



RIKEN
NiSHiNA
CENTER

Technical Considerations for In-Beam Gamma-Ray Experiments at the RIBF

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Outline

Accelerators

BigRIPS

F8 Area

Summary

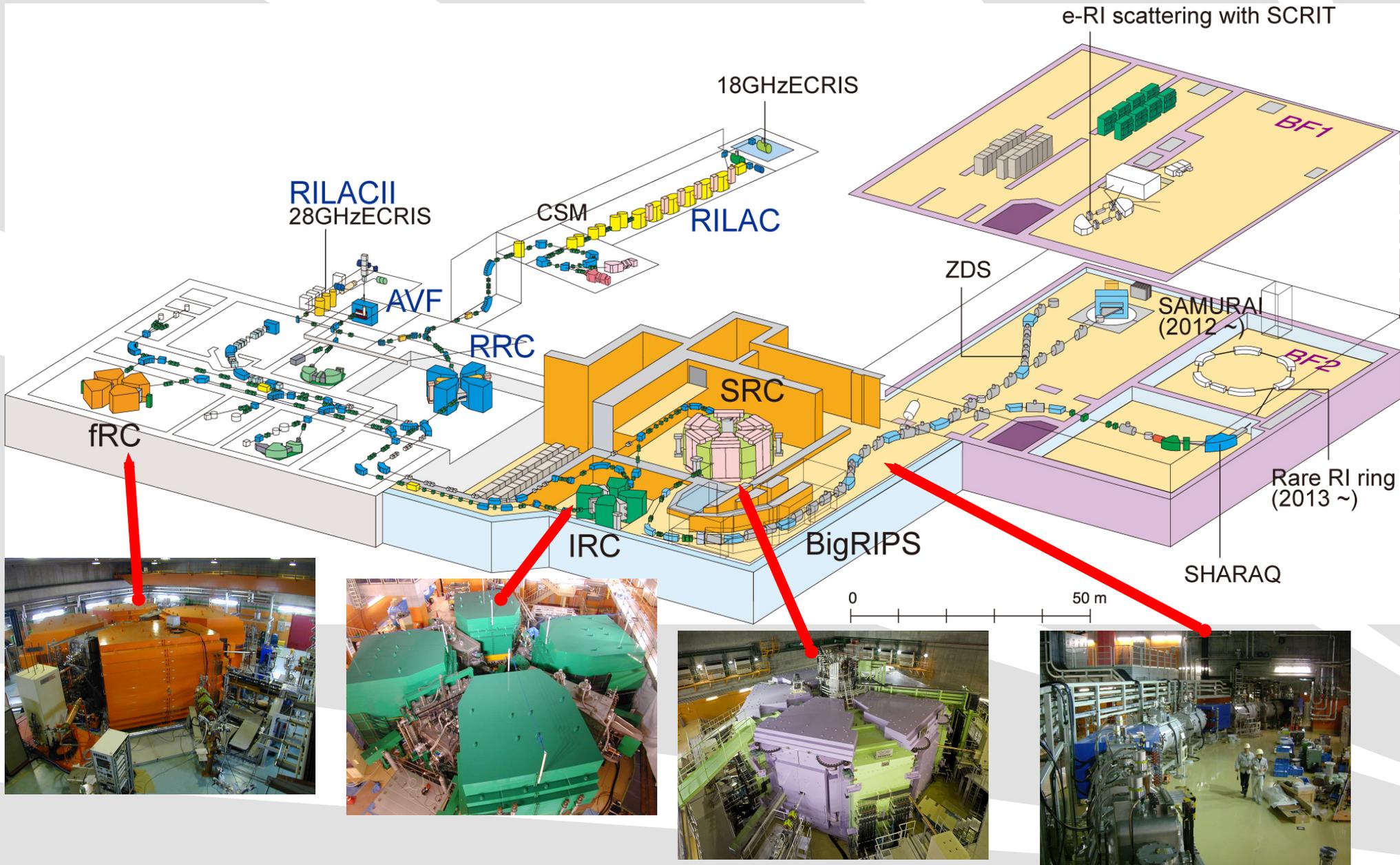
- Accelerators
- BigRIPS
 - ◆ Secondary and total beam rates
 - ◆ PID
 - ◆ Resolution
- F8 area
 - ◆ Space
 - ◆ Tracking
 - ◆ Atomic background
- ZeroDegree



Accelerators



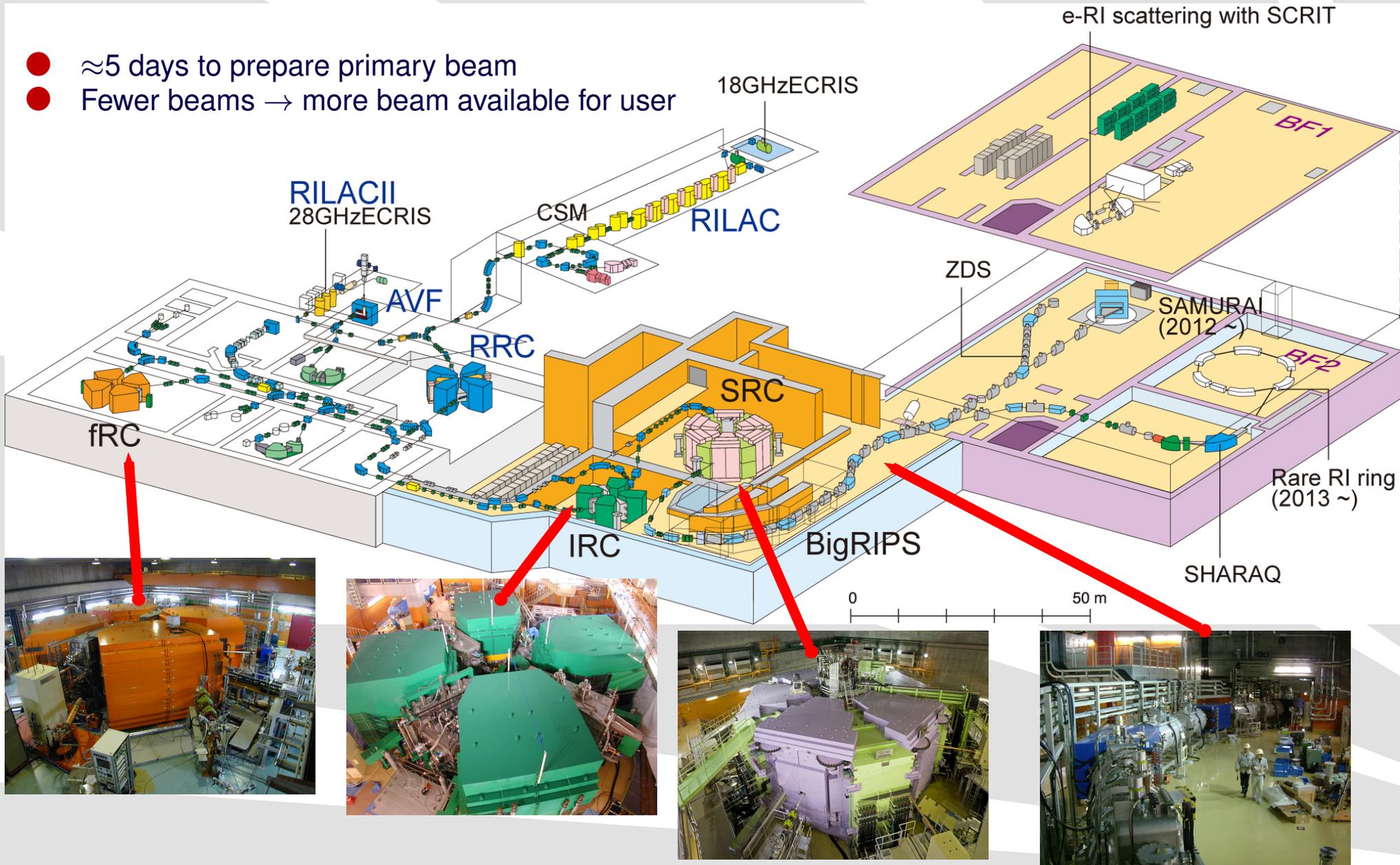
RIBF Overview





RIBF Overview

- ≈ 5 days to prepare primary beam
- Fewer beams \rightarrow more beam available for user





Superconducting Ring Cyclotron (SRC)



Intensities of 345 MeV/ u beams from the SRC

Nucleus	Beam Intensity / pA		
	Goal	Achieved Max	Average
^{48}Ca	1000	730	500
^{70}Zn	1000	250	200
^{78}Kr	1000	486	300
^{124}Xe	100	100	80
^{238}U	100	58	40

- $K = 2500$ MeV
- 8300 tons
- 5.36 m extraction radius
- 6 sector magnets
- Four main RF cavities



Superconducting Ring Cyclotron (SRC)

- ^{48}Ca might not be available in 2020.
- In fall 2018, a stable primary beam intensity of 60 pA was maintained for ^{238}U .



Intensities of 345 MeV/ u beams from the SRC

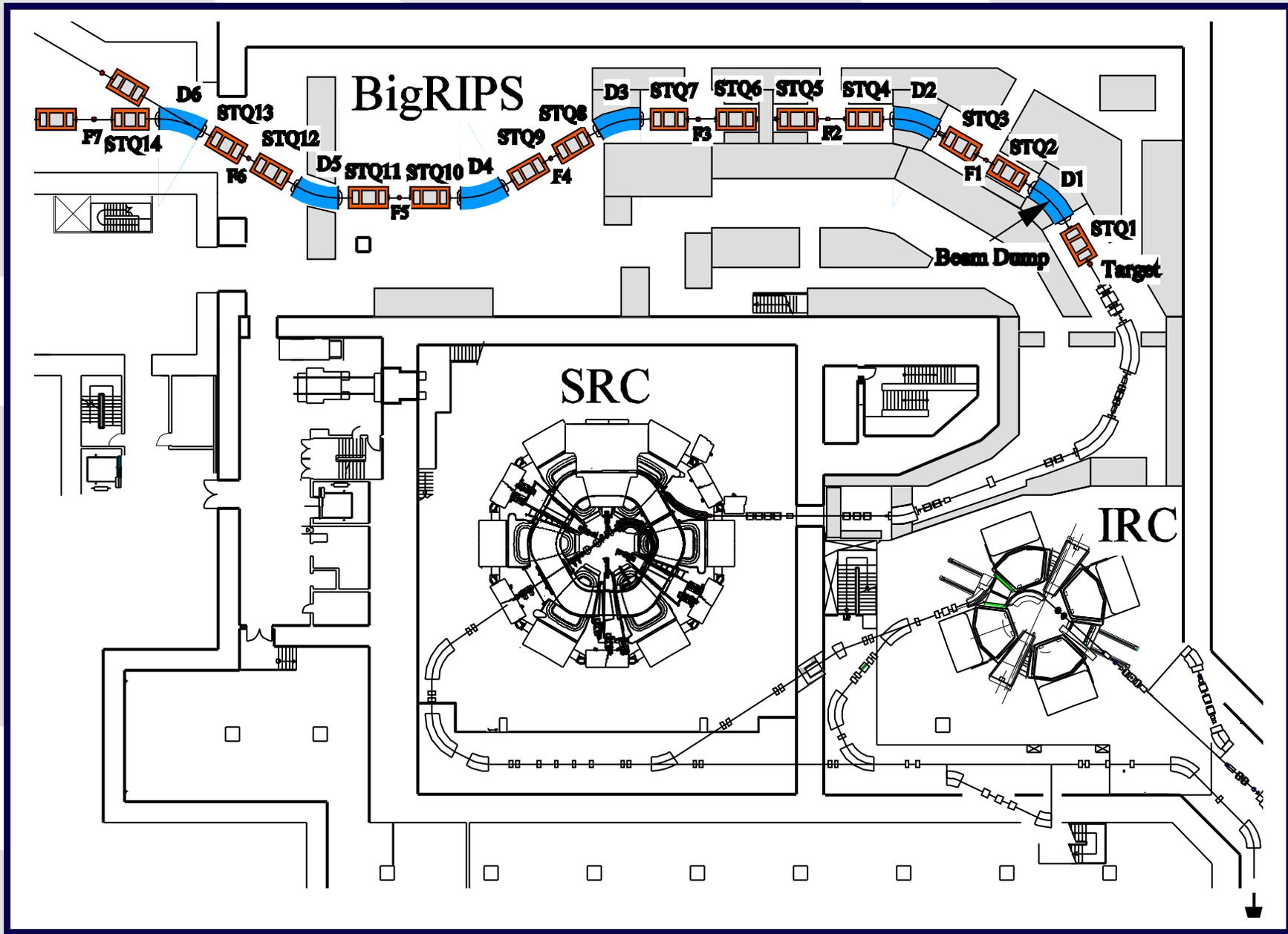
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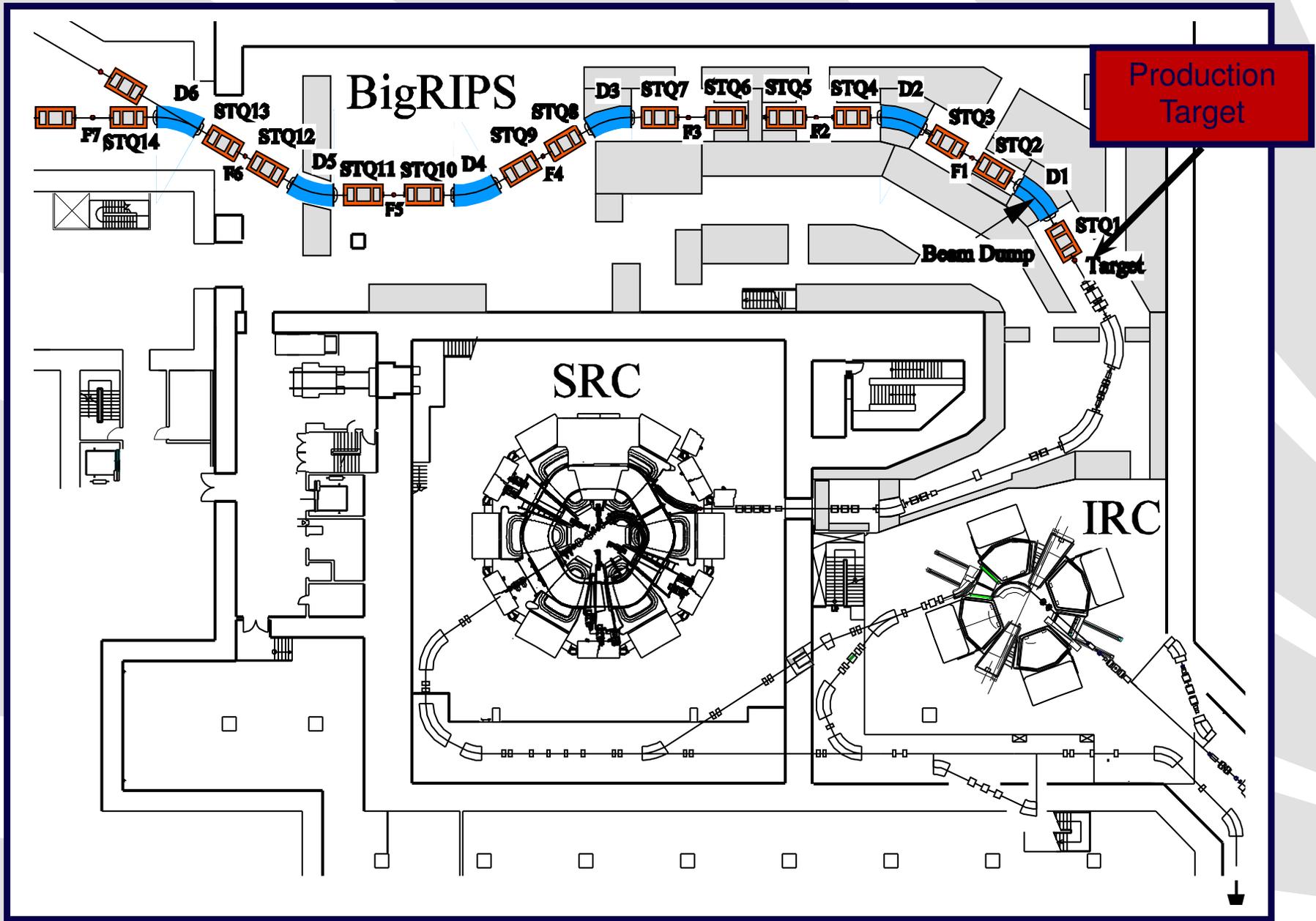


BigRIPS

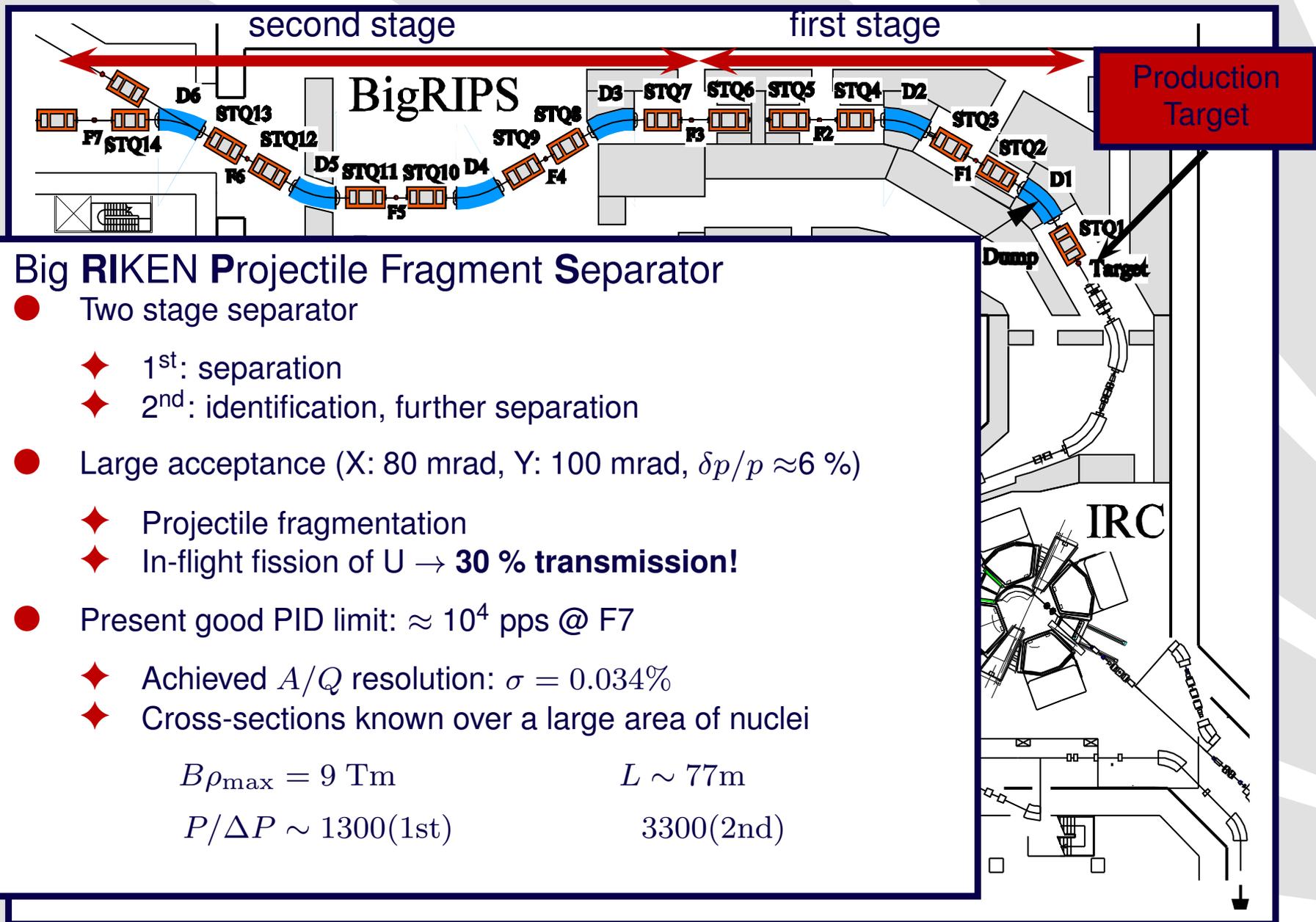
BigRIPS Overview



BigRIPS Overview



BigRIPS Overview



Big RIKEN Projectile Fragment Separator

- Two stage separator
 - ◆ 1st: separation
 - ◆ 2nd: identification, further separation
- Large acceptance (X: 80 mrad, Y: 100 mrad, $\delta p/p \approx 6\%$)
 - ◆ Projectile fragmentation
 - ◆ In-flight fission of U \rightarrow **30 % transmission!**
- Present good PID limit: $\approx 10^4$ pps @ F7
 - ◆ Achieved A/Q resolution: $\sigma = 0.034\%$
 - ◆ Cross-sections known over a large area of nuclei

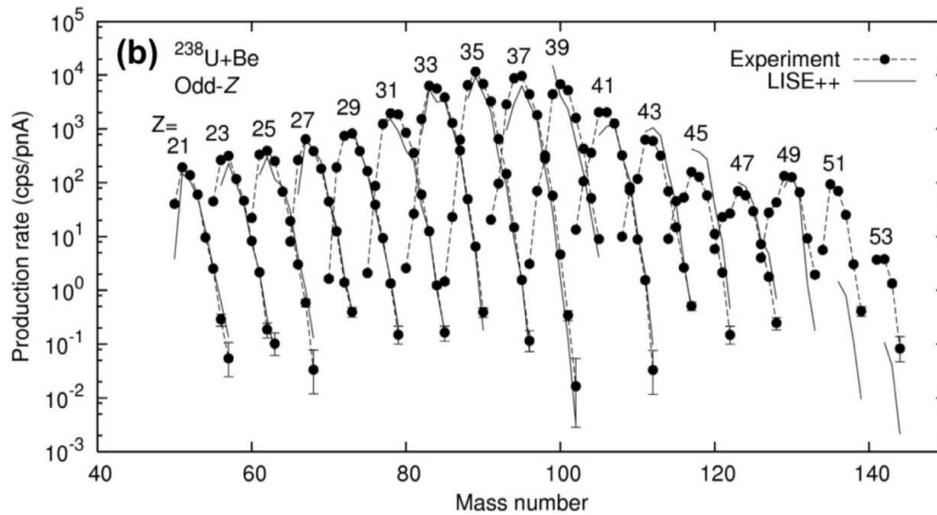
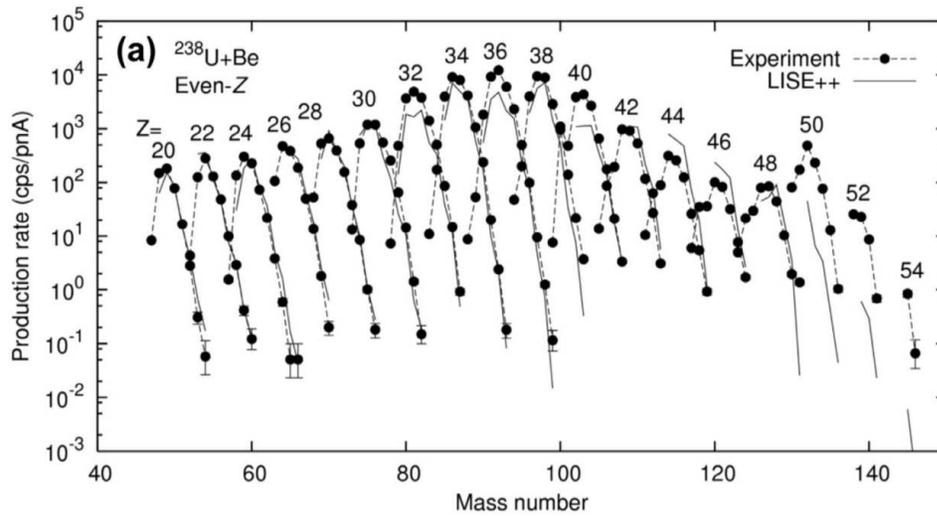
$$B\rho_{\max} = 9 \text{ Tm}$$

$$L \sim 77\text{m}$$

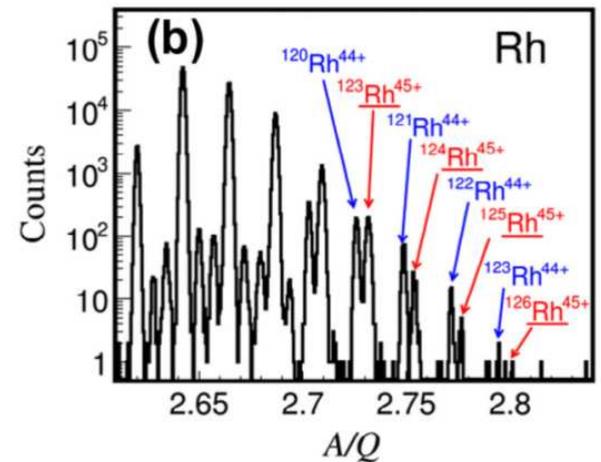
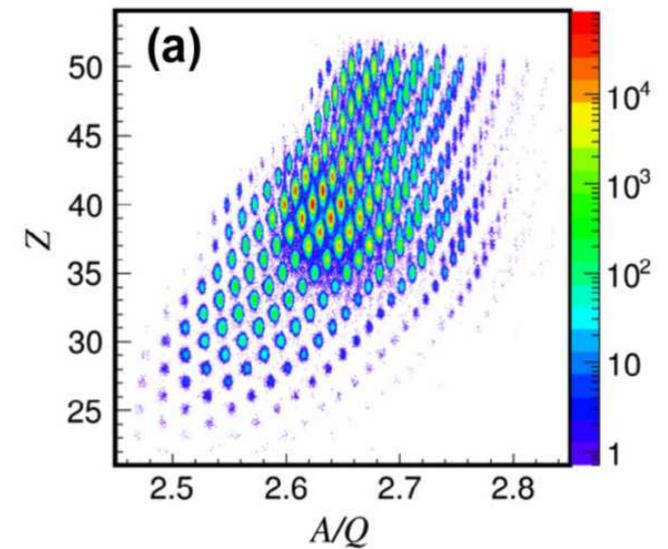
$$P/\Delta P \sim 1300(1\text{st})$$

$$3300(2\text{nd})$$

BigRIPS Overview



H. Suzuki *et al.*, NIMB 317, 756 (2013)



N. Fukuda *et al.*, NIMB 317, 323 (2013)

Production cross sections known for many nuclei

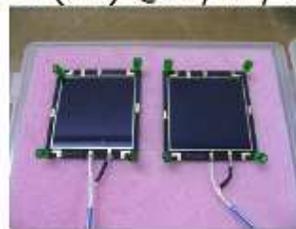
PID Detectors

Standard beam-line detectors at BigRIPS/ZeroDegree focuses

DL-PPAC
(position)



Si (ΔE) @F7, F2, F3



NaI (E) @F7



Plastic
scinti.
(TOF)



Ge @F7 for
isomer γ -decay
measurement
(Isomer PID)



MUSIC
(ΔE)
@F7, (F2,
F3)



Intensity monitor (primary beams) @F0



Plastic



Si



FCT

Detailed technical information provided under:

<http://ribf.riken.jp/BigRIPSInfo/>



Secondary Beam Rate Estimation and Production

- Calculated with LISE++
 - ◆ Files available here:
<http://www.nishina.riken.jp/RIBF/BigRIPS/intensity.html>
 - ◆ Many measured cross sections included
- Include beam dump (beam power ≈ 10 kW)
 - ◆ Visit here:
<http://ribf.riken.jp/BigRIPSInfo/beamdump/>
- Typical total rate limitations: 100 kHz at F3, 10 kHz at F7
 - ◆ Momentum selection with dipole D1 and F1 slits
 - ◆ Degraders at F1 and F5
 - ◆ Slits at F1, F2, F5, F7
- Secondary beams are prepared by the BigRIPS team
 - ◆ User provides LISE++ file, already with proposal

Secondary Beam Rate Estimation and Production

- Calculations
- ◆ Final
- ◆ Monte Carlo
- Inclusion
- ◆ Validation
- Typical
- ◆ Monte Carlo
- ◆ Data
- ◆ Simulation
- Secondary
- ◆ Uncertainty

⁸¹ As	⁸² As	⁸³ As 3.41e+1 0%	⁸⁴ As	⁸⁵ As
⁸⁰ Ge	⁸¹ Ge 5.08e+0 0%	⁸² Ge 6.27e+3 0.067%	⁸³ Ge 1.64e-2 0%	⁸⁴ Ge
⁷⁹ Ga	⁸⁰ Ga 3.73e+0 0%	⁸¹ Ga 6.15e+3 0.712%	⁸² Ga 8.16e-2 0%	⁸³ Ga
⁷⁸ Zn	⁷⁹ Zn 3.57e-1 0%	⁸⁰ Zn 1.06e+3 2.346%	⁸¹ Zn 4.7e-2 0.001%	⁸² Zn
⁷⁷ Cu	⁷⁸ Cu 2.86e-3 0%	⁷⁹ Cu 2.53e+1 4.484%	⁸⁰ Cu 4.49e-4 0.002%	⁸¹ Cu
⁷⁶ Ni	⁷⁷ Ni 1.48e-6 0%	⁷⁸ Ni 3.07e-1 6.391%	⁷⁹ Ni 1.02e-6 0.001%	⁸⁰ Ni

density.html

/beamdump/

kHz at F7

slits

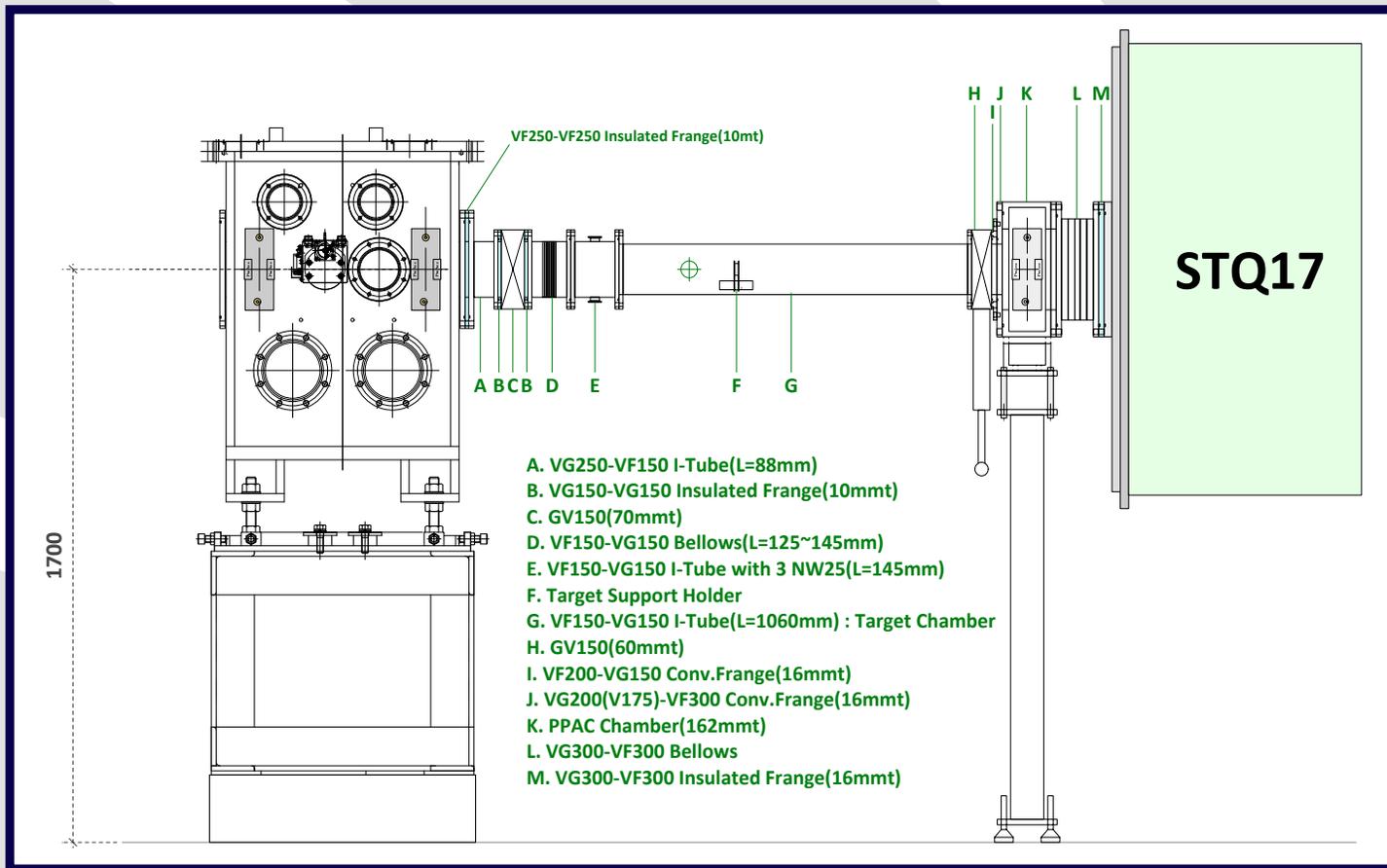
S team

proposal



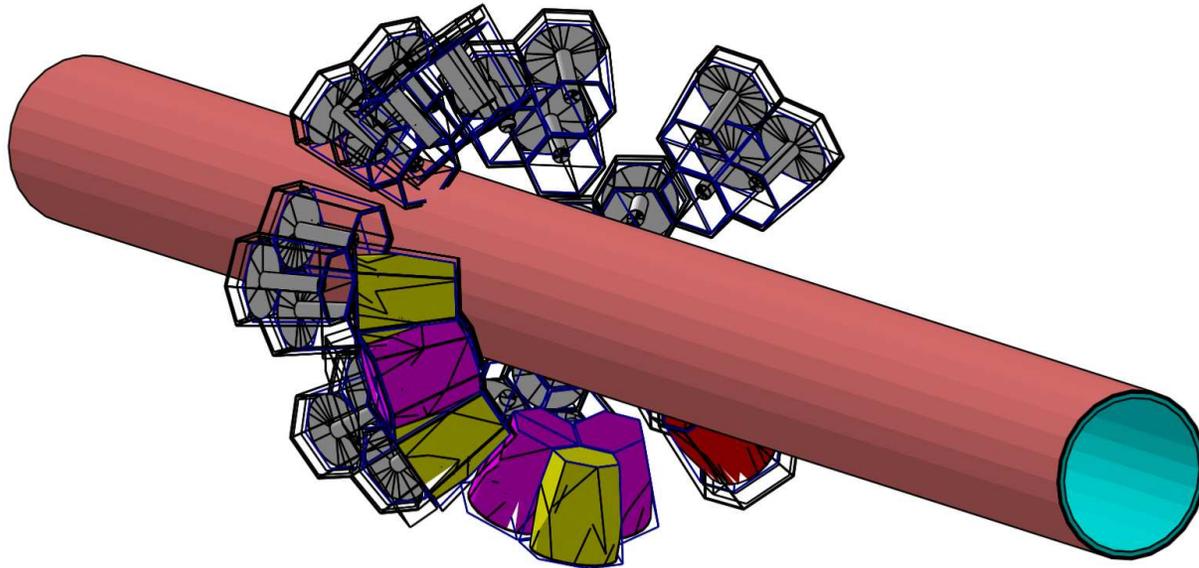
F8 Area

Our Standard F8 Setup



- 2m gap between F8 chamber and STQ17
- Inner diameter of 140 mm for beam pipe
- ◆ Also used as beam transport line for SAMURAI
- PPACS at -1292, -792, and +1024 mm of standard F8 focus
- ◆ Scattering angle reconstruction resolution of 5 mrad (σ)

High-Resolution Setup

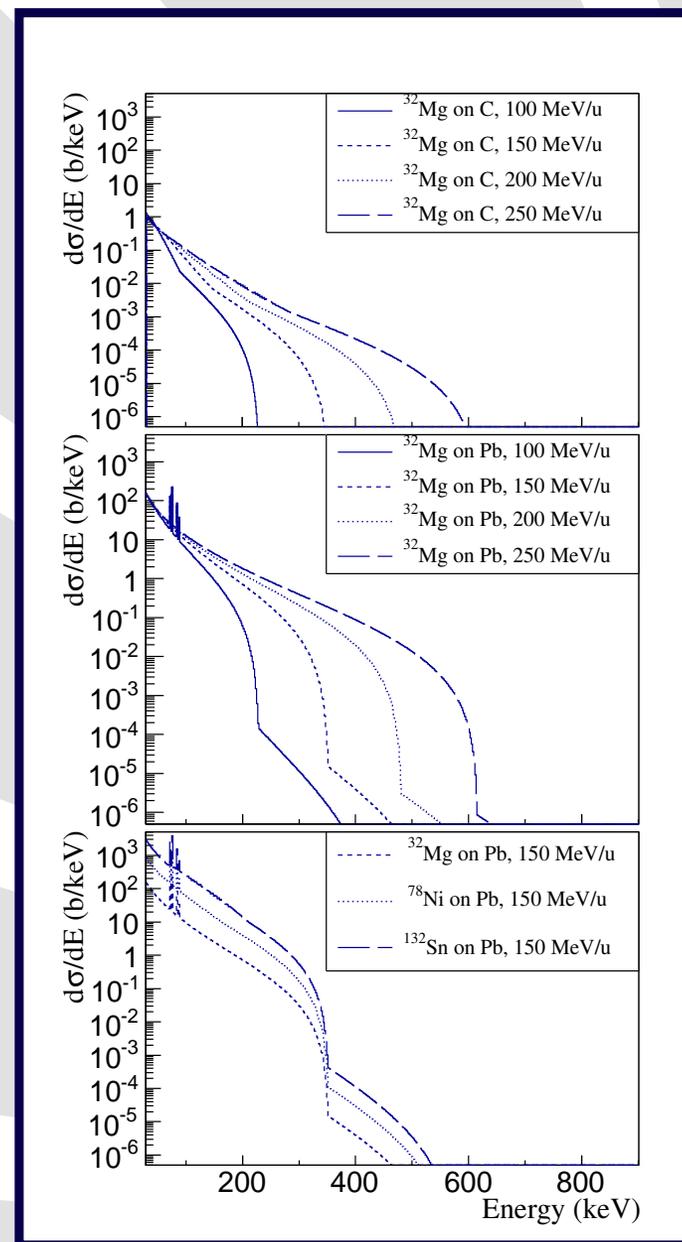
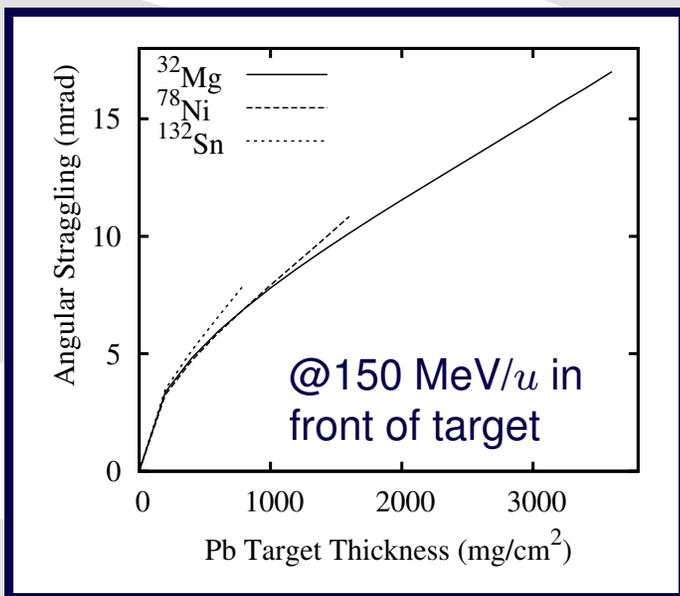


- 6 Miniball clusters at 30° , 270 mm distance
- 2 additional Miniball at 65° , 200 mm distance
- Berkeley P3 triple, RCNP quad at 65° , 130 mm distance
- DAGATA triple at 65° , 130 mm distance
- With 1 mm Pb, 1 mm Sn shielding, standard beam pipe
 - ◆ 8 % efficiency at 1 MeV
- Further/other detectors are under discussion

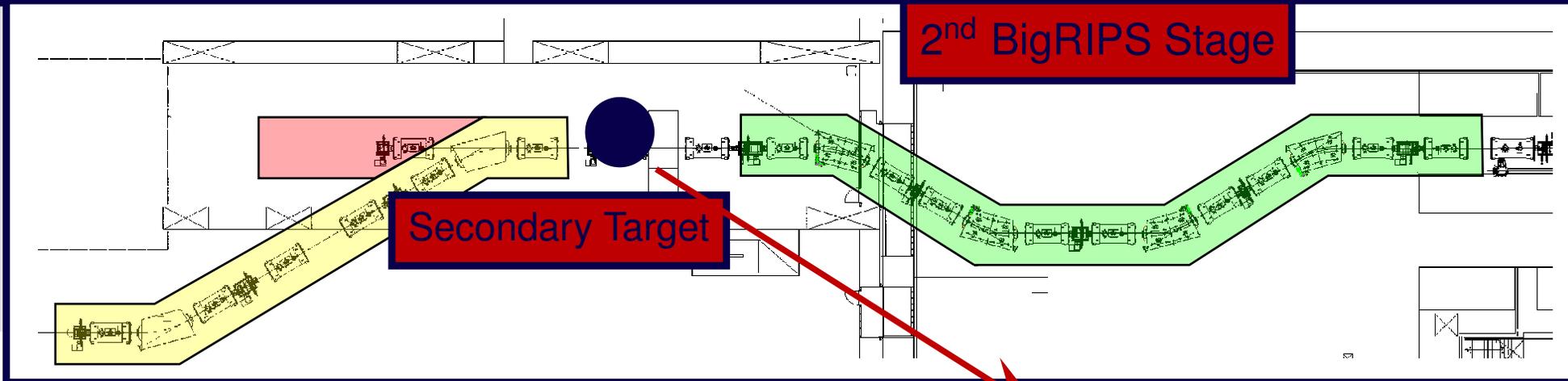
Details on the expected performance will be discussed by Kathrin

Secondary Targets and Atomic Background

- Large atomic background
 - ◆ Depends on secondary beam and target
- Requires Shielding
 - ◆ 1 mm Pb, 1 mm Sn rather conservative
 - ◆ Further simulations necessary
 - ◆ Better in front of detectors, not along beam
- Large angular straggling
 - ◆ No safe cut
 - ◆ See Presentation by Andrea



ZeroDegree Spectrometer



- DALI2+ array
 - ◆ 226 NaI(Tl) crystals
 - ◆ 4 π coverage
 - ◆ 20 % efficiency w/o add-back
 - ◆ 10 % resolution
- $E_{\text{beam}} \sim 100 - 250 \text{ MeV}/u$

0° Spectrometer ZeroDegree

- Particle ID after secondary target
- Fragment momentum distribution
- Various modes of operation

mode	$p/\Delta p$	Δp	Ang. Accep.
Large Accep.	1240	$\pm 3\%$	$\pm 45 \text{ mrad(H)} \pm 30 \text{ mrad(V)}$
High res.(achrom)	2120	$\pm 3\%$	$\pm 20 \text{ mrad(H)} \pm 30 \text{ mrad(V)}$
Dispersive	4130	$\pm 2\%$	$\pm 20 \text{ mrad(H)} \pm 30 \text{ mrad(V)}$



Summary

Cost Estimation

Budget required for Array		57,400 (x 1k¥)	
Item	Cost	Item	Cost
Travel	2,000	Maintenance Ge	2,000
Pumping system	1,600	HV Power	5,000
UPS	2,000	Liq. N2 system	3,000
Liq. N2 Dewar	3,500	Cooling pipes	400
Shipping	2,000	Rail system	4,000
Digitizer	10,000	Trigger modules	2,500
VME crates	1,400	IOC	4,000
Computer Cluster	10,000		

- Need electronics to readout 568 channels in total
 - ◆ $8 \times 3 \times 7$ for MINIBALL
 - ◆ 10×40 for Ge tracking detectors
- RCNP and CAGRA collaboration provide electronics for ≈ 400 channels
- Kakenhi approved, Kiban A, $\approx 27,000$ k¥, rest should come from RIKEN



Summary

- Accelerator beam intensities, production cross sections well known
 - ◆ We have good predictions for expected rates
- Typical rate limitations are 100 kHz at F3 and 10 kHz and F7
- BigRIPS selection along isotonic chains
- Common dead time for beam line detectors ($\approx 50\mu s$)
- Atomic background severe
- With present setup tracking resolution of 5 mrad (σ)
 - ◆ Less than typical angular straggling in high-Z secondary targets
- Can start ordering equipment since April 1st



Thank You!