



MICE ANALYSIS STATUS

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NFMC Collaboration Meeting
Mar 12, 2006



MuCool





Context



- **MICE is an accelerator R&D experiment**
 - usual kinematics issues common to HEP experiments (momentum resolution, efficiency and bias in PID..)
 - but no interaction vertices, branching ratios, cross sections, rare event searches..
 - all we want is a set of muons
 - **the beam is the experiment**
 - tricky analysis
 - **virtual bunches**
 - beam dynamics in nonlinear transport
 - 0.1% emittance resolution goal
- **MICE is the flagship of Neutrino Factory R&D**
 - Our success in building/operating/verifying one cooling channel is much more important than which one we build

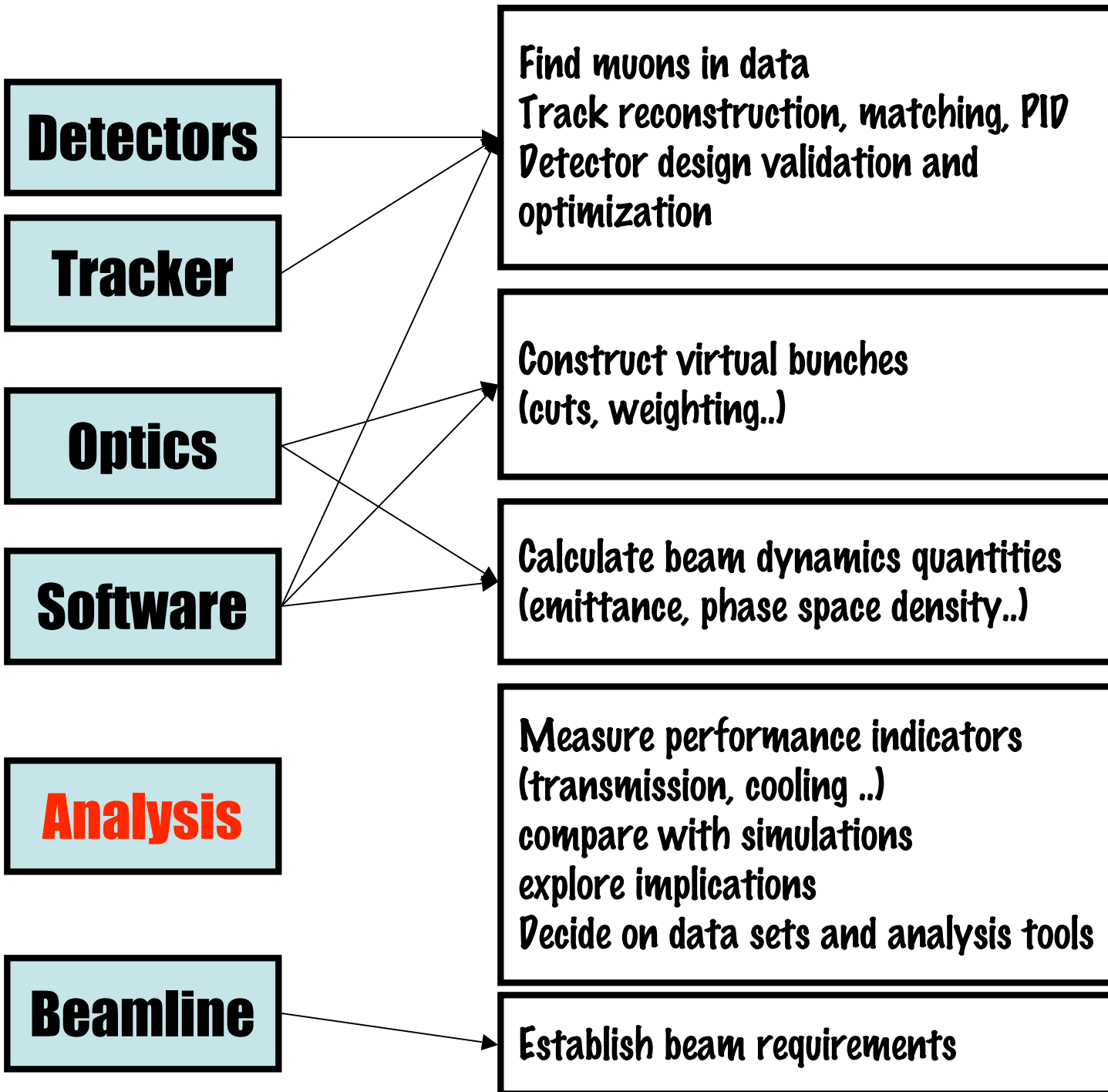


Group Mission



MICE Analysis Forum formed at cm1 2 (NuFact05)

- **Study how to achieve the physics goals of MICE**
 - ✓ **Run plan: what sets of measurements do we need to convince ourselves and others that ionization cooling is feasible (operations, beamline)**
 - Need detailed plan by Apr 07
 - **Cooling channel: acceptance and required alignment tolerances (Optics, beamline, engineering groups)**
 - Complete/document beam dynamics for all stages
 - **Parameters that need to be monitored/controlled and associated tolerances (Controls/DAQ, AFC, RFCC)**
 - Accuracy and frequency requirements
 - ✓ **Detector performance requirements (Tracker, PID)**
 - Longitudinal emittance resolution
 - Set of detectors needed for global PID
 - ✓ **Analysis tools and techniques (Software)**
 - Make G4MICE Optics/Analysis tools more accessible
- **Identify and follow up on issues, link to/document existing work**





Setup and meeting schedule



- All material under: <http://mice.iit.edu/analysis/forum.html>
- And for discussion: mice-analysis@mice.iit.edu
- “Bi-weekly” phone meetings
 - Aug 5 [Run plan (Blondel)]
 - Aug 19 [Emittance analysis (Rogers)]
 - Sep 15 [Detector performance]
 - Tracker resolution (Ellis)
 - Time-of-flight resolution (Sandström)
 - Sep 30 [Cooling channel]
 - Optics (Bravar)
 - Beamline matching (Rogers)
 - MANX (Yonehara)
 - Dec 1
 - Physics parameter list for monitoring/controls [Cummings]
 - Beam and data rate considerations [Torun]
 - Dec 15 [Longitudinal dynamics (Rogers)]
 - Jan 12 [EPAC06 abstracts]
 - Jan 26 [Meeting schedule]
 - Feb 9 [Energy spread and angular momentum effects (Rogers)]



Beam and Trigger Rates



- **Poisson distribution**
 - $P(n;\mu) = \mu^n e^{-\mu} / n!$
 - Probability of getting n muons in a fixed time interval Δt when the average rate is μ per Δt

| μ | 0 | 1 | >1 |
|-------|------|------|------|
| 1/8 | 0.88 | 0.11 | 0.01 |
| 1/4 | 0.78 | 0.20 | 0.03 |
| 1/2 | 0.61 | 0.30 | 0.09 |
| 1 | 0.37 | 0.37 | 0.26 |
| 2 | 0.13 | 0.27 | 0.59 |
| 3 | 0.05 | 0.15 | 0.80 |

- If limited to single muon per digitization cycle, increasing beam rate above digitization speed doesn't help
- Need to fold in beam spill/transport and readout substructure



Parameter table (Cummings, Blondel)



| Quantity | MICE organs | Tolerance | Monitor | Beam measurement (suggested) | Responsible | Channel count |
|----------------|--|-----------------------------|--|---|---|---------------|
| Beam | ISIS beam target magnets Collimators Diffuser... | TBD Alignment with expt? | Settings Beam instrumentation (profile & halo monitors ?) others | Measure beam averages and correlations, composition and emittance With/without diffuser | Drumm/Tilley | ✓ |
| Beam detectors | TOF Cherenkov | TBD | Volts, currents Occupancies, Dead channels others | Measure TOF vs nominal beam momentum Calibrate in configuration with electrons in beam ? | Palladino/ Bonesini Summers | |
| Emittance | tracker | $\ll 10^{-3}$ | TBD | Compare one tracker to the other with empty abs and no RF | Bross/ Long | |
| | PID | 10^{-3} | TBD | | Palladino/ Bonesini Gregoire Tortora | ✓ |
| DE/dX | Hydrogen absorber | A few 10^{-3} | Temperature Pressure thickness Others | Measure energy difference in configuration without RF and with full absorber(s) | Zisman Wing Lau MACC Ishimoto | ✓ |
| ΔE | RF system | A few 10^{-3} | Volts Phases Temps | Measure energy of outgoing muons vs phase or with/without RF | Zisman Derun Li | ✓ |
| optics | positions of coils internal survey | some mm | ISIS alignment system position monitors? | transfer matrix: (pt, pL, phi, x0, y0) ⁱⁿ <-> (pt, pL, phi, x0, y0) ^{out} measure with no RF and empty absorbers each time one changes the magnetic set-up. | Green /Black | |
| | currents | few 10^{-4} | amp-meter | | Zisman / Green | |
| | mag field | some 10^{-4} ~ | mag probes temp probes | | Zisman/Green / Linde | ✓ |

Y. Torun

NFMCC Mtg

Cooling Channel Parameters



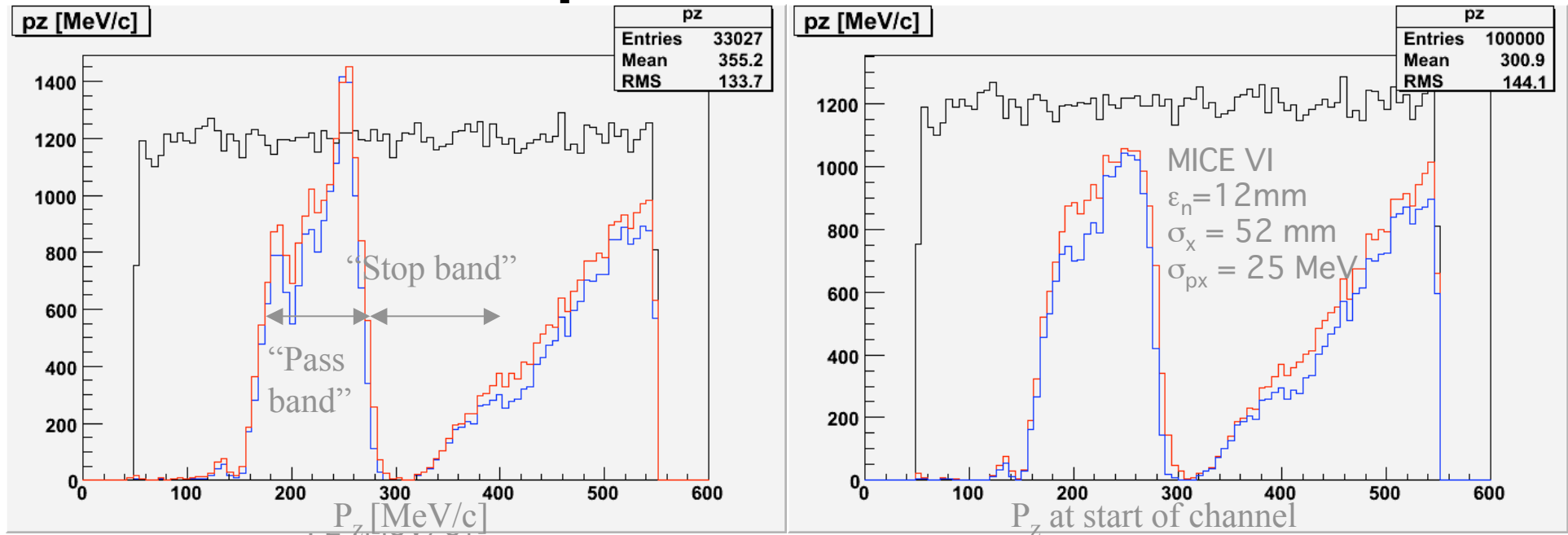
- **Material in beam path [minutes]**
 - Windows
 - Absorber (liquid and solid)
 - temperature, thickness, level?
 - dE and X_0 proportional to number of molecules (g/cm^2), not density (g/cm^3)
 - For cryogenic absorber
 - Volume determined by Al vessel
 - Density function of temperature
 - Bubbles?
- **Magnetic field**
- **Rf field/phase [pulse by pulse]**

$$\frac{d\varepsilon}{ds} = \frac{\left\langle \frac{dE}{ds} \right\rangle}{\beta^2 E} (\varepsilon - \varepsilon_0)$$

$$\varepsilon_0 \sim \frac{\beta_{\perp}}{\beta \left\langle \frac{dE}{ds} \right\rangle X_0}$$

MICE VI Momentum Acceptance

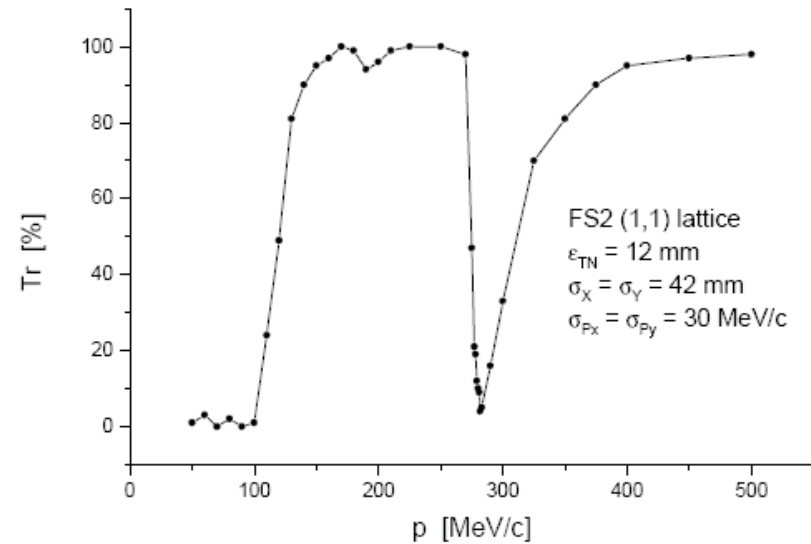
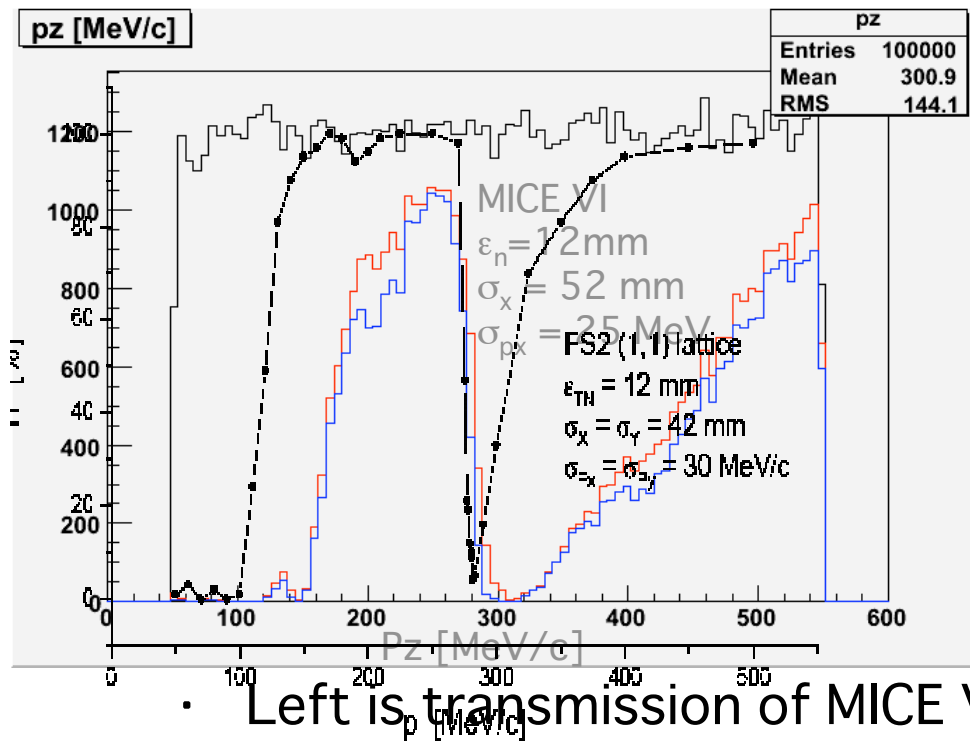
C. Rogers



- Transmission of MICE magnetic lattice vs P_z
 - _ Particles matched for 200 MeV/c
 - _ Red is 10 MICE lattices, blue is 20 lattices, 1 metre aperture
 - _ Left is histogram of P_z at various points in the channel
 - Particles seem to diffuse away from 180 MeV/c (" $3\pi/2$ ")
 - _ Right plot show p_z at beginning of the channel of particles that survive

Comparison with FS2

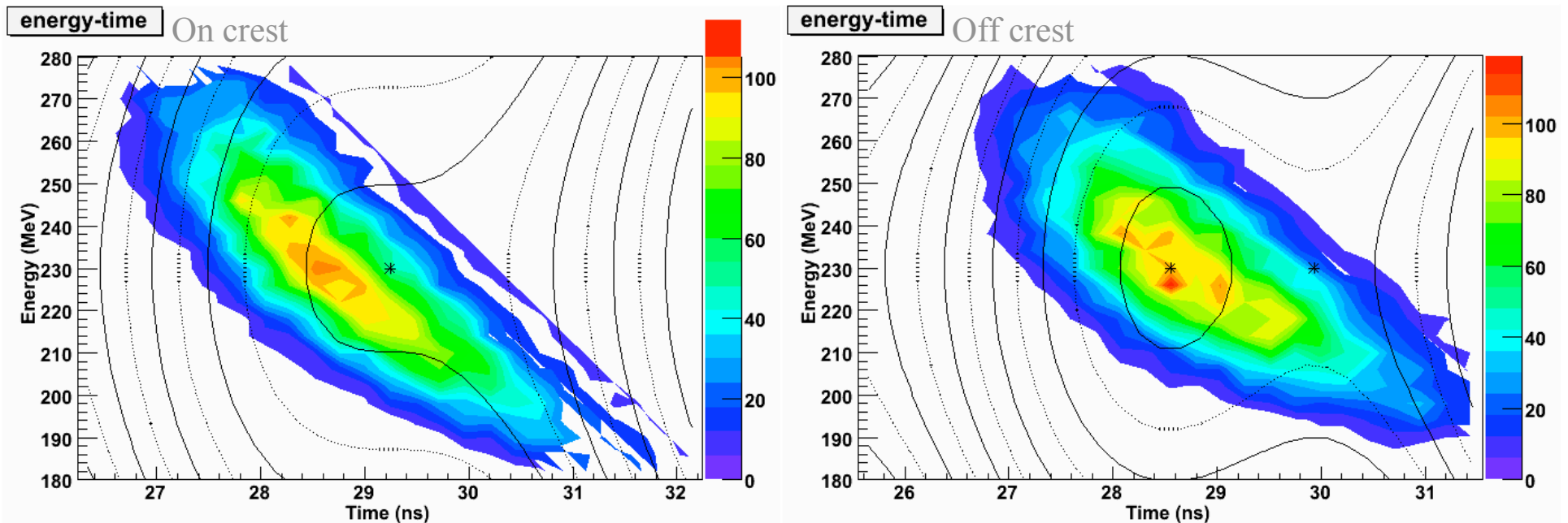
C. Rogers



- Left is transmission of MICE VI, right is FS2 (1,1) lattice (Fernow, Muc-241)
 - _ FS2 (1,1) exhibits broader momentum acceptance in the 200 MeV/c region
 - _ FS2 (1,1) lattice has $\beta=280 \text{ mm}$ in the absorbers
 - _ Both use 1 metre apertures
 - Not realistic


Longitudinal Phase Space *C. Rogers*


- MICE is scheduled to run on-crest
 - RF power too expensive to run off-crest
 - FS2 RF runs at 40° (relative to $E_z=0$)
 - May be possible to run MICE V off-crest
- Off-crest allows us to look at debunching due to Energy straggling
 - Longitudinal phase space at the centre of the 8th RF cavity:




Results – Stage 6, summary BG rejection, expressed in *impurity*

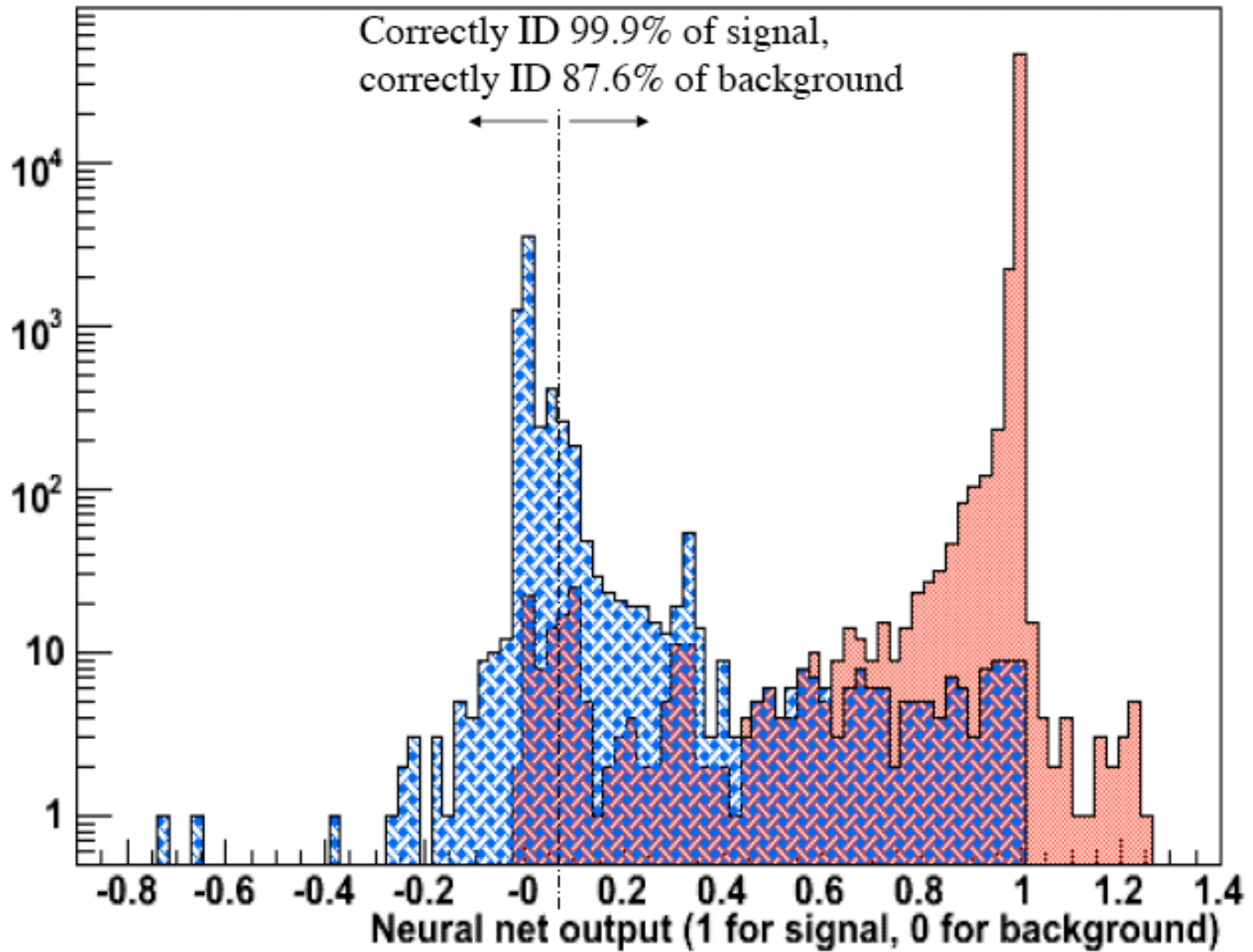
| Initial mom. | No cal., with TOF | KL, no TOF | SW, no TOF | KL, with TOF | SW, with TOF |
|--------------|-------------------|------------|------------|--------------|--------------|
| 140±14 MeV/c | 0.24% | 0.20% | 0.093% | 0.19% | 0.093% |
| 170±17M eV/c | 0.17% | 0.19% | 0.17% | 0.16% | 0.12% |
| 200±20M eV/c | 0.14% | 0.15% | 0.091% | 0.073% | 0.044% |
| 240±24M eV/c | 0.089% | 0.088% | 0.022% | 0.050% | 0.020% |
| TURTLE | | | | 0.070% | |

 Not meeting req.

 Meeting basic req.
(0.2%)

 Meeting safety req.
(0.067%)

Stage 6, 200 MeV/c








Forum Meetings



- **Preliminary plans until cm15**
 - **Mar 23**
 - SFoFo dynamics (Rogers)
 - Step III (Apollonio)
 - **Apr 6**
 - TOF issues (Rogers)
 - PID status (Sandström)
 - **Apr 20**
 - Status of simulation tools (Ellis/Rogers/Torun)
 - **May 4, May 18, Jun 1 - TBA**
 - **Other topics**
 - Material in beam path (Green)
 - Physics parameters (Bross/Graulich?)
 - Run plan (Blondel/Torun)
 - SFoFo dynamics (Fernow)
 - 6D cooling with wedge (Palmer)
 - Suggestions?

Meeting Schedule - Mar 06

| Sun | Mon | Tue | Wed | Thu | Fri | Sat |
|-------------------------|-----|------------------------------|--|---|-----|------|
| 26 | 27 | 28 - Collab Mtg (cm 14) - | 1 | 2 | 3 | 4 -- |
| 5 Software WS -- | 6 | 7 | 8 | 9 | 10 | 11 |
| 12 - NFMCC Meeting - | 13 | 14 | 15 | 16 - MUTAC - | 17 | 18 |
| 19 | 20 | 21 | 22  | 23  | 24 | 25 |
| 26 | 27 | 28 | 29  | 30 | 31 | 1 |





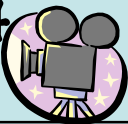


Meeting Schedule - Apr 06

| Sun | Mon | Tue | Wed | Thu | Fri | Sat |
|---|-----|-----|--|---|-----|-----|
| 26 | 27 | 28 | 29  | 30 | 31 | 1 |
| 2  | 3 | 4 | 5  | 6  | 7 | 8 |
| 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| 16 | 17 | 18 | 19  | 20  | 21 | 22 |
| 23 | 24 | 25 | 26  | 27 | 28 | 29 |
| 30 | 1 | 2 | 3  | 4  | 5 | 6 |

- Software WS -

- Scoping Study Meeting -

Meeting Schedule - May 06

| Sun | Mon | Tue | Wed | Thu | Fri | Sat |
|-----|-----|-----|--|---|-----|-----|
| 30 | 1 | 2 | 3  | 4  | 5 | 6 |
| 7 | 8 | 9 | 10 | 11 | 12 | 13 |
| 14 | 15 | 16 | 17  | 18  | 19 | 20 |
| 21 | 22 | 23 | 24  | 25 | 26 | 27 |
| 28 | 29 | 30 | 31  | 1  | 2 | 3 |



Random Sample of Questions Mentioned at cm14



- **What special runs and configurations do we need for calibration, alignment, monitoring, physics?**
 - pencil beams, pions/protons, high intensity
 - empty absorber, off-crest rf, 1 cavity at a time
- **Do we understand the optics of the cooling channel and beamline matching well enough?**
 - don't want cooling measurement to be obscured by subtle optics
- **What analyses do we want/need?**
 - emittance calculation in nonlinear transport
 - offline bunching/weighting methods
 - PID algorithms



Outlook



- The forum is becoming more of a working group
- Existing effort/interest not consistent with MICE schedule and needs
 - We need more people (both senior and junior) to show more interest
 - We are concentrating on the most pressing issues
 - Plenty of interesting problems in beam dynamics, reconstruction and cooling analysis
 - Urgent items
 - Understand longitudinal dynamics and TOF requirements
 - Study stages I-III
 - Clarify PID performance
 - Review physics parameters
 - Other fun stuff
 - Weighting/analysis for offline bunching
 - Other experiments using MICE hardware/infrastructure