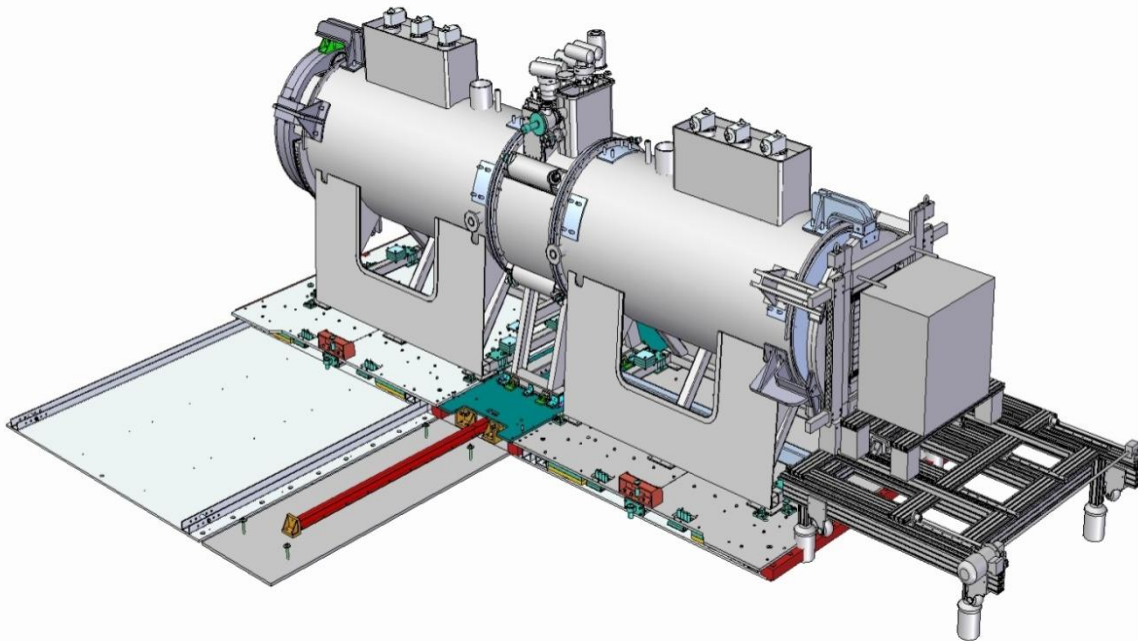
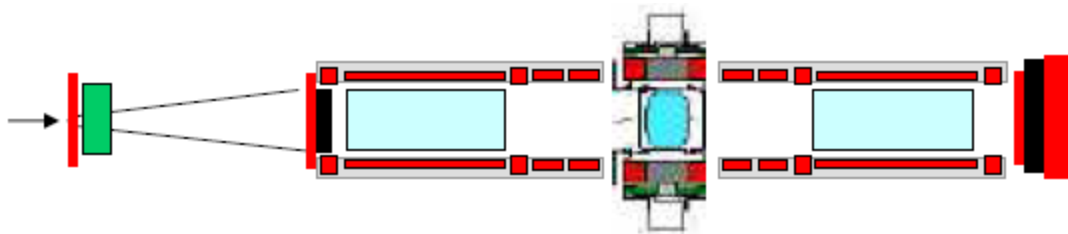
Task Name	2009	Half 2, 2009	Half 1, 2010	Half 2, 2010	Half 1, 2011	Half 2, 2011	Half 1, 2012	Half 2, 2012	Half 1, 2013	Half 2, 2013	Half 1, 2014	Half 2, 2014	Half 1, 2015	H	
	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J
MICE HALL INSTALLATION SCHEDULE															

- Installation and commissioning of Step IV run through Q3 2012
- Installation and commissioning of Step V run from Q4 2012 to Q4 2013
- This sets limits on the amount of time we have for Step IV configuration tests including solid absorber experiments
- ISIS schedule limits this window further



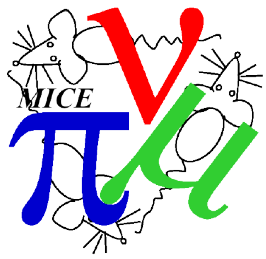


STEP IV



Component	Date
Spectrometer solenoid #1 + #2	April'12
Fibre tracker #1 + #2	Ready
Focus coil #1	July'11*
LH ₂ delivery	Dec '11
Solid absorber	??
Liquid absorber	Ready
Diffuser	June'11
Virostek plate	??
Substation upgrade	June'11
EMR installation	Dec'11
Radiation shutter	??
AFC Moving platform #1	July'11

Step IV ready...Q3, 2012



Solid Absorber Program Motivation

- First observation of cooling
- Test a variety of materials [...that occur in the Neutrino Factory]
- Test a number of different configurations (3 momenta, 3 emittances, field flip/non-flip configuration, different betas)
- Compare data/theory/simulation
- Measure/verify equilibrium emittance, multiple scattering, energy loss
- Test hardware/software

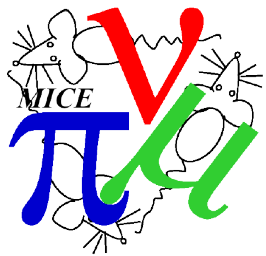
Step IV Absorbers

	X_0 (gcm ⁻²)	dE/dX (MeV g ⁻¹ cm ⁻²)	ρ (gcm ⁻³)	Δx
LH ₂	63.04	4.103	0.07	350 mm
LiH	79.62	1.897	0.82	63 mm
PolyE	44.77	2.079	0.89	52 mm
Be	65.19	1.595	1.848	34 mm
C	42.7	1.742	2.21	26 mm
Al	24.01	1.615	2.699	23 mm
Ti	16.16	1.477	4.54	15 mm
Cu	12.86	1.403	8.96	8 mm

Blue = materials used in the Neutrino Factory;
material thickness corresponds to 10 MeV energy loss

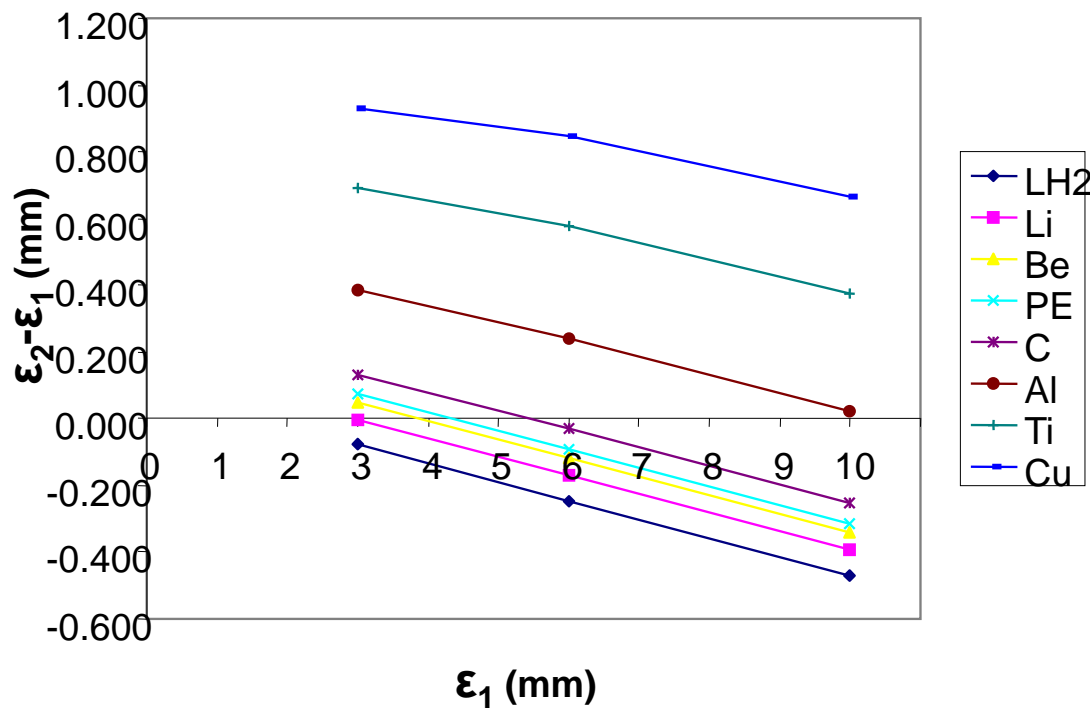
courtesy Timothy Carlisle

$$\frac{d\varepsilon_n}{dz} = \frac{-\varepsilon_n}{\beta^2 E} \left\langle \frac{dE}{dX} \right\rangle + \frac{\beta_t (0.014 \text{ GeV})^2}{2\beta^3 E m_\mu X_0}$$



Observations

$d\varepsilon_n$ vs ε_n



- Materials up to $Z \approx 12$ both cool and heat
- Al ($Z=13$) and above will heat even a 10 mm beam
- Be behaves similar to Polyethylene
- Ti and Cu are too heavy to give useful measurement of equilibrium emittance
- Suggest sufficient set is LH2, LiH, Al and C (could add/use PE in place of C)
- $\beta=42$ cm
- Material thickness corresponds to energy loss of 10 MeV



MICE Step IV Evolution

ϵ_{in}

ϵ_{out}

STEP IV.0

Vacuum

Diffuser
Spectrometers
Trackers
EMR
Focus coil

STEP IV.1

Solid absorbers

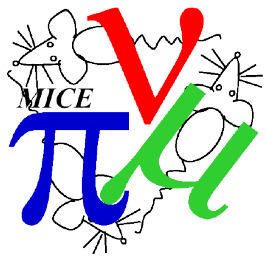
Plastic	50 mm
LiH	65 mm
Be	34 mm
Al	23 mm
Fe	9 mm
Cu	8 mm
Wedge	

STEP IV.2

Liquid absorbers

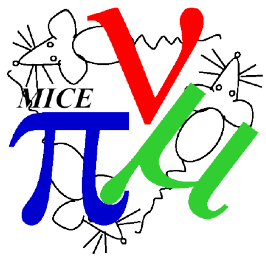
LiqH2	350 mm
LiqHe?	

PREMIUM ON FAST and ROBUST PUSH-PULL OPERATION OF FC MODULE



Variables

- 3 momenta (140, 200, 240 MeV/c);
- 3 emittances (3, 6, 10 mm);
- Flip/non-flip solenoid optics;
- Two different betas (?);
- Up to 36 configurations;
- Might take prohibitively long for all materials;
- Make full set of measurements on one material (LiH?), for others: one solenoid configuration (flip), one beta, different momenta/emittances.



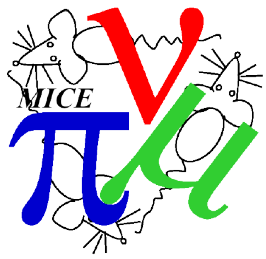
Statistics, Overheads

- Data statistics: 50-100k muons per configuration;
- 50k muons will take 3-4 hours to acquire (assuming 5 useful muons per spill);
- Overheads:
 - Replace absorber (8 days, Andy Nichols at CM28);
 - Solenoid configuration (run down magnets, swap polarity, check, run up; needs an expert);
 - Change momentum and beta (retune coils, may need an expert);
 - Change momentum and emittance (some magnet retuning + diffuser).

Rough estimates of time for one solid absorber – large error bars!

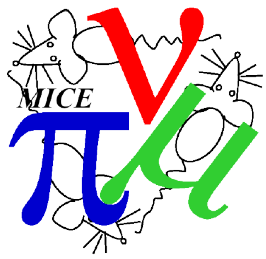
		Times	Hrs	Days	Tot	
Change absorber		1		8.00	8	A.N. at CM28
Change Flip /non-flip	Need experts, times are	1		1.00	1	<i>Guess - cables must be swapped, checks....</i>
Change momentum & beta of Cooling chan	working days	12		0.50	6	3 momenta x 2 betas x flip / non-flip
Change beam momentum & emittance		36	1	0.04	1.5	3 beam emittances at each of above settings
Run	Non -experts	36	4	0.17	6	~50,000 muons at 5 good muons / spill
Total time					23 days	24 hour / day running
					30 days	12 hour / day running

- No large efficiency factors or contingency
 - but many guesses
- Overheads seem to dominate
- May like better to balance overheads & running?
- Suggests ~3 weeks for a complete set of measurements with one material plus 8 days (~2 weeks) to change an absorber
- **Would also like empty (no absorber) running – so double the time?**
 - but do this only once
- Would we really want to do this with all materials?
 - 5 materials → ~150 days ~ 1/2 a year



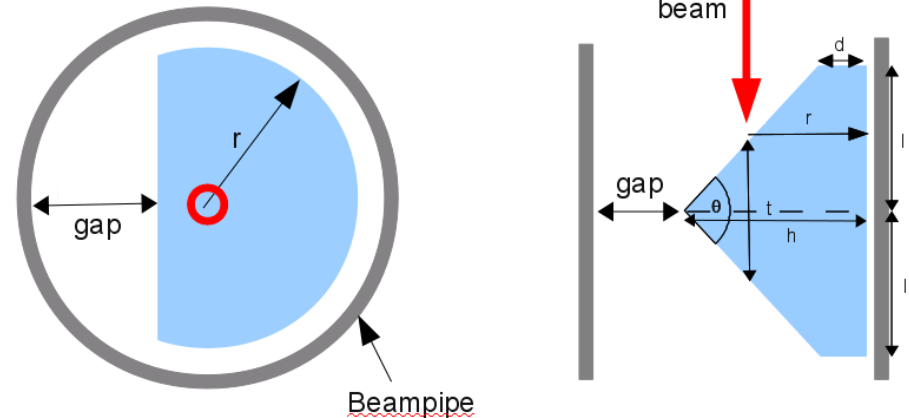
Time Estimates: Bottom Line

- One material (LiH): 3 weeks for a full set of measurements + 2 weeks to replace absorber;
- Other materials (Al, Be; PE or C): 2 weeks for measurements + 2 weeks to replace (maybe less, once there is experience replacing the first one);
- Hence:
 - 5 materials: approximately 21 weeks, of them 11 weeks to collect data;
 - 4 materials: approximately 17 weeks, of them 9 weeks for data.
 - Assuming there is also a wedge LiH absorber (next slide), 5 materials might be too much.



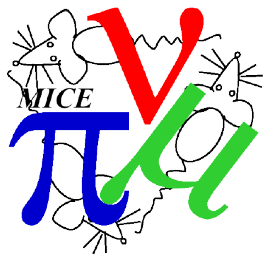
Wedge Absorber

- MICE is a 4D cooling experiment: transverse emittance is reduced while longitudinal emittance stays the same or increases slightly due to stochastic processes in the energy loss.
- By replacing a flat absorber with a solid (LiH) wedge absorber emittance exchange will be demonstrated.
- The beam needs to be properly matched (dispersion is introduced).
- Similar to flat absorbers, wedge absorber installation and data taking will take another 3-4 weeks (some more overhead).



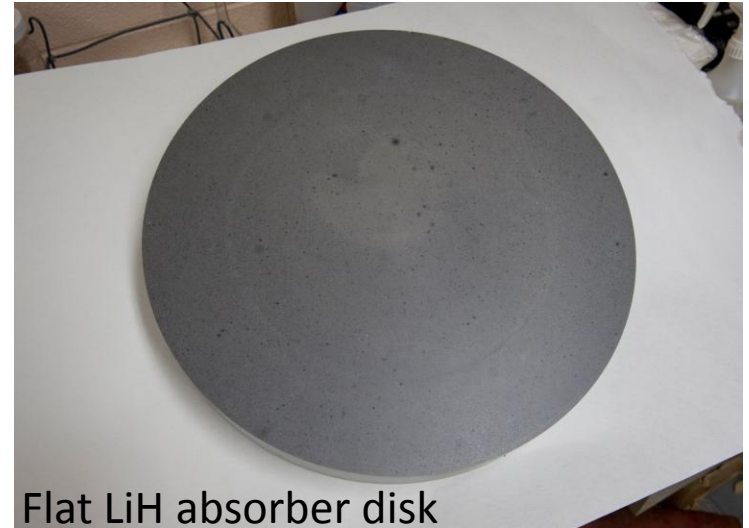
Wedge absorber = cylinder intersected with a triangular prism.

Opening angle = 90 degrees,
 on-axis length = 75.4 mm (corresponding to 12 MeV energy loss at $p=200$ MeV/c),
 radius=225 mm (may be reduced to 160 mm),
 gap=187.3 mm.

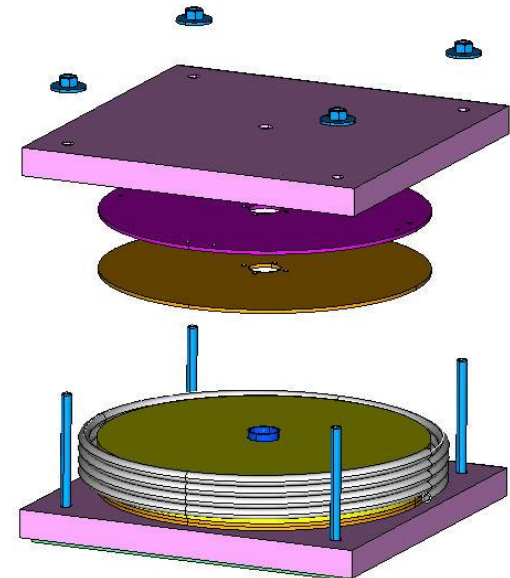


Current Status

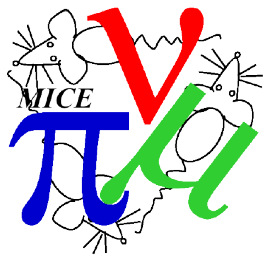
- Flat LiH absorber is complete, going through inspection. No firm date when it will be shipped to Fermilab for testing.
- Wedge LiH absorber will take approximately 2 month to fabricate. The original due date was June, however, there was an issue with the starting material.
- Eventually, we will need to decide on the other flat absorbers to have them done by the time they are needed.



Flat LiH absorber disk



Thermal test set up for Fermilab



Thank you!