



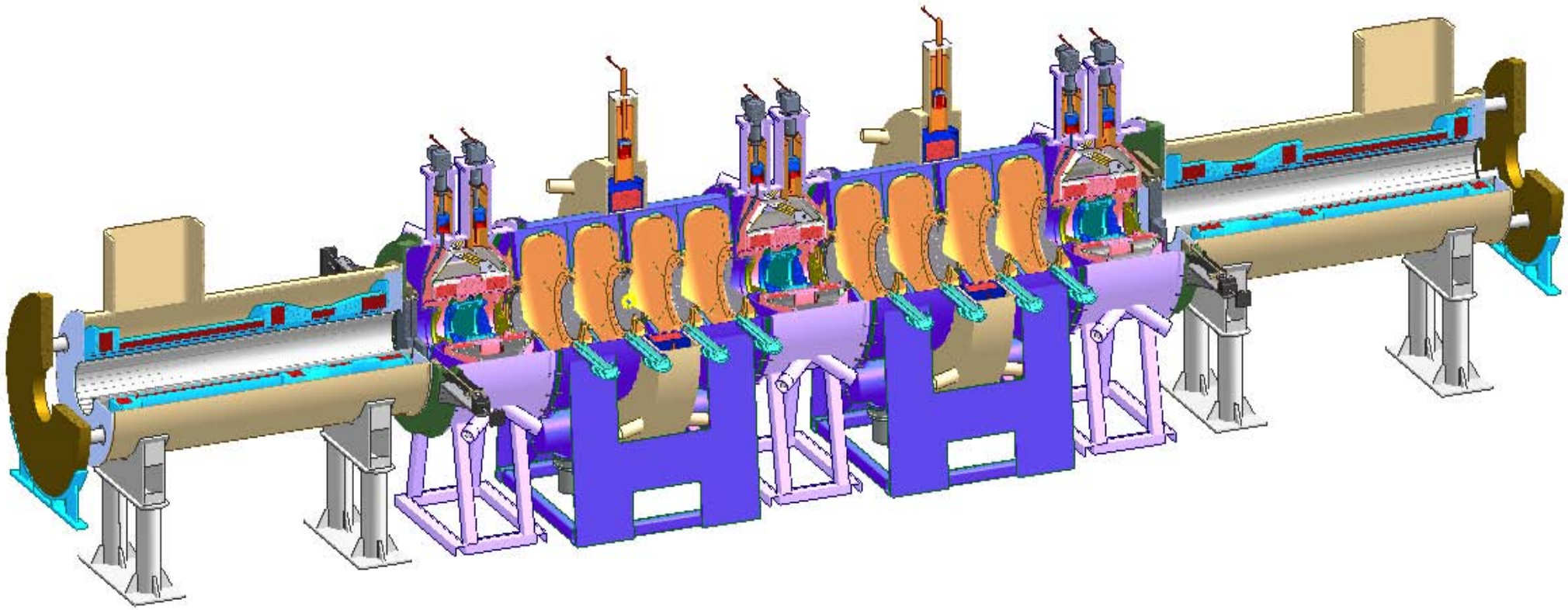
Of MICE and Muons

Daniel M. Kaplan
US Spokesperson, MICE Collaboration



Muon Collaboration Meeting
Lawrence Berkeley Lab
Feb. 14, 2005

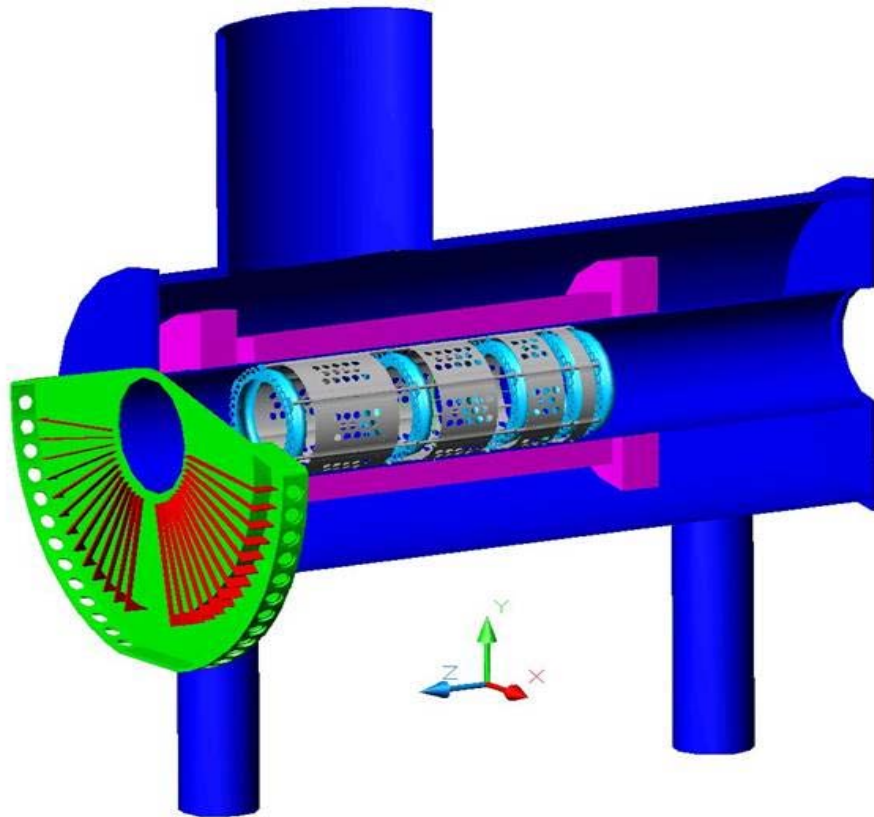
Muon Ionization Cooling Experiment



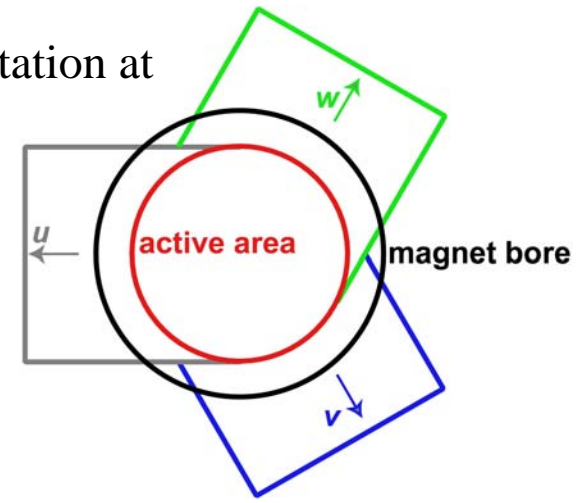
- Goal: measure ε_N before and after cooling section to $\sigma(\varepsilon_N) = 10^{-3}$, giving $\sigma(\Delta\varepsilon_N) \approx 1\%$

How is $\sigma(\varepsilon) = 10^{-3}$ achieved?

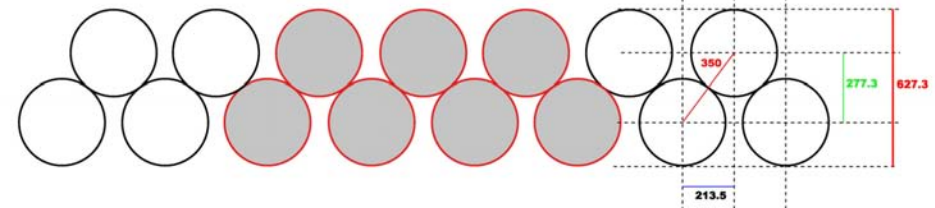
- 5-plane 350- μm SciFi solenoidal spectrometers measure each muon before and after cooling section:



3 views per station at
60° stereo:



Doublet arrangement in each view:



- We have $(\sigma_i^{meas})^2 = (\sigma_i^{true})^2 + (\sigma_i^{res})^2 \Rightarrow \sigma_i^{meas} = \sigma_i^{true} \sqrt{1 + \left(\frac{\sigma_i^{res}}{\sigma_i^{true}}\right)^2} \approx \sigma_i^{true} \left(1 + \frac{1}{2} \left(\frac{\sigma_i^{res}}{\sigma_i^{true}}\right)^2\right)$

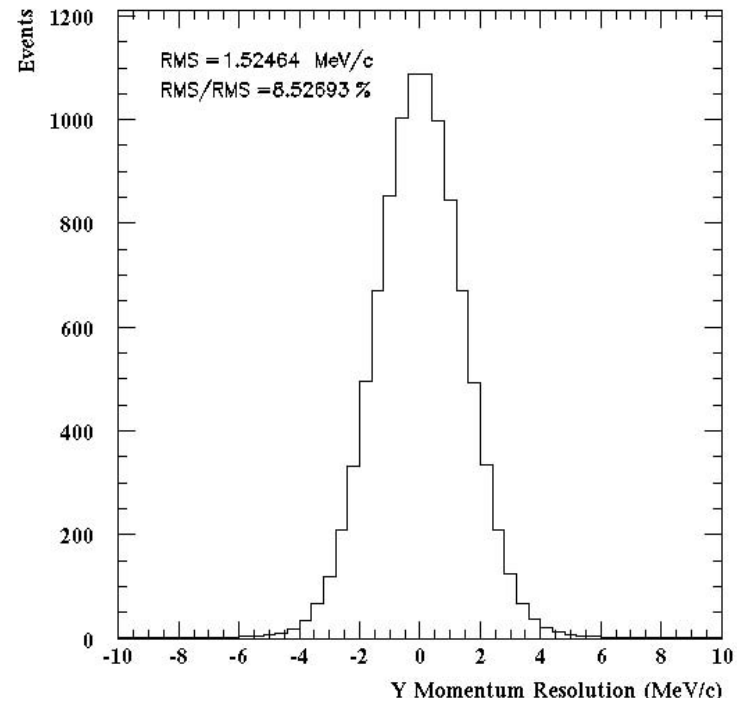
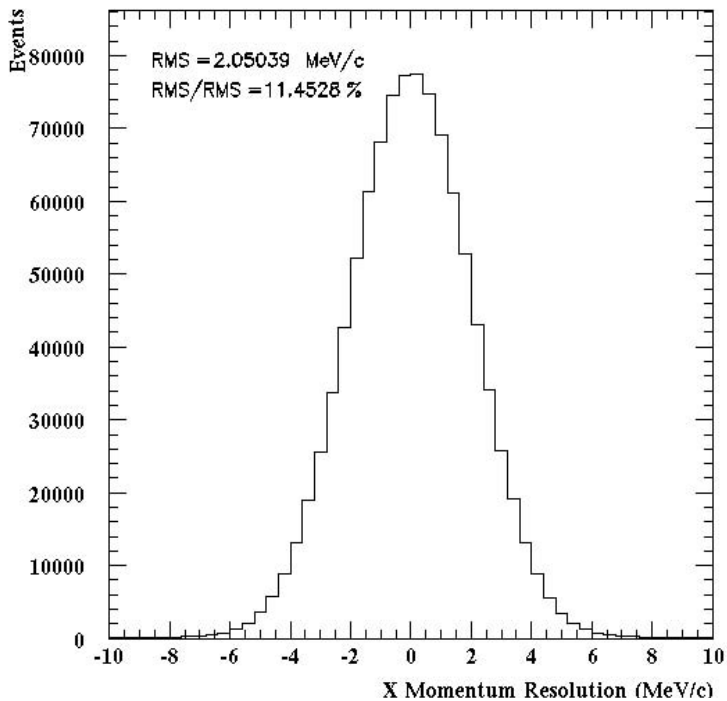
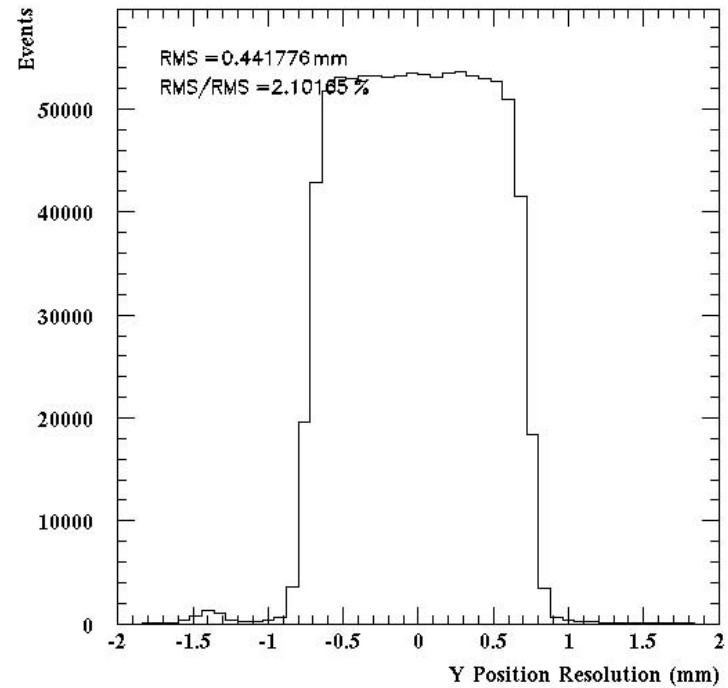
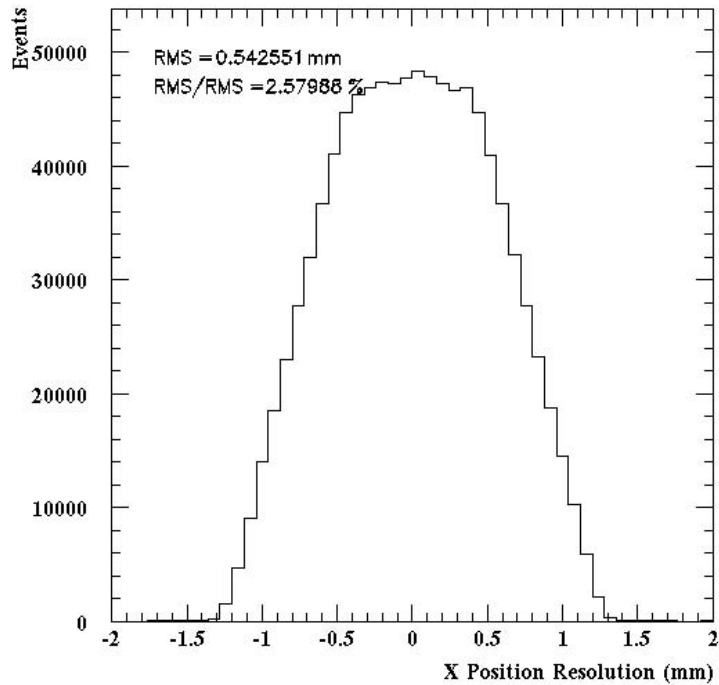
- Thus, for each phase-space variable i , must have $\frac{\sigma_i^{res}}{\sigma_i^{true}} \leq \frac{1}{7} \approx 14\%$

Simulated Tracker Performance in G4MICE

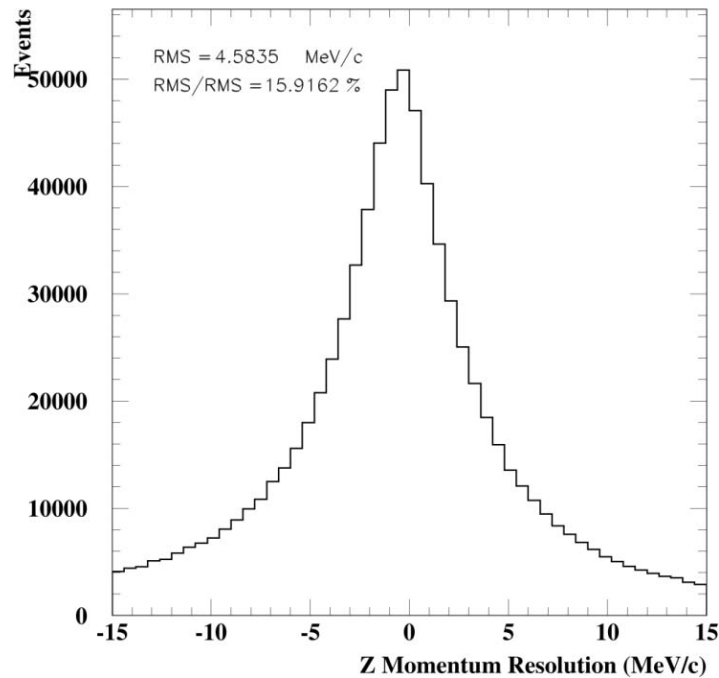
(from A. Khan et al., MICE Note 90, Feb. 2005)

2.5 pi mm rad

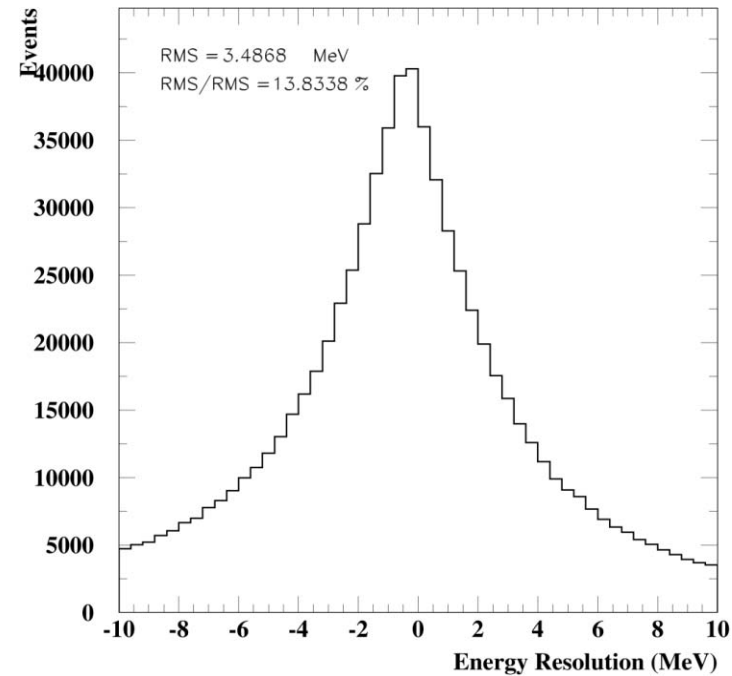
2.5 pi mm rad



2.5 pi mm rad



2.5 pi mm rad



- **Conclude:**

The 5 phase-space variables measured by the trackers (x , y , p_x , p_y , E) are all measured to better than 14% of the RMS of their distributions at the equilibrium emittance of the cooling section (2.5π mm rad)

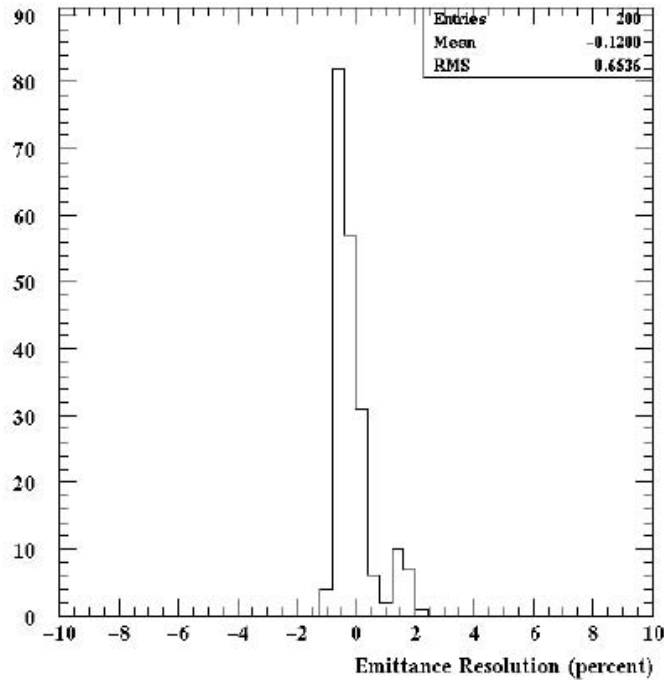
I.e., the requirement is satisfied

...but there's more to this:

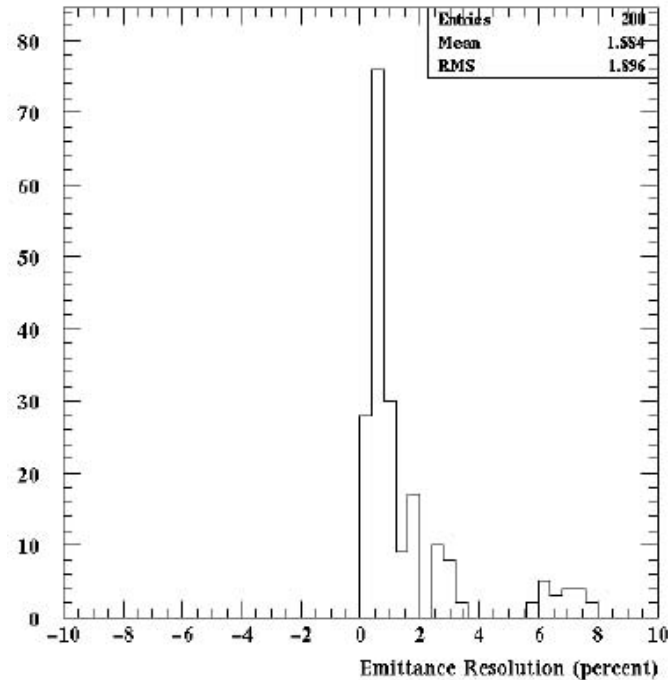
Bias Correction

- “Empty-channel” simulation, before correction:

Upstream Tracker – 50k events per bin



Downstream Tracker – 50k events per bin



- Correction scheme:

$$\varepsilon_N = \frac{1}{m_\mu} \sqrt[4]{|V_{4D}^{true}|}$$

– For each variable i , the true value is $w_i = m_i - \delta_i$

– Covariance matrix: $C_{ij} = \langle (\delta_i - \bar{\delta}_i)(\delta_j - \bar{\delta}_j) \rangle$

– Correlation matrix: $R_{ij} = \langle (m_i - \bar{m}_i)(\delta_j - \bar{\delta}_j) \rangle$

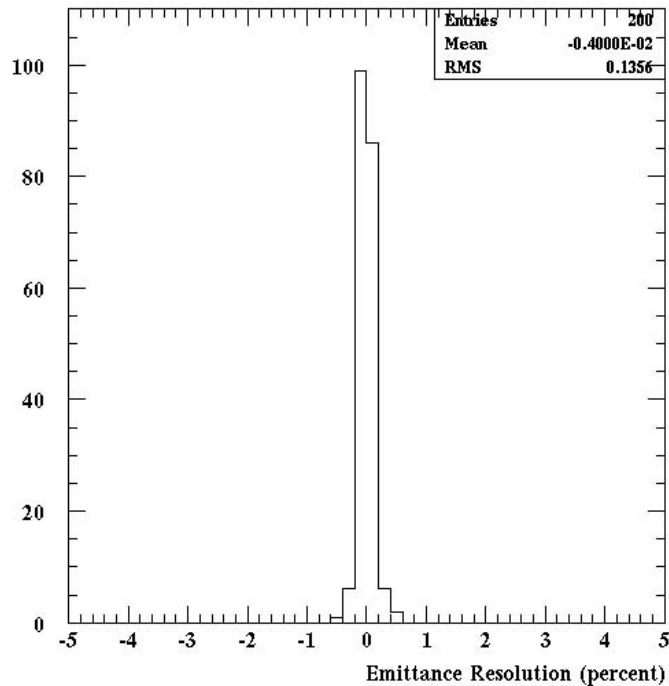
⇒ Then

$$V_{4D}^{true} = V_{4D}^{meas} + R + R^T + C$$

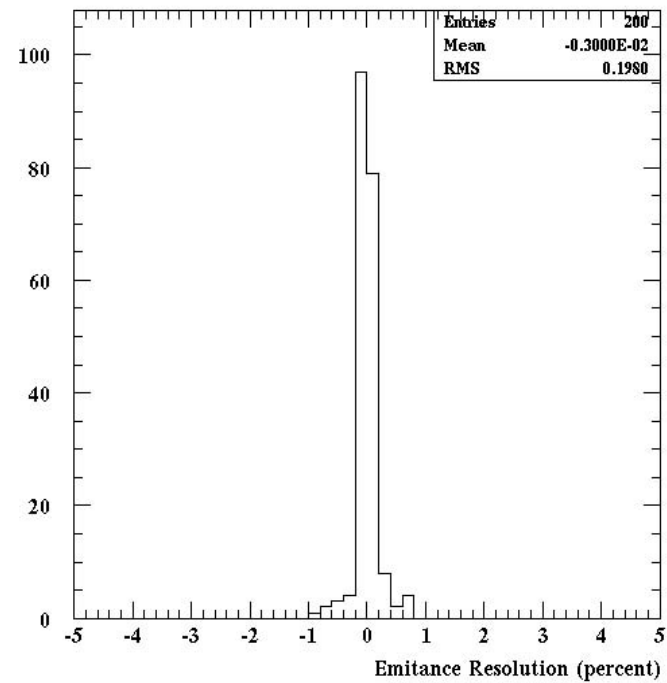
Bias Correction (cont'd):

- After correction:

Upstream Tracker – 50k events per bin



Downstream Tracker – 50k events per bin

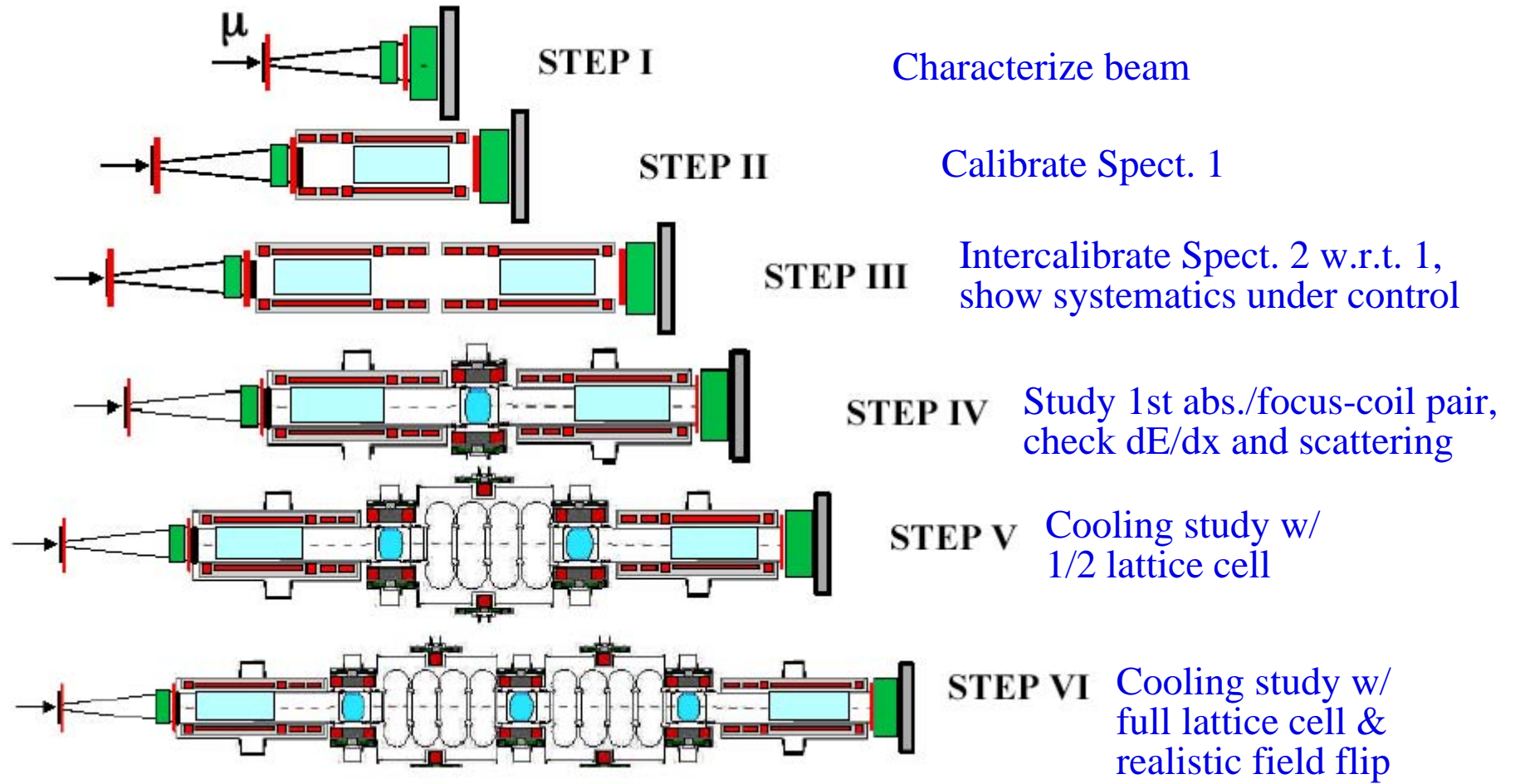


So far, so good! But...the crucial question:

→ *How well can this be done in practice?*

Avatars of MICE

- The MICE program is subdivided into a logical sequence of steps:

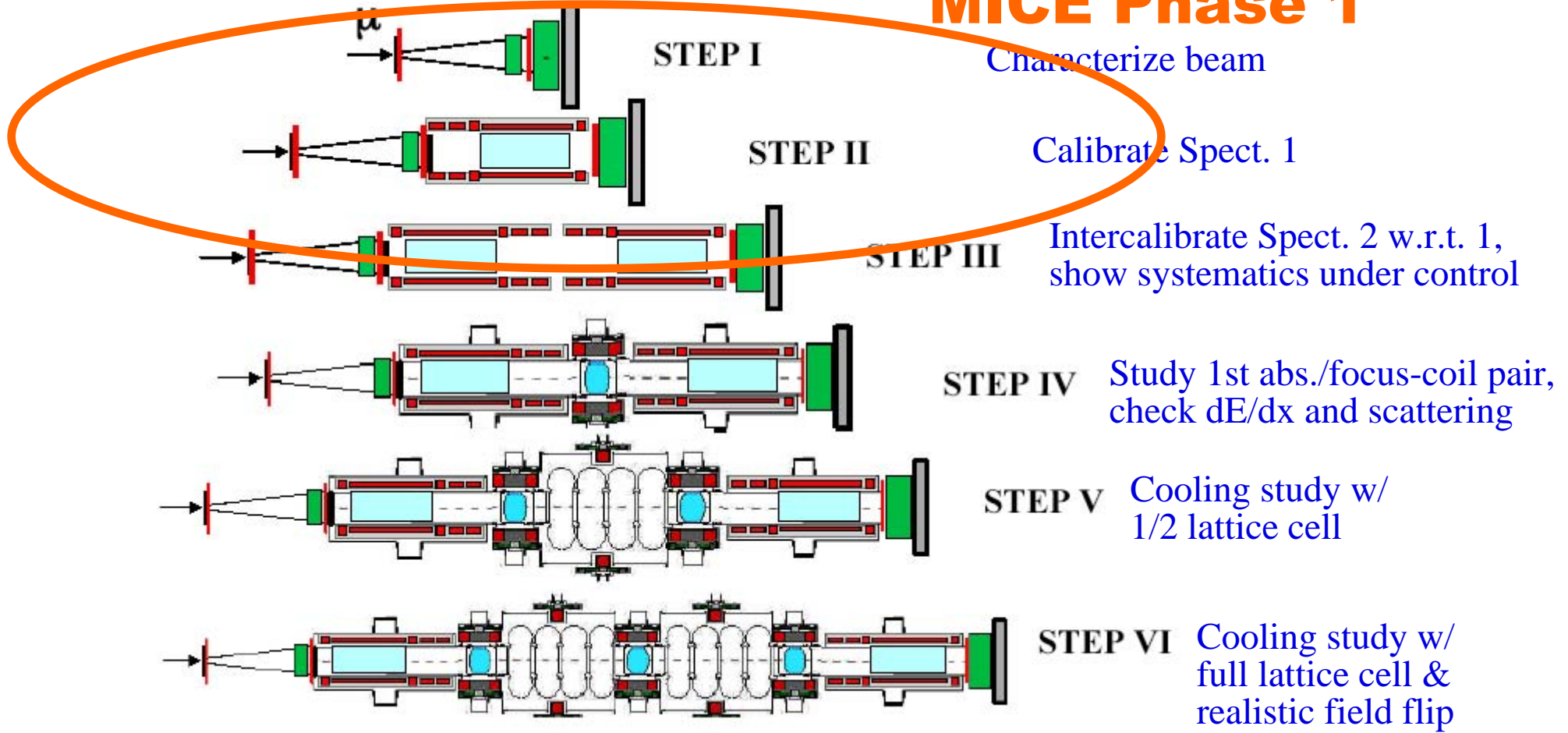


- Now focusing on “MICE Phase 1”

Avatars of MICE

- The MICE program is subdivided into a logical sequence of steps:

MICE Phase 1



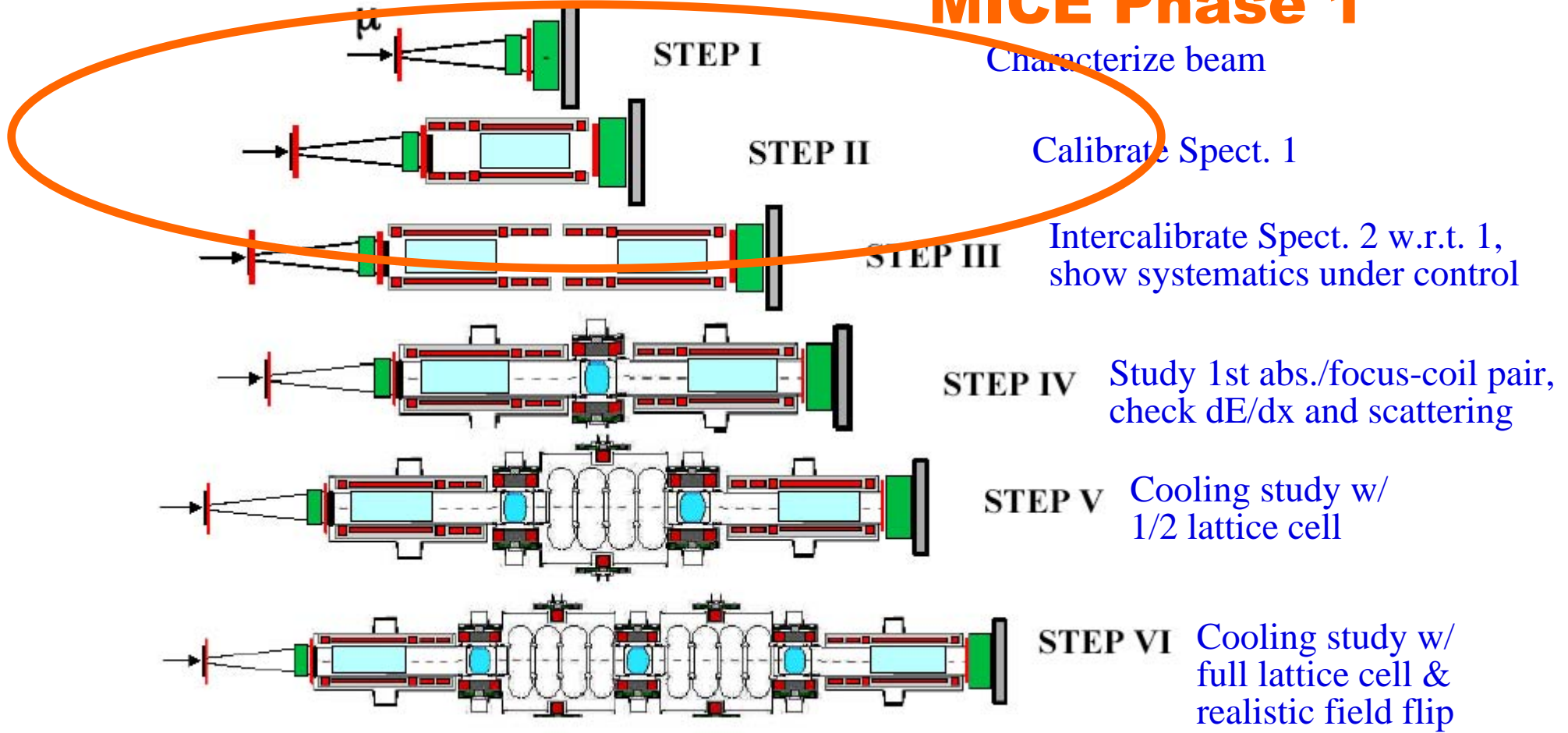
- Now focusing on “MICE Phase 1”

- Goal: get to Step III, demonstrate bias correction and control of emittance-measurement systematics to 10^{-3}

Avatars of MICE

- The MICE program is subdivided into a logical sequence of steps:

MICE Phase 1



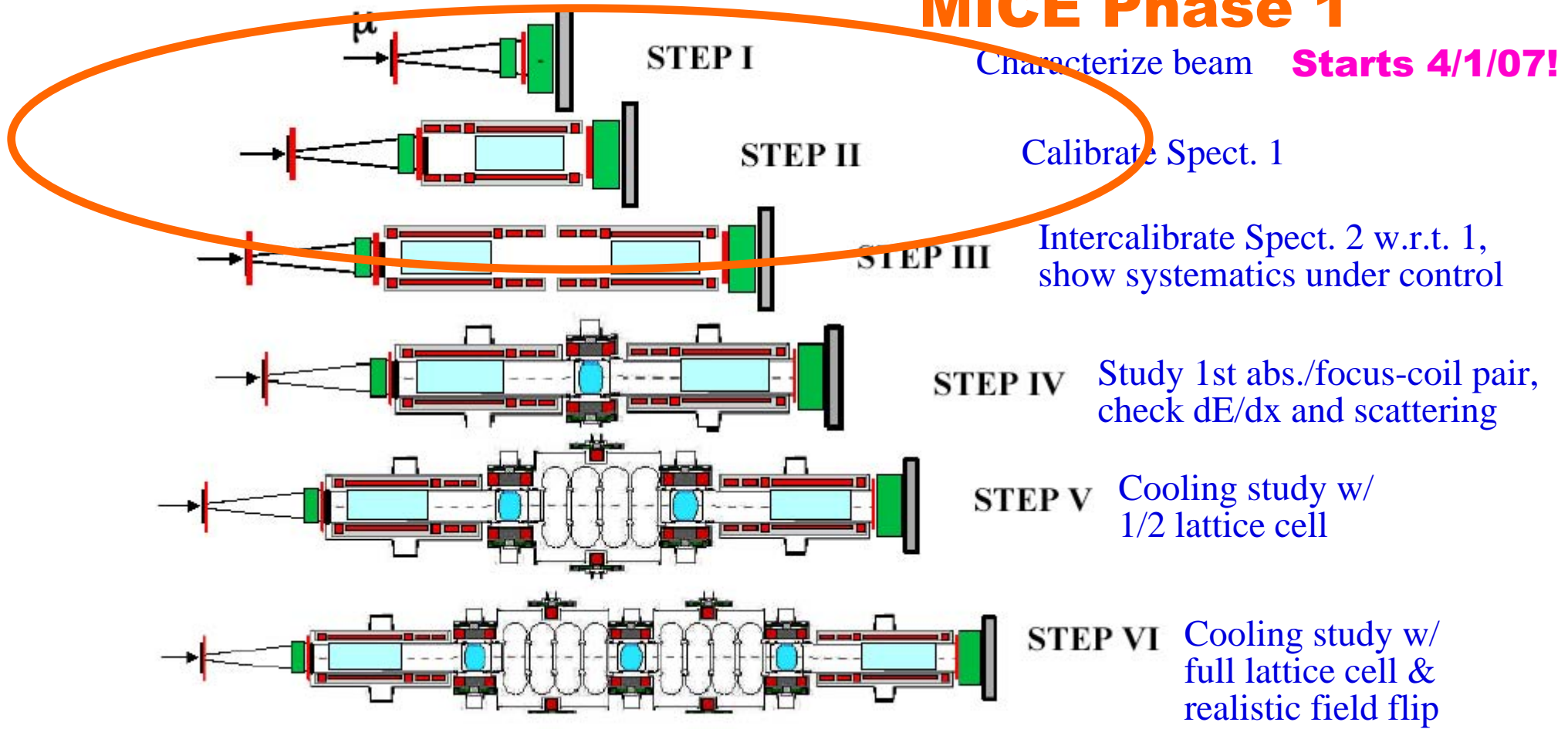
- Now focusing on “MICE Phase 1”

- Goal: get to Step III, demonstrate bias correction and control of emittance-measurement systematics to 10^{-3}
- **Can also ease funding process → reduces cash flow needed at start**

Avatars of MICE

- The MICE program is subdivided into a logical sequence of steps:

MICE Phase 1



- Now focusing on “MICE Phase 1”

- Goal: get to Step III, demonstrate bias correction and control of emittance-measurement systematics to 10^{-3}
- **Can also ease funding process → reduces cash flow needed at start**

US Contributions to MICE

- Originally proposed US contributions to MICE:
 - RF/Coupling-Coil (RFCC) modules
 - LH₂-absorber windows
 - Tracker assembly, photosensors & readout electronics
 - Beam Cherenkov counter
 - DAQ buffers
 - 1st spectrometer solenoid recently added to list (possibly in place of 2nd RFCC module) as part of US MICE Phase 1, because Italian funding originally proposed could cause undue delay
 - combination of long lead time plus timing of proposal to INFN
 - Of agreed US contributions, RFCC modules most expensive (have large superconducting Coupling Coils, beryllium RF windows, etc.)
 - 1st one costs ≈\$2.2M, 2nd ≈\$1.5M
 - Spectrometer solenoids come in 2nd:
 - 1st one costs ≈\$1.8M
- ⇒ To get to Step VI, need ≈\$5.5M in equipment funds, preferably before 2010

From whence might this come?

- Italian MICE groups now preparing proposal to INFN, due in June, to fund (*inter alia*) both spectrometer solenoids
 - European MICE groups preparing “I3” proposal to EU (“Integrated Infrastructure Initiative”), due March 3
 - But, fabrication of superconducting spectrometer solenoid will take about 2 years, and “MICE Avatar” schema shows 1st solenoid needed in 2007/8
- ⇒ Depending on success of above proposals, keeping MICE on track may require full US expenditure as above

US MICE Funding Picture

- IIT+BNL/FNAL/LBNL/NIU/UCLA/UCR/UMiss submitted 5y US MICE Consortium NSF proposal for \$23.9M in Fall 2002 (also sent to DOE)
 - Approved! by NSF in Fall 2004 for 3 yrs @ \$100k/y
 - DOE has agreed to 3 yrs @ \$300k/y

⇒US MICE now funded by DOE + NSF @ \$400k/y

- But this is insufficient to meet above needs
- NSF Major Research Instrumentation proposal recently submitted by IIT+FNAL/LBNL for \approx \$2M (maximum allowed) over 2 years to build solenoidal spectrometer for MICE Phase 1
- One or more NSF “Partnerships for International Research and Education” proposal(s) in the works (from UCR/NIU/UNH? TBD, subject to limit of one per institution)
 - Program limit is \$500k/y for up to 5 y
 - Might cover travel plus some personnel
 - Proposal deadline 3/10/05

Request to Muon Collaboration

As the Targetry experiment and MuCool Test Area refurbishment & beamline installation wind down, could additional funds be made available for MICE by the Muon Collaboration?

US MICE Milestones

- 1st assume favorable scenario:

FY	US MICE \$	MRI \$	Σ (non-MRI \$)	milestone
'05	400K	1.1M	0.4M	
'06	400K	0.9M	0.8M	<i>US MICE Phase 1 done ~end 2006</i>
'07	400K		1.2M	
'08	800K		2.0M	<i>1st RFCC done ~end 2008</i>
'09	800k		2.8M	
'10	800k		3.6M	<i>2nd RFCC done ~end 2010</i>

MTA
beam
done?

Tgtry
expt
done

- What if MRI proposal fails?

FY	US MICE \$	Σ \$	milestone
'05	400K	0.4M	
'06	400K	0.8M	
'07	400K	1.2M	
'08	800K	2.0M	<i>US MICE Phase 1 done ~end 2008</i>
'09	800k	2.8M	
'10	800k	3.6M	<i>1st RFCC done ~end 2010 or 2011?</i>

Conclusions

- US *may* be able to “hold up our end” of MICE
 - including 1st spectrometer solenoid, really it’s *more* than our end, but we’re not complaining
- Our ability to do so will depend on our luck with NSF proposals recently or soon to be submitted (as well as the Italian proposal to INFN and joint European MICE proposal to EU now in preparation)

⇒ We hope to know better in ≈ 6 months

- Depending on degree of success of these NSF proposals, additional support of MICE by the Muon Collaboration (up to 1:1 match with NSF+DOE), starting in a few years, could play an important role