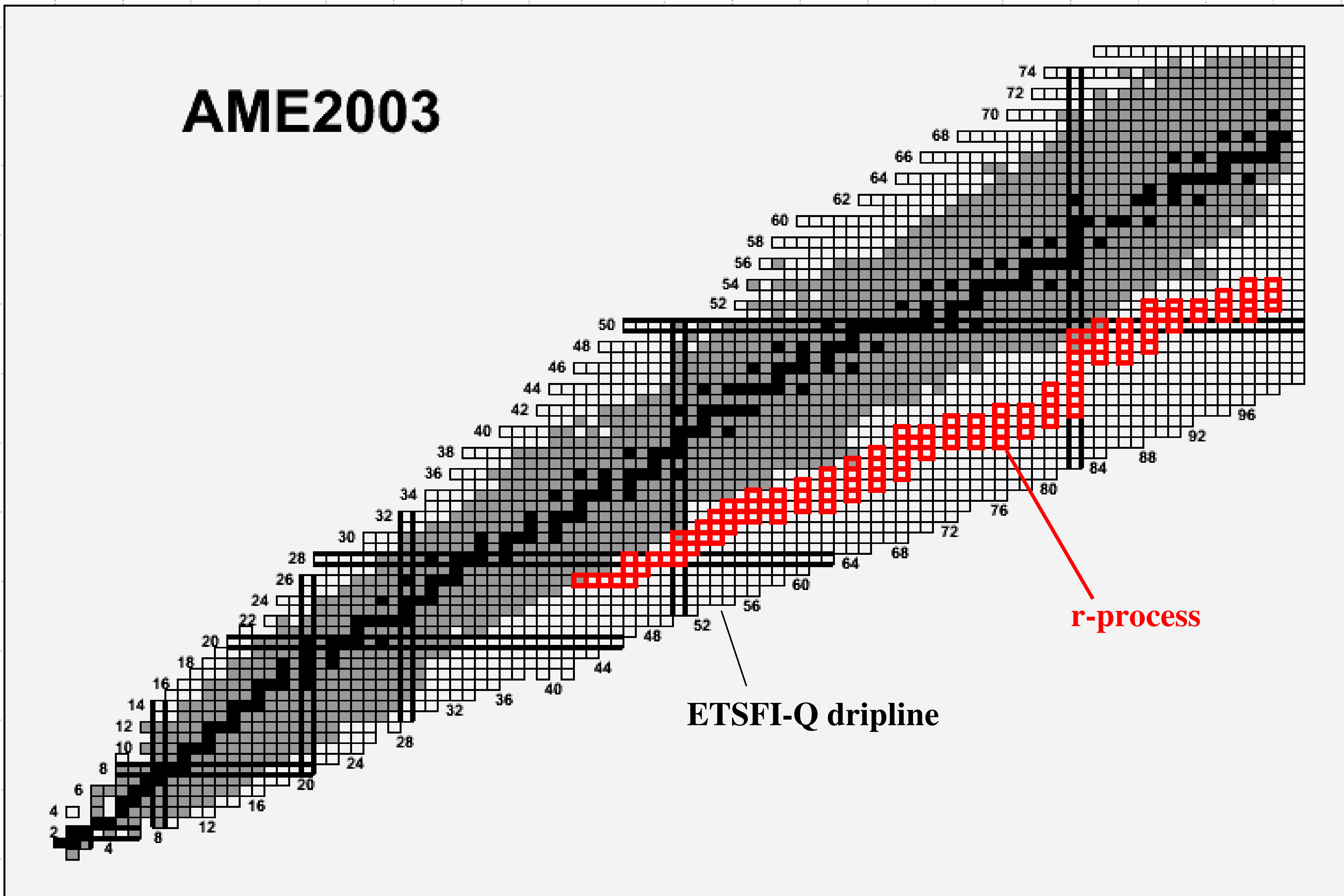
TOF Mass Measurements: Status and Future

(or When the Masses of the R-Process Nuclides will be Measured?)

Milan MATOŠ

Known Masses (AME 2003)



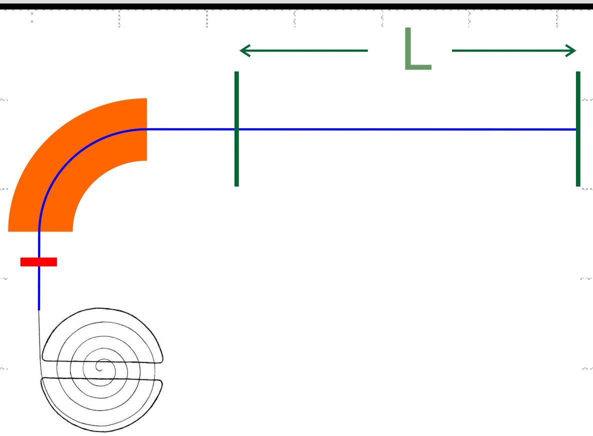
Mass Measurement Techniques

Penning traps	**Time-of-Flight**
very precise ~ 1 keV	less precise ~100 keV
half life > 10 ms	half life > 1μs
rate > 100 part/s after the nuclide production	rate > 0.01 part/s after the nuclide production
complex	simple

⇓

expected to be first to measure r-process masses

Principle of Time-of-Flight Mass Measurements

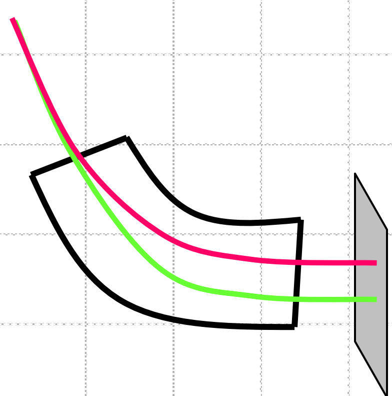


$$B\rho = \frac{m}{q} v \quad \xrightarrow[\substack{L = const \\ B\rho = const}]{v = \frac{L}{t}} \quad \frac{m}{q} = const \times t$$

usually Bρ acceptance ± several percent ~~$B\rho = const$~~

solutions

Bρ measurement — isochronicity

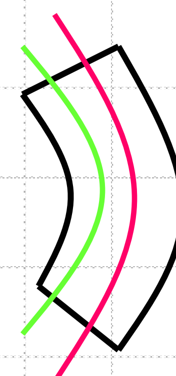


dispersive mode

$$B\rho \approx x$$

t constant for fixed m/q
even if $v_1 < v_2$

$$\frac{B\rho}{L} = const$$



Existing Time-of-Flight Mass Measurement Facilities

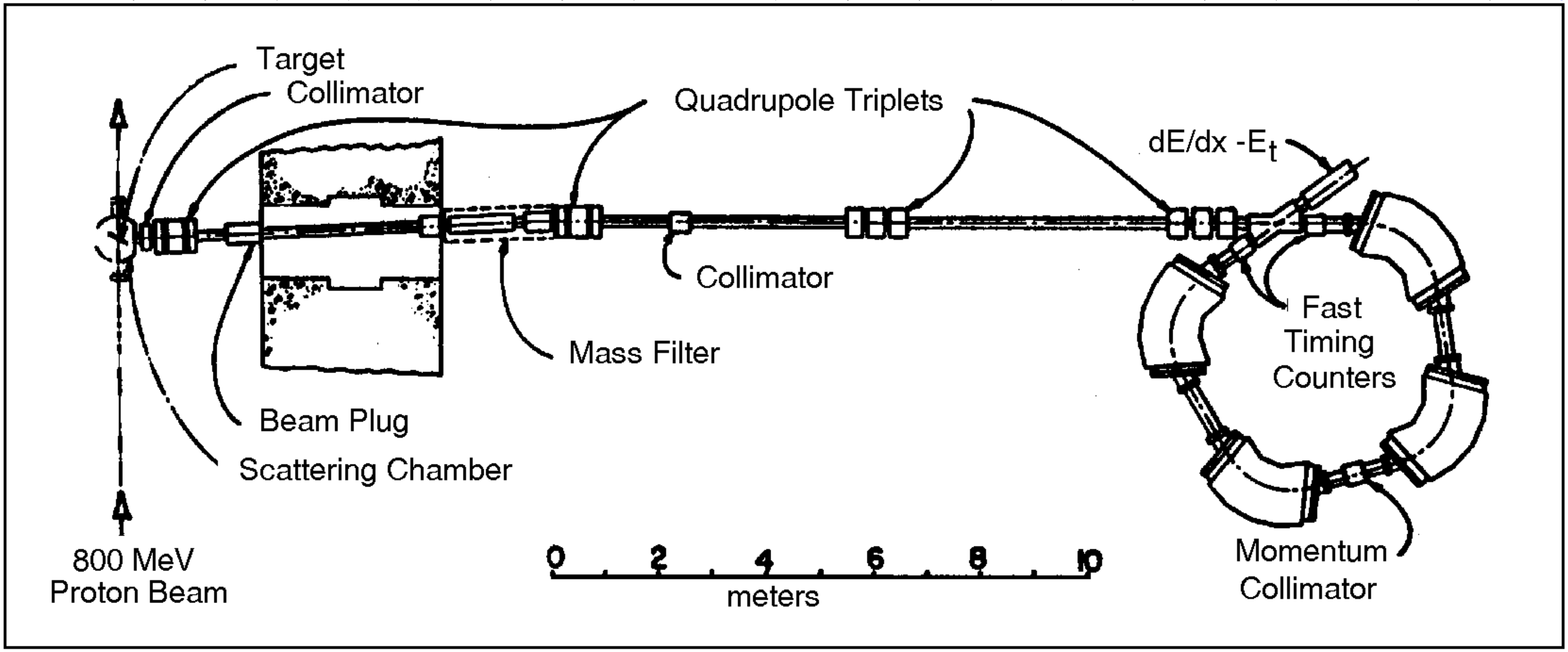
Bρ distribution

- Bρ measurement
- isochronicity

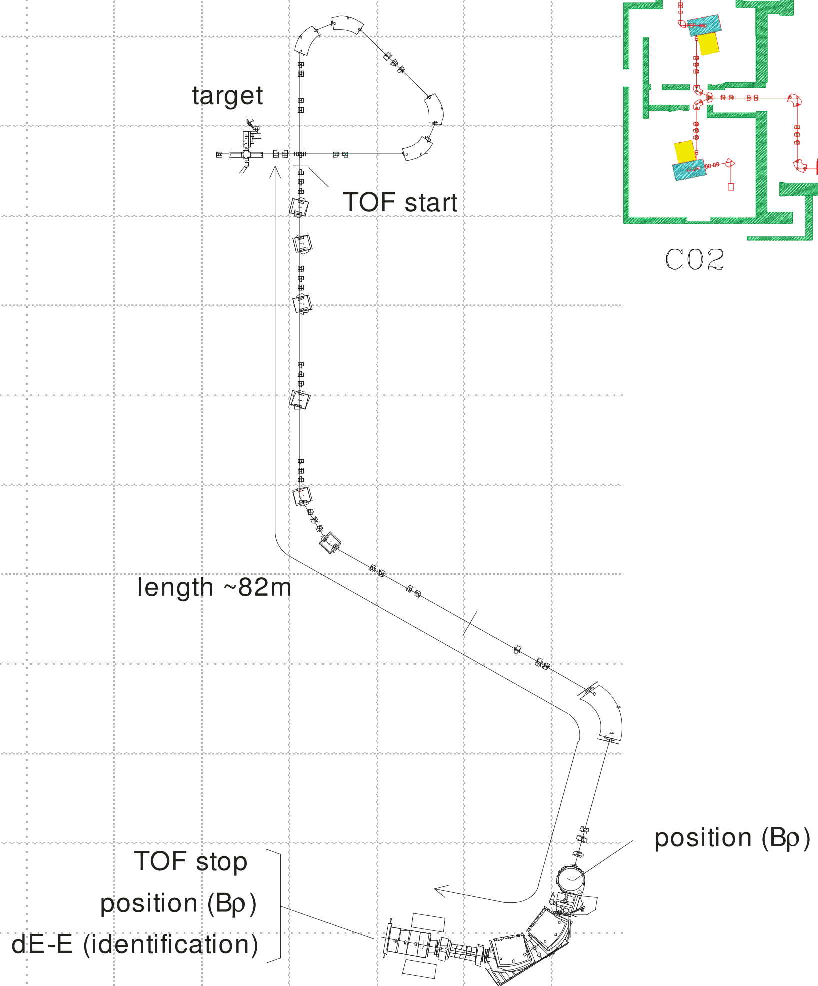
flight path

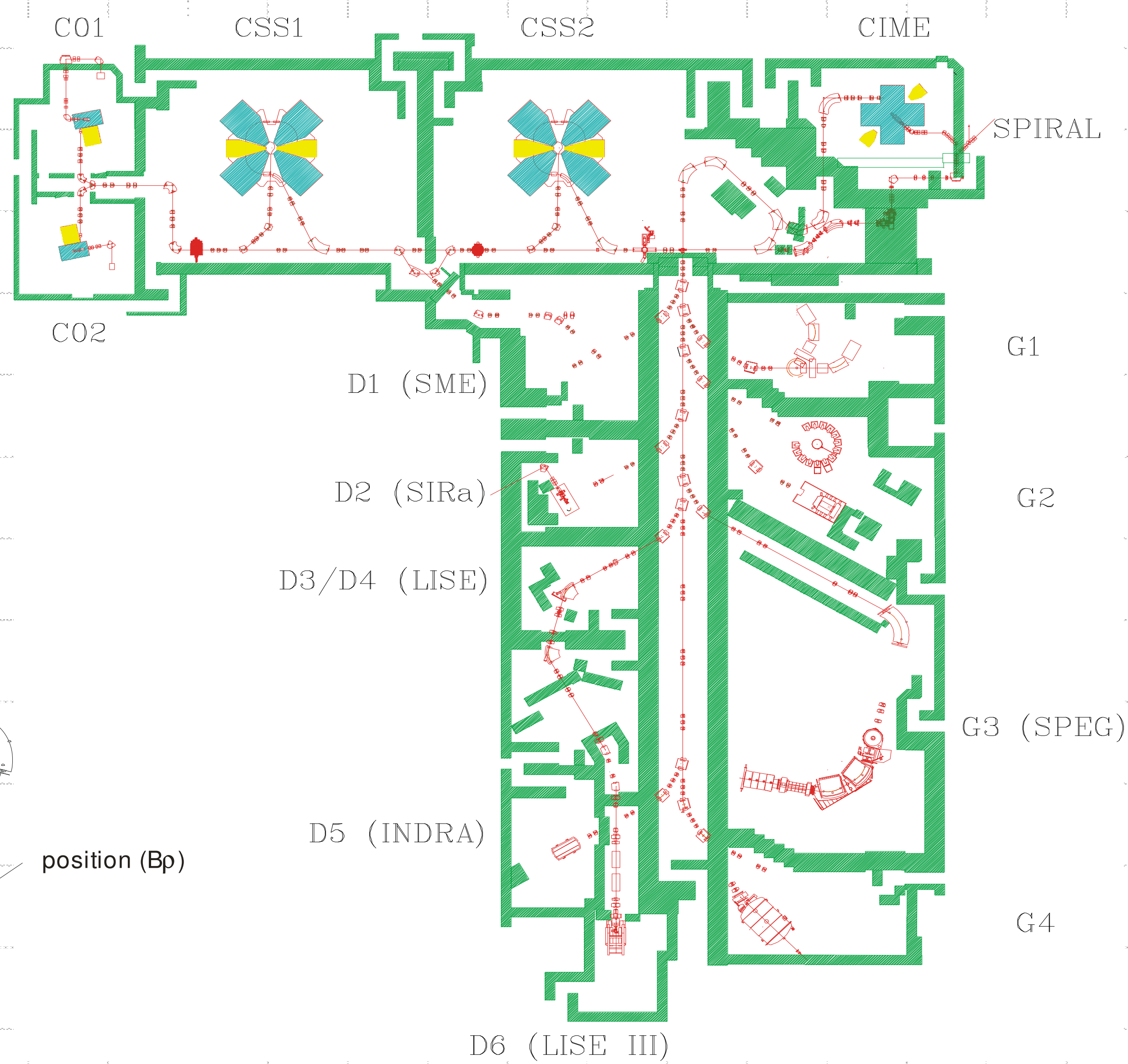
- linear
- multi-turn

TOFI at Los Alamos

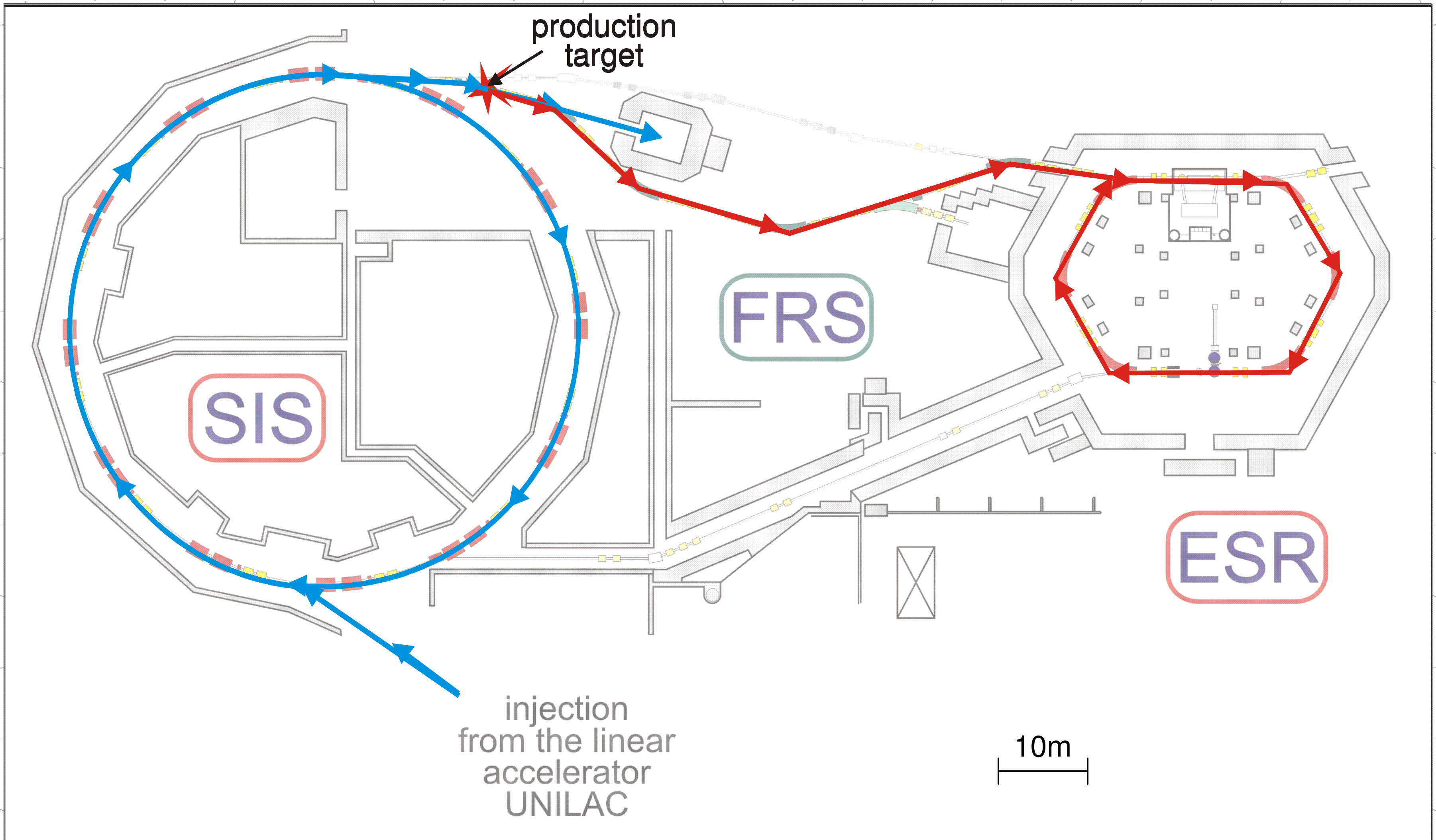


SPEG at GANIL

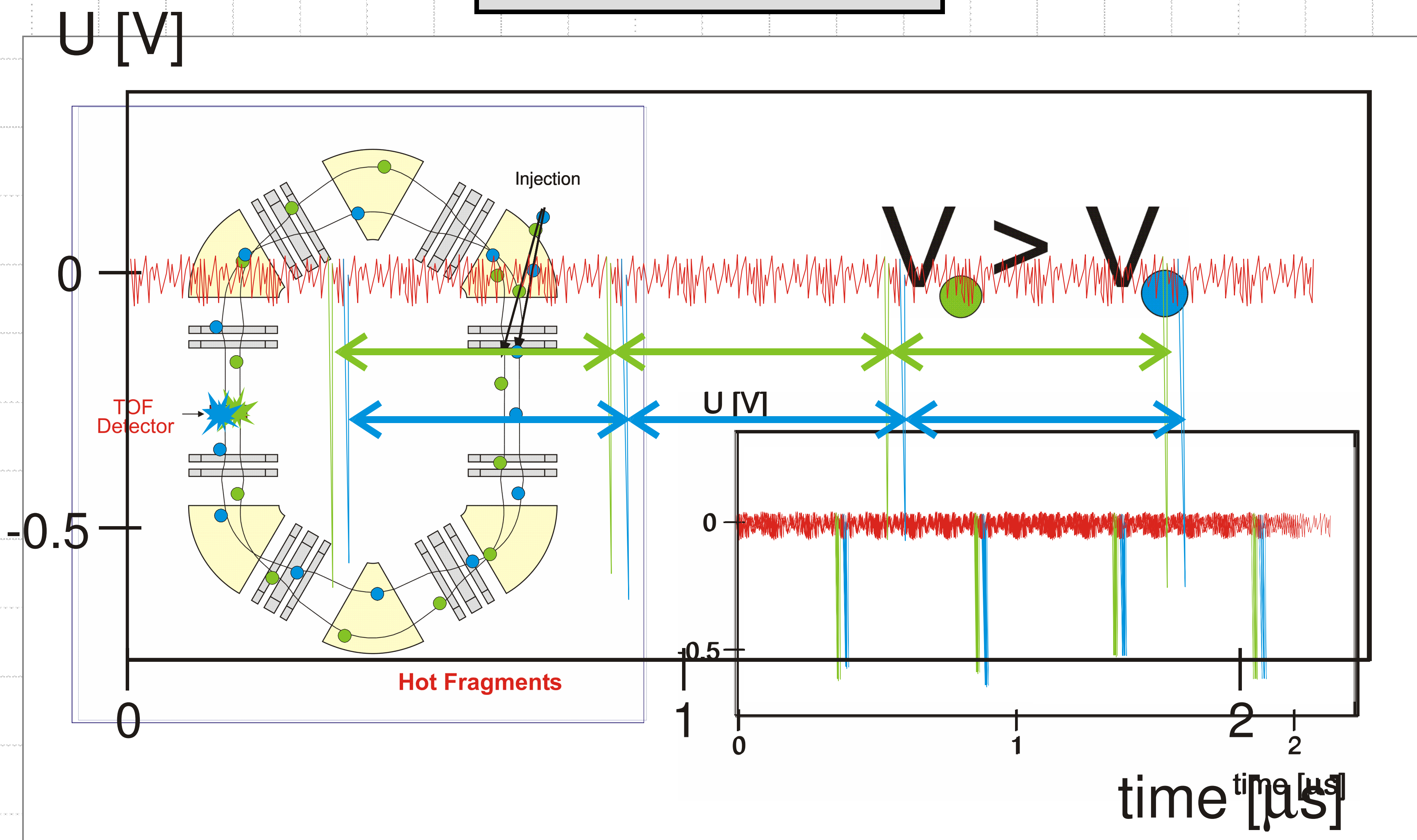




Isochronous Mass Spectrometry in ESR (at GSI)

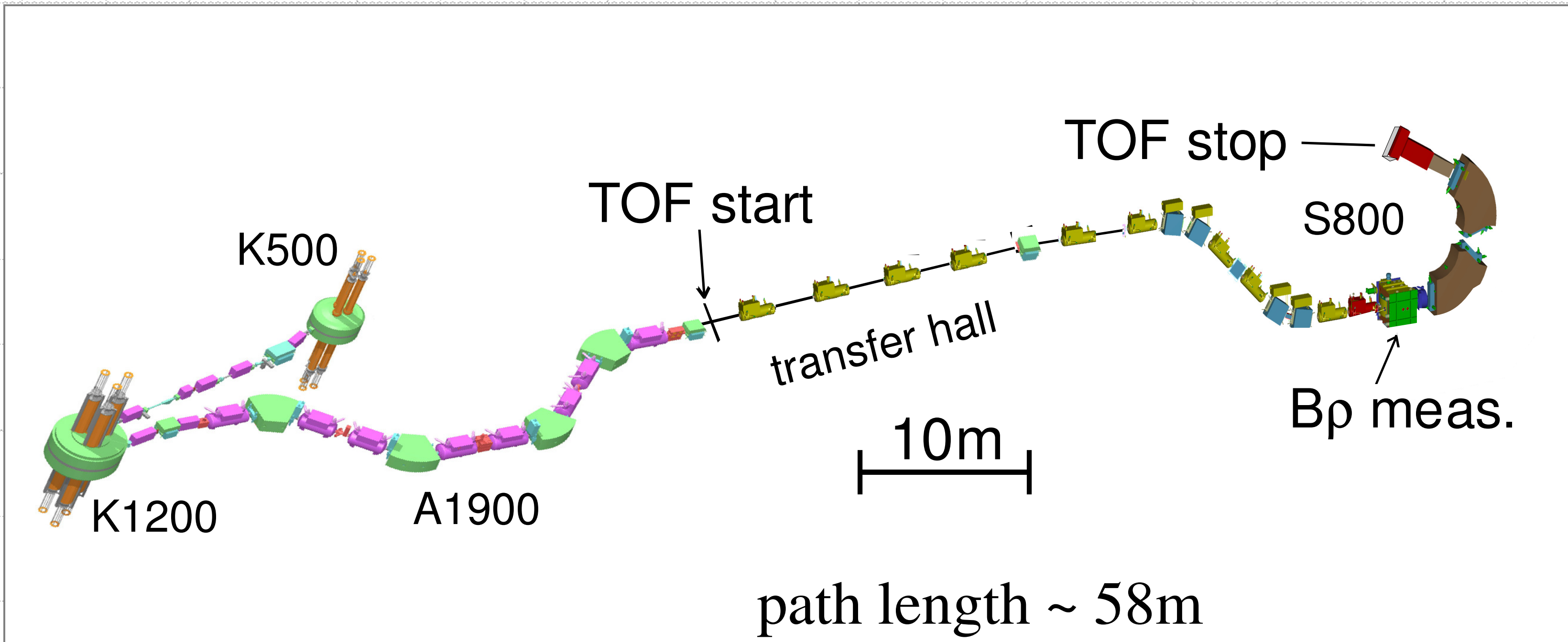


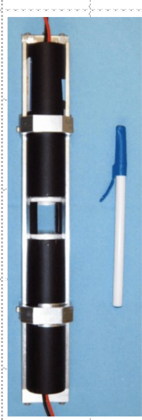
IMS at GSI



U [V]
0
-0.5
Injection
TOF Detector
Hot Fragments
V > V
U [V]
0
-0.5
0
1
2
time [µs]

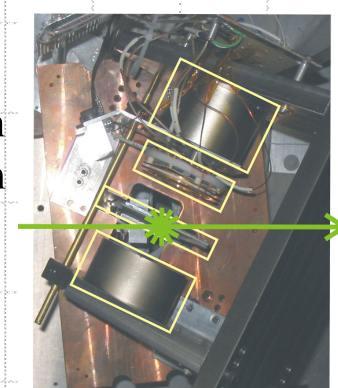
TOF-Bρ at the NSCL





fast PMTs:
Timing Resolution
σ ~ 30ps

MCP:
Position Resolution
σ < 0.5mm



see next talk by A. Estrade

Comparisons

	TOFI at LANL	**SPEG at GANIL**	**SMS at GSI**	**TOF-Bρ at NSCL**
Bρ distribution	isochron.	Br meas.	isochron.	Br meas.
flight path	N/A	82m	100 x 108m	58m
relative resolution	N/A	$1x10^{-4}$	$2x10^{-5}$	$1x10^{-4}$
relative uncertainty	$2x10^{-6}$	$1\text{-}2x10^{-6}$	$1\text{-}2x10^{-6}$	$1\text{-}2x10^{-6}$
typical energy	N/A	40 MeV/u	350MeV/u	100MeV/u

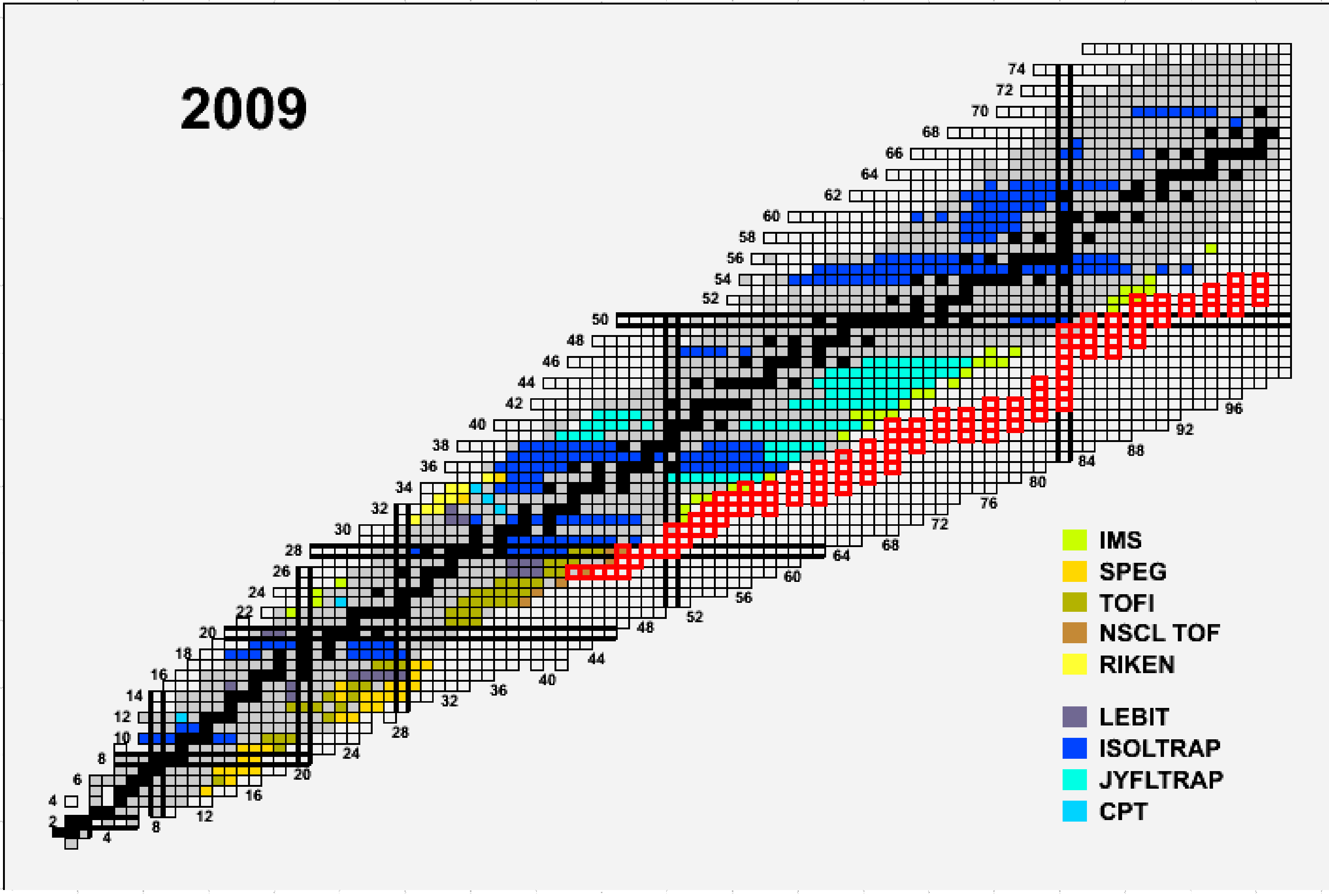
Comparisons

Isochronicity	vs.	Bρ measurement
difficult to set up		easy to set up
no Bρ measurement needed (no detector)		position sensitive required
limited m/q range for one setting		unlimited m/q range for one setting

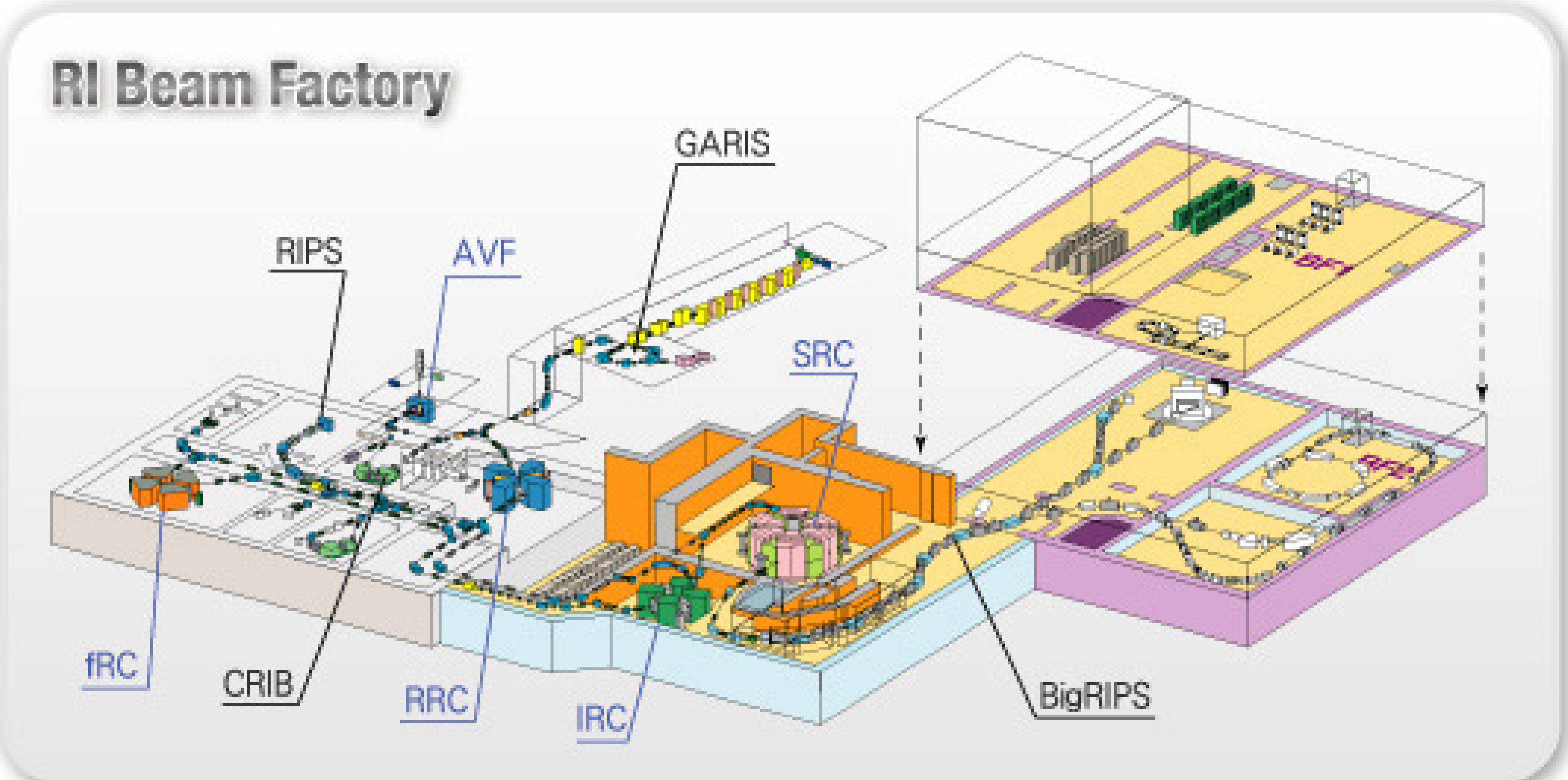
linear	vs.	multi-turn
worse resolution		better resolution
total statistics < 1000pps		limitation on total statistics < 10pps
isomeric contamination: fully covered by γ detectors		isomeric contamination: resolved for E > 500keV
transmission ~ 10%		transmission ~ 0.1%

low energy	vs.	high energy
large charge contamination		low charge contamination
large energy losses in detectors		low large energy losses in detectors
longer flight time		shorter flight time

TOF (yellow) vs. Penning traps (blue)

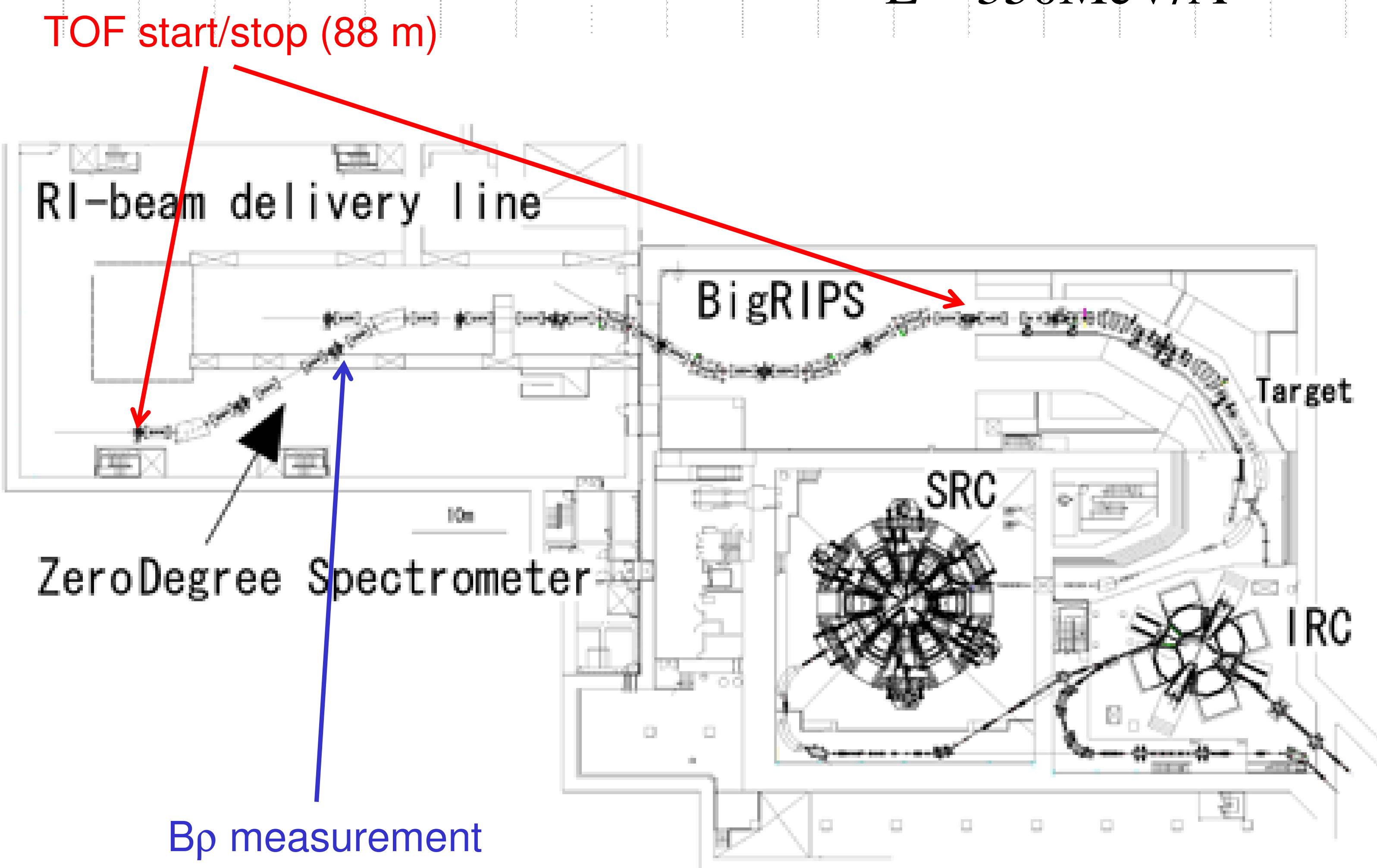


RIKEN – BigRIPS



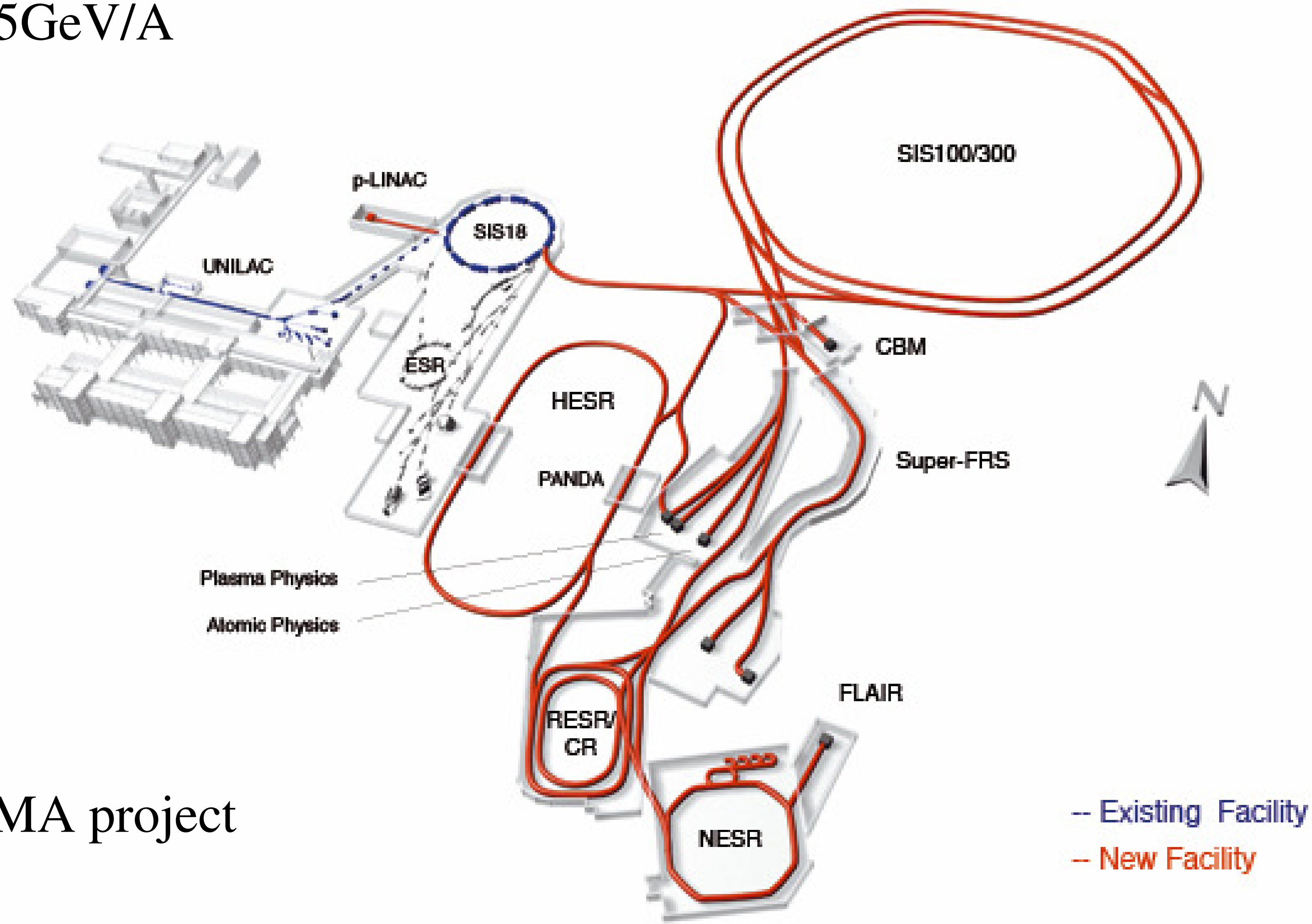
RIKEN – BigRIPS+ ZDS

E ~ 350MeV/A



FAIR – isochronous CR

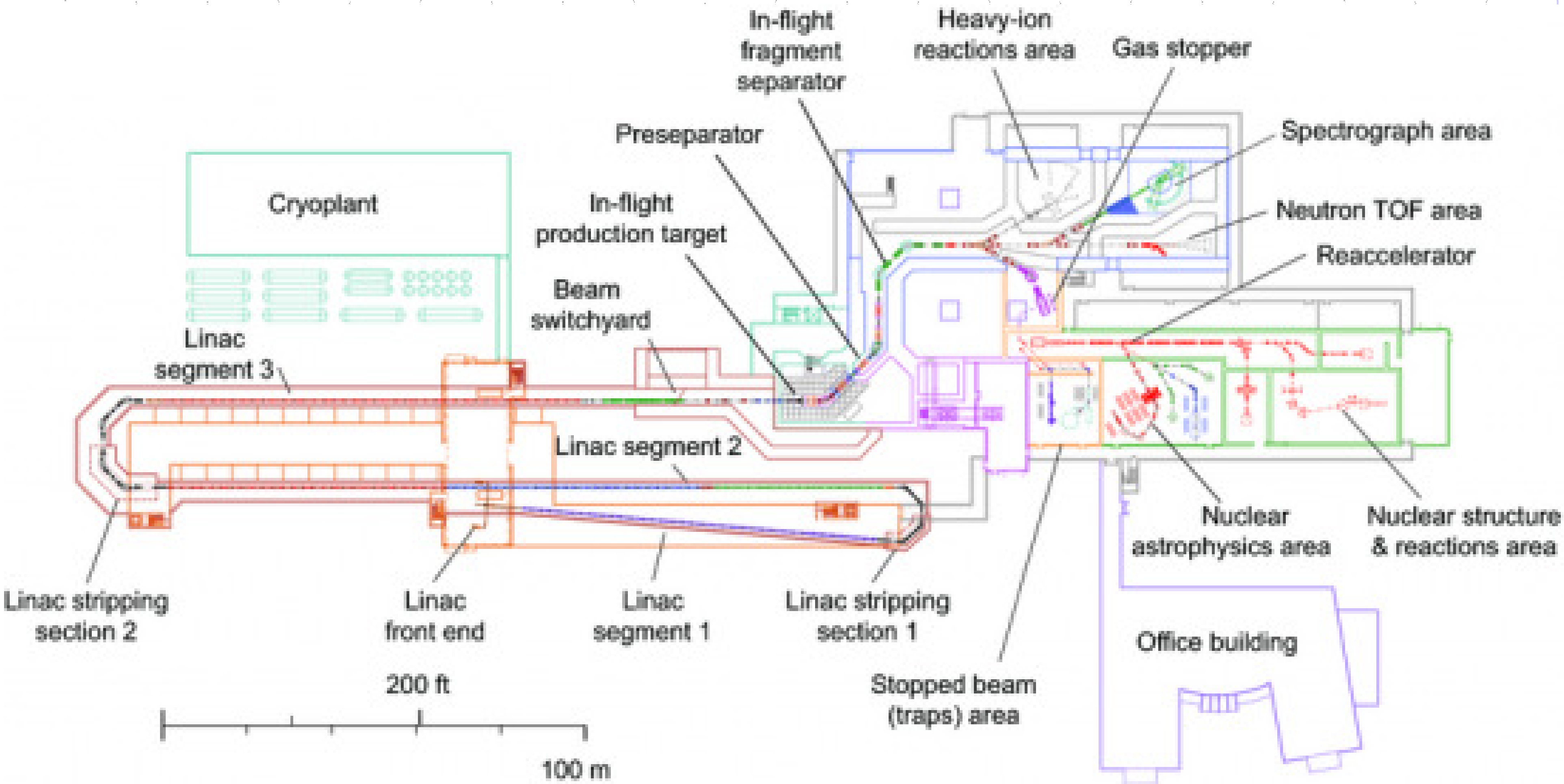
E ~ 1.5GeV/A



ILIMA project

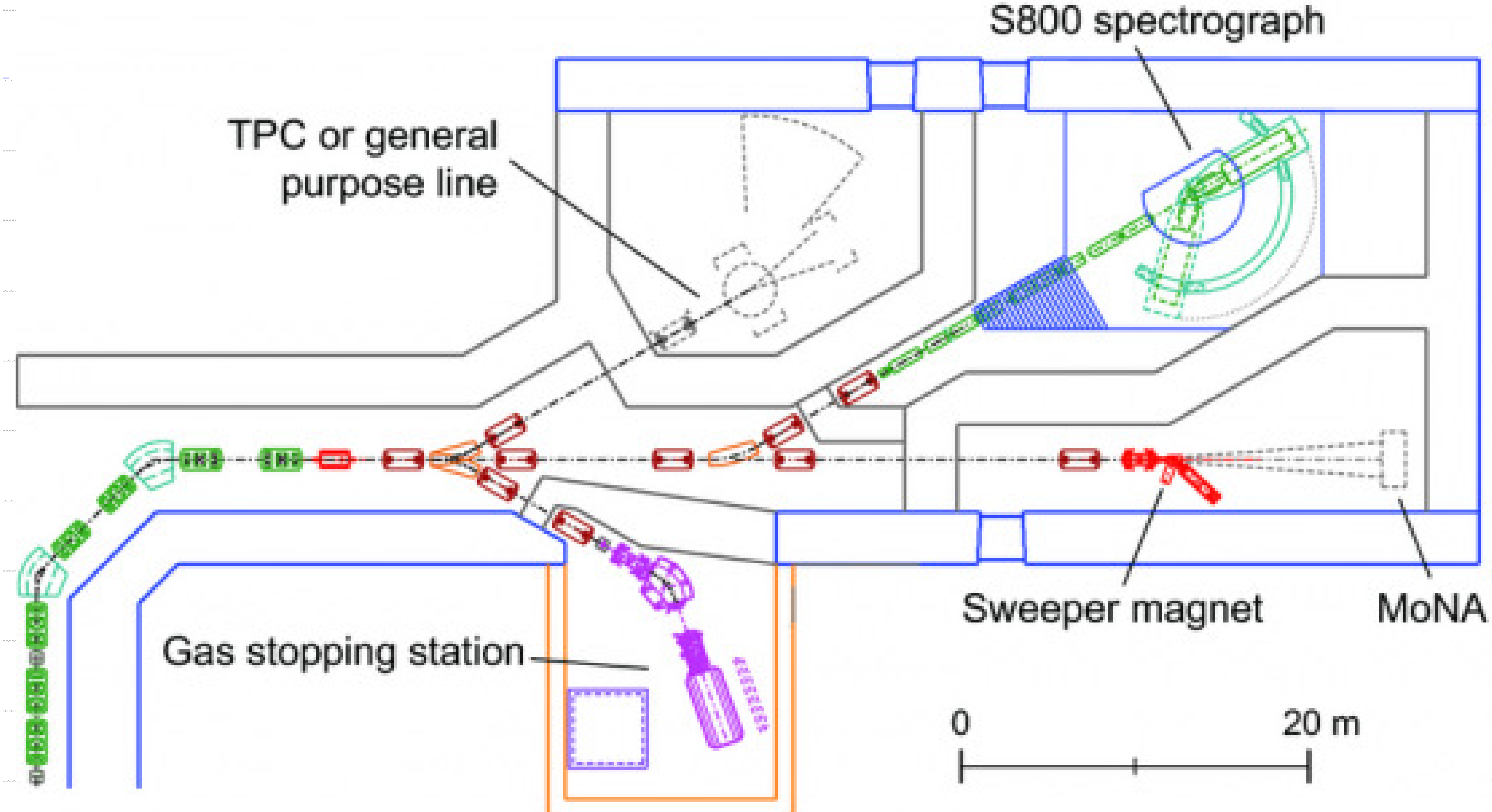
ISF at MSU

E ~ 250MeV/A

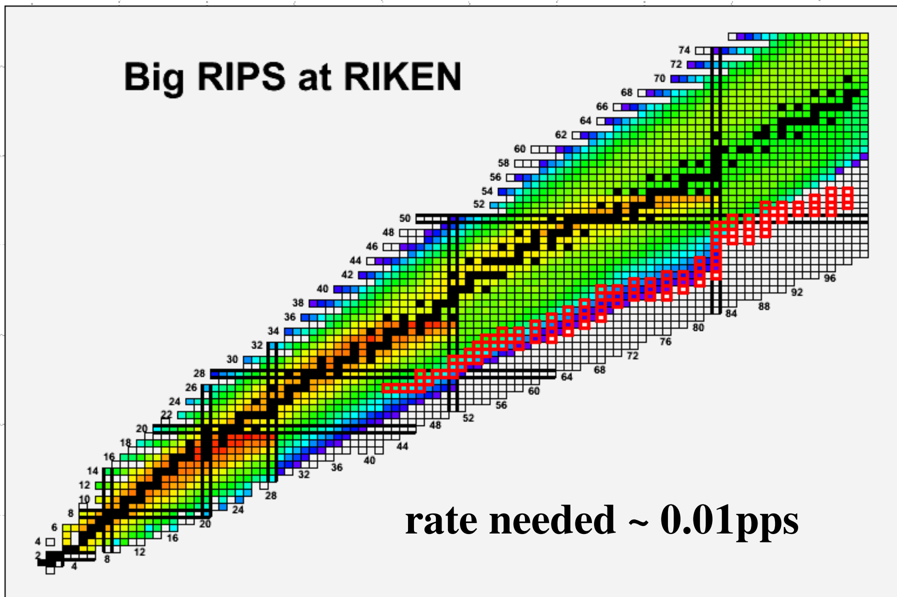


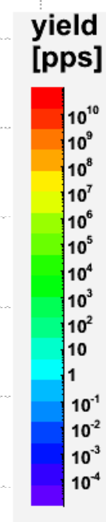
ISF at MSU

E ~ 250MeV/A



Future Facilities Rates



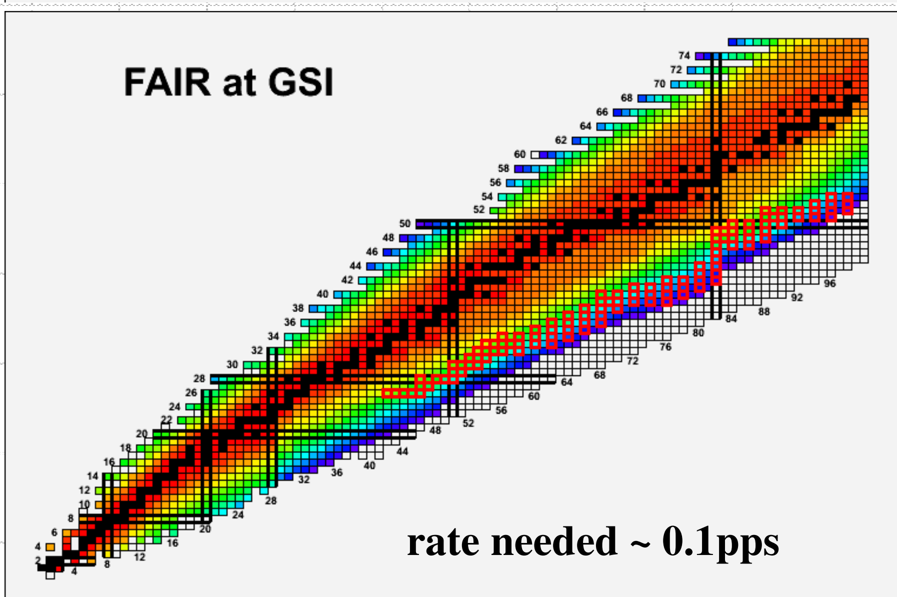


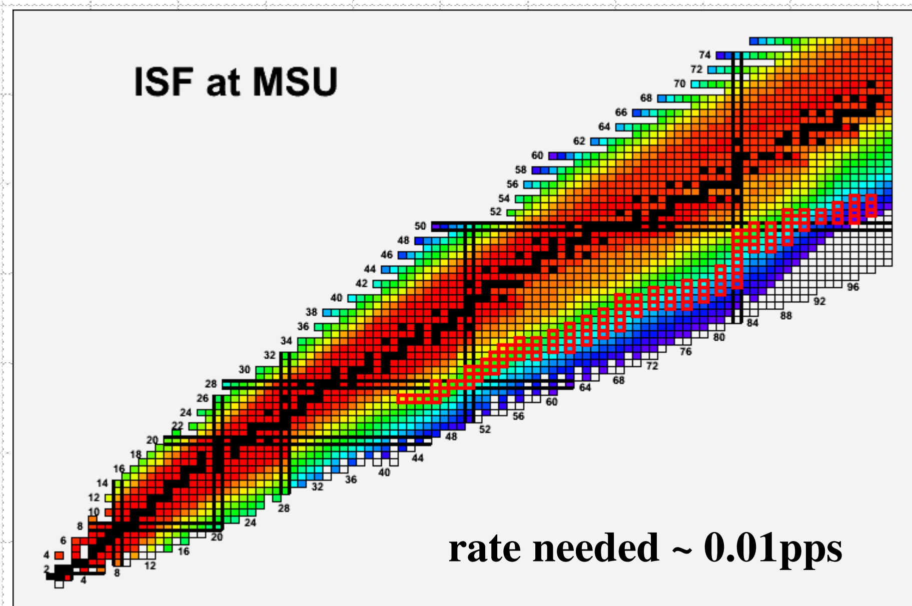
timelines

Big RIPS: 2007 first experiments

FAIR: 2012 first experiments
2015 completion

ISF: 2016 if approved





Conclusions

in 5 years – first large r-process areas by RIKEN Z < 40 & Z~50
in 10 years – Z < 40 & Z~50 fully covered by MSU or GSI
In 15 years – Penning trap measurements in the r-process area
penetration into more exotic r-process areas
In 20 years – ????

- **competition has already started**
- **who will be the winner?**
  depends on decisions
- **many surprises are expected**
- **theoreticians (nuclear models, r-process)**
  should be prepared

JINA should be involved