19th Russbach School on Nuclear Astrophysics

Neutron capture reaction of r-process in Common Envelop Jet Supernova

Shilun Jin

Institute of Modern Physics, Chinese Academy of Sciences

Rußbach, Austria
3/6/2024

outline

1 Rapid neutron capture process
- sites of r-process
- r-process in common envelop jet supernova

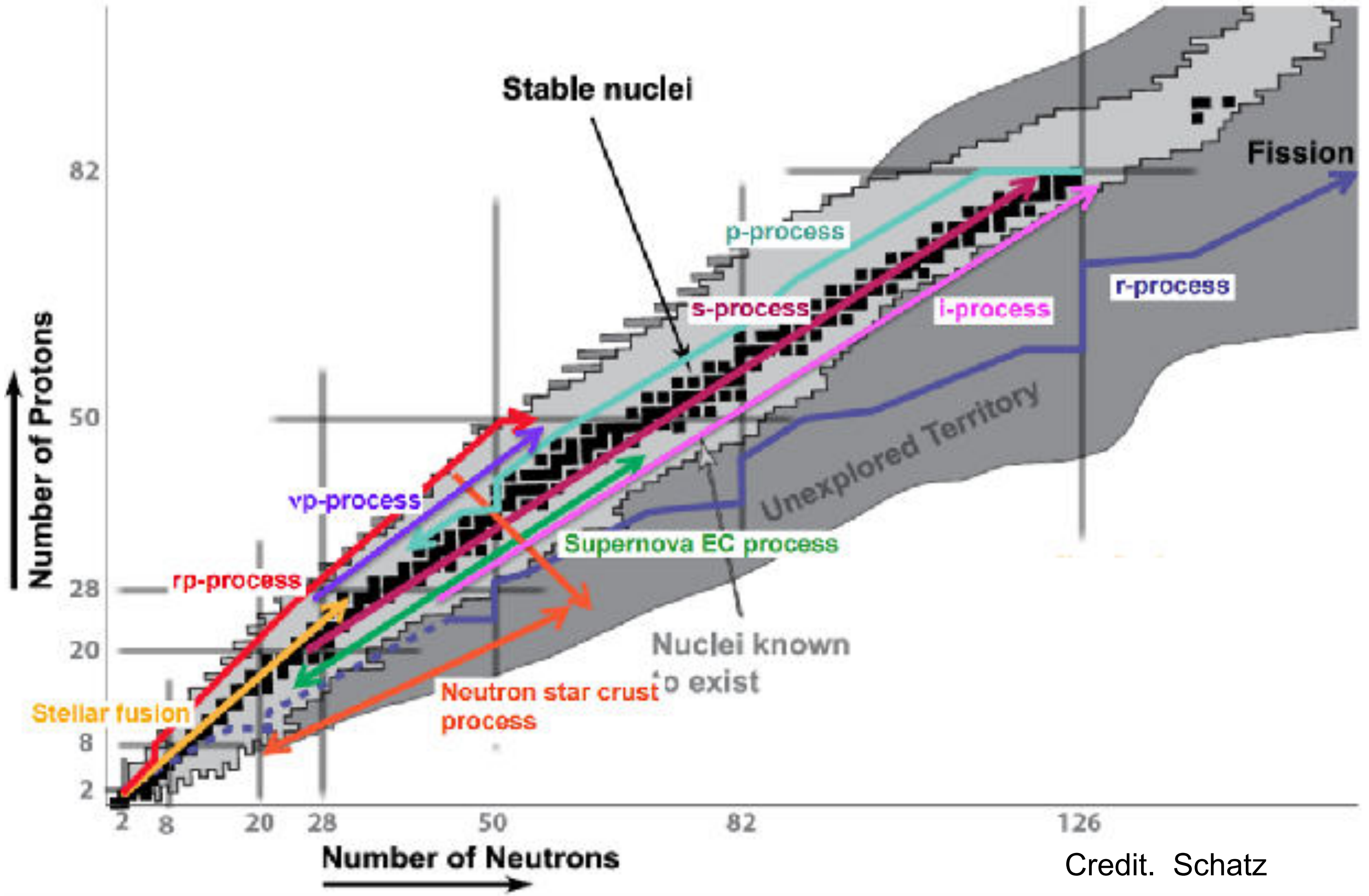
2 Measurement of reaction rate on 59Fe(n,γ)
- setup
- preliminary results
- HIAF in future

How were elements from Iron to Uranium made?

Nucleosynthesis process

N-deficient side:
- rp-process
- P-process:
  - p-nuclide ^{74}Se-^{196}Hg
- νp-process:
  - $^{92,94}Mo$ $^{96,98}Ru$

N-rich side:
- s-process:
  - -slow (n,g) fast β decay
  - -AGB
  - -weak, strong/main
- r-process:
  - -fast (n,g) slow β decay
  - -sites?
  - -weak, strong/main
- i-process



Credit. Schatz

Site of r-process

Neutron Star Merger

GW170817

-GW LIGO/VIRGO 2017

-Afterglow AT 2017gfo

-Lanthanides 2017

-Strontium 2019

-^{191}Os, ^{234}Th 74days later 2019

Core Collapse Supernovae

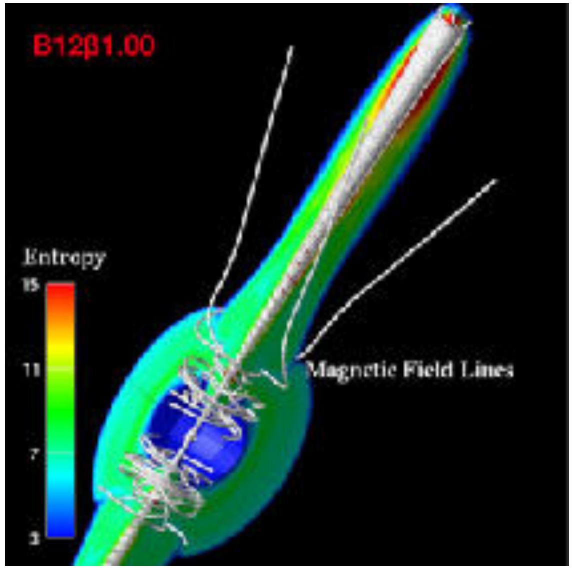
-death of massive star

-core collapse & shock wave

-neutrino driven wind

-no heaviest element

-can be proton rich



Magneto HydroDynamics Supernovae

-strong magnet $10^{12\text{-}15}$G,

-high spin

-3D & 2D models

-2021 UMP SMSS J200322.54−114203.3

-Weak & strong r-process

Collapsar

-massive, rapidly rotating star

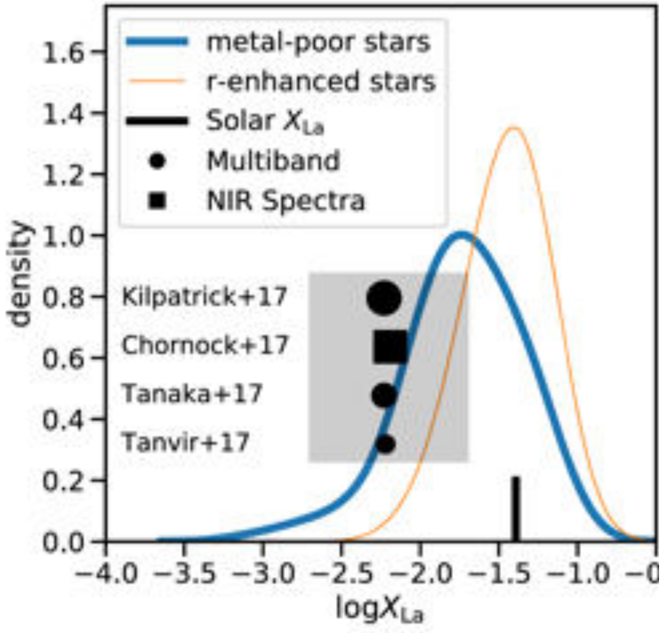
-accretion onto the black hole

-produce a beamed jet

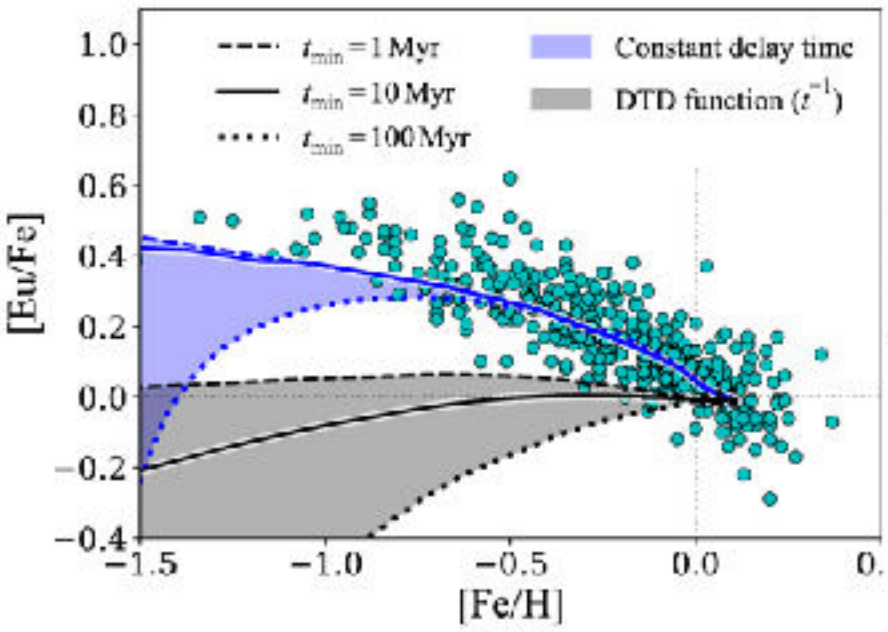
-long-duration γ-ray bursts

-3D model 2019, Seigel et al

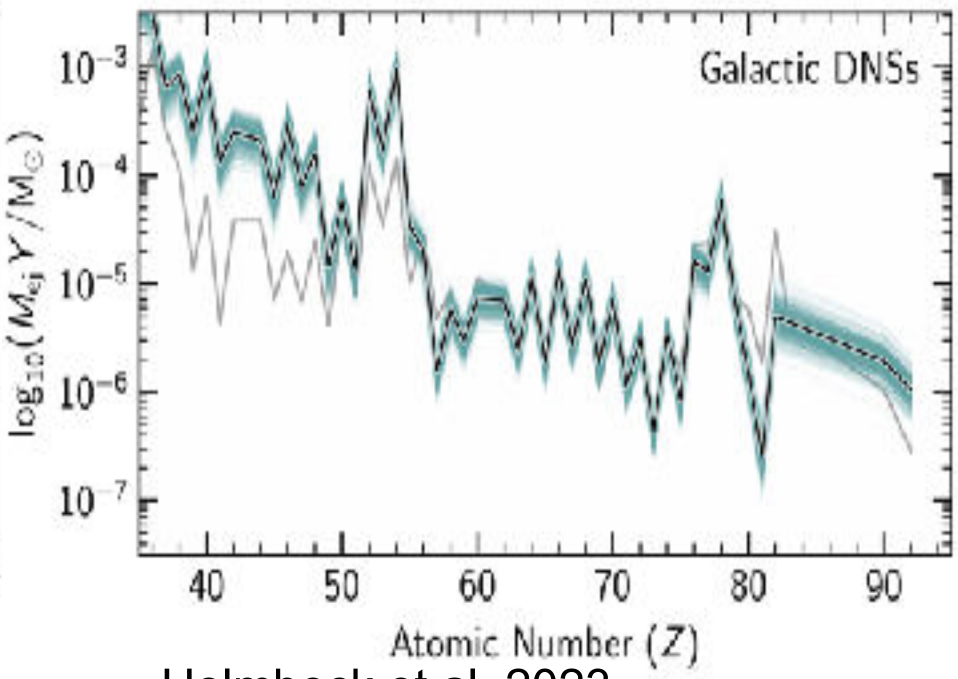
Is the neutron star merger only dominated site of r-process?



Ji et al. 2019
insufficient La



Côté et al. 2019
Inconsistent with [Eu/Fe]



Holmbeck et al. 2023
Data of DNS, weaker than solar

Common Envelope Jet Supernovae

-death of two stars

-RSG and NS

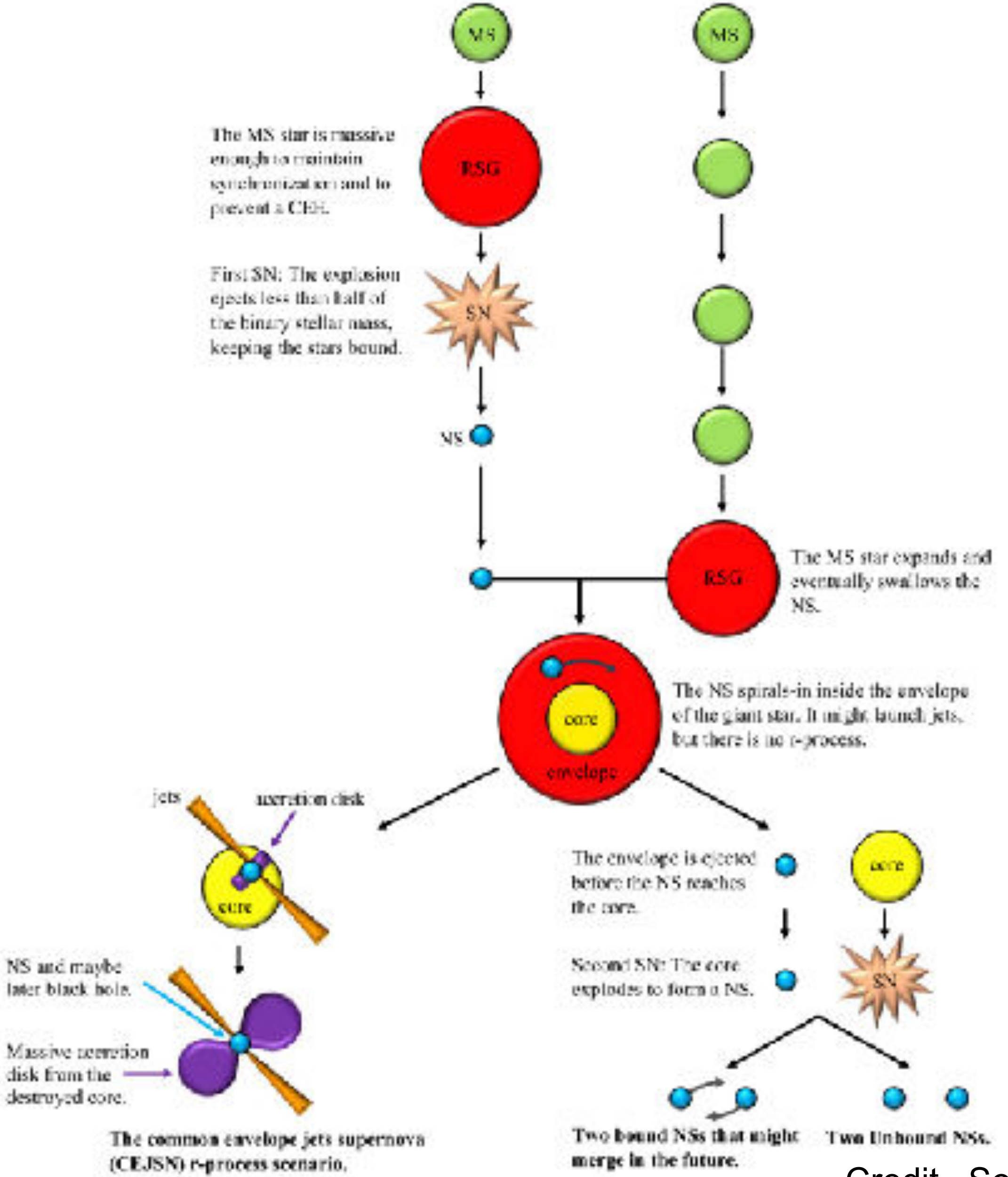
-RSG swallows NS

-Ns spirals in core

-accretion disk formed

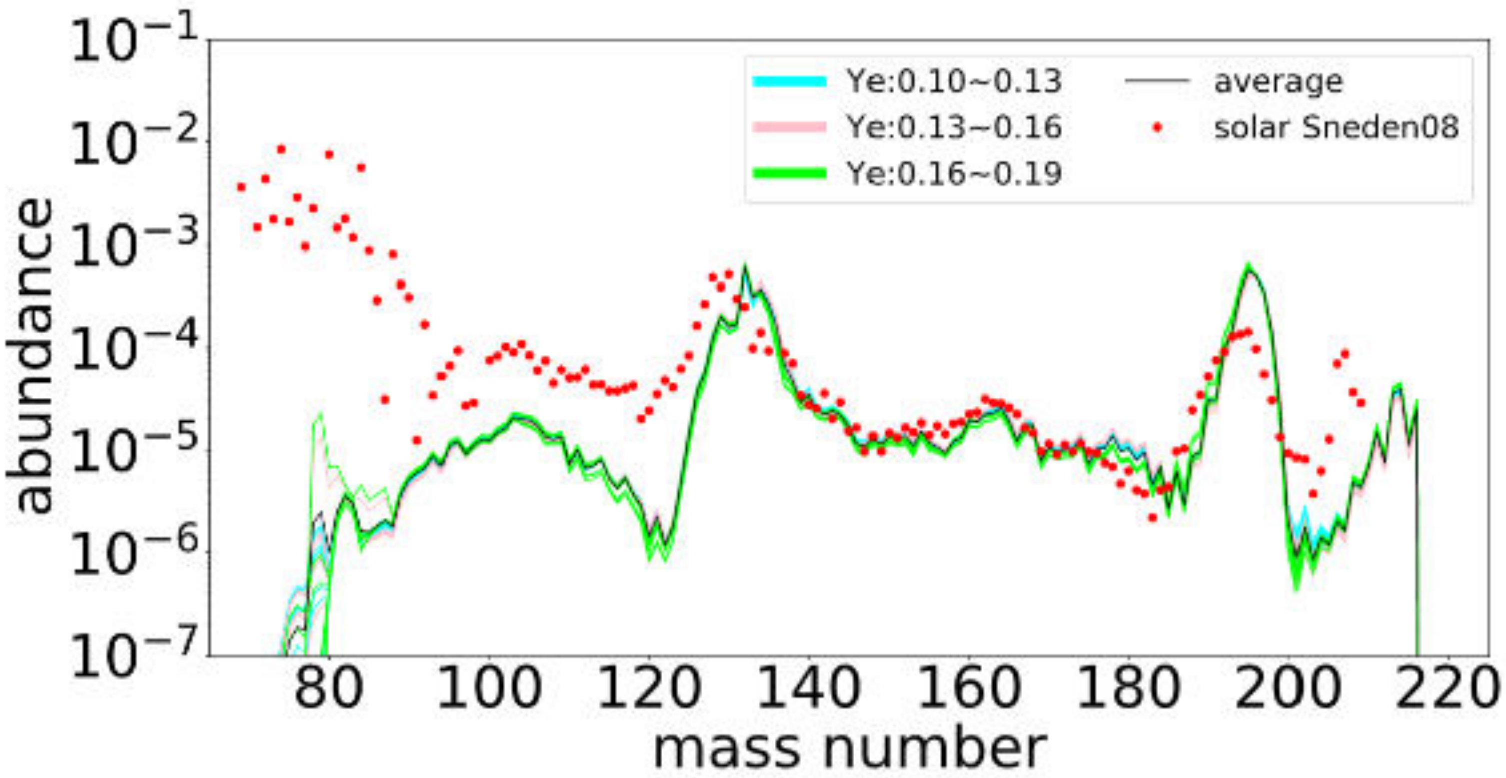
-core destroried

-bipolar jet



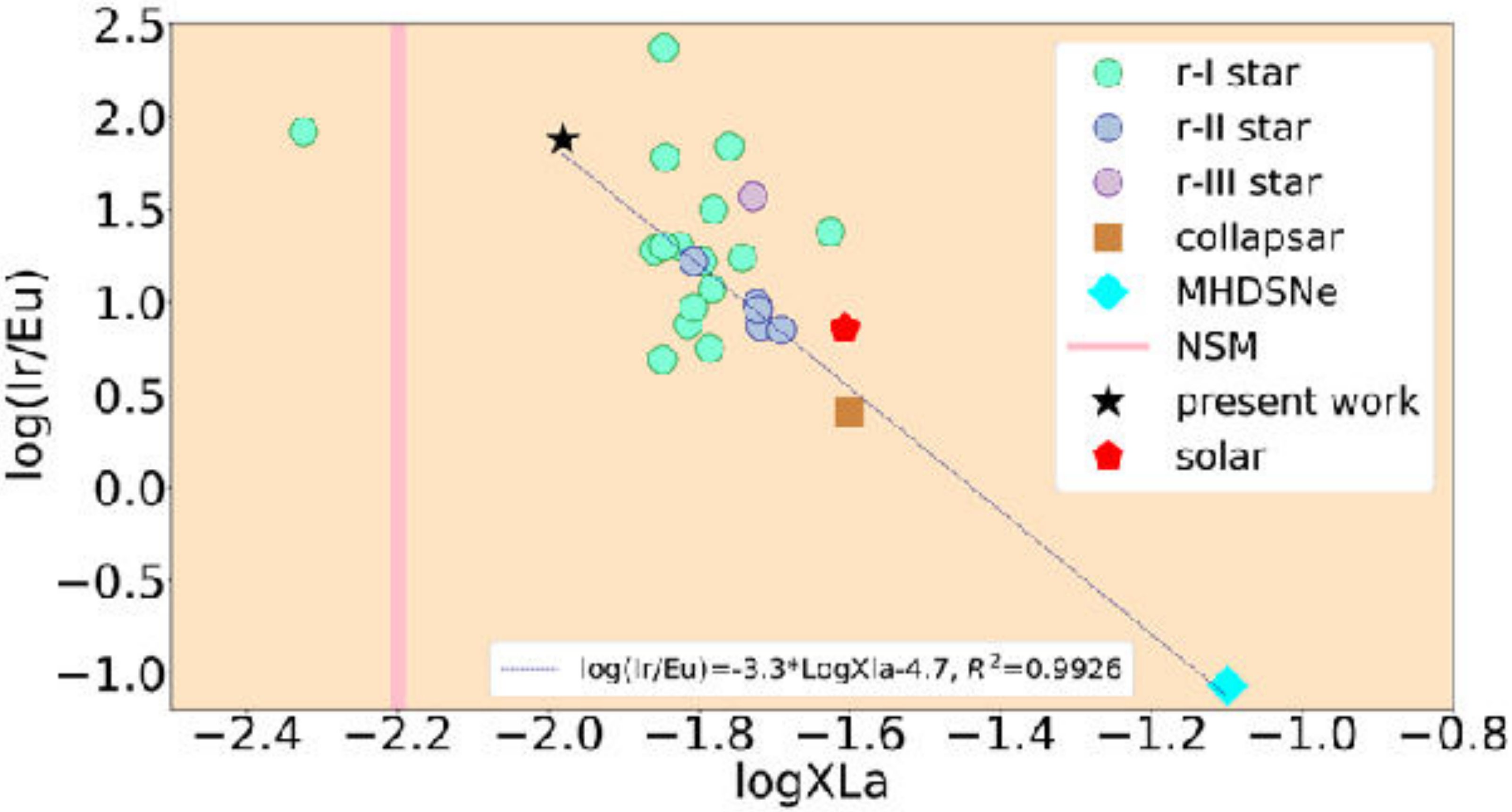
Credit. Soker

CEJ-SNe



- New density function
- Favor A>140
- Agreement with La
- Strong 3rd peak

Jin & Soker 2024



Jin & Soker 2024

- Define log(Ir/Eu)
- Explain r-enhanced stars
- Actinde Boost Star

2MASSJ09544277+5246414

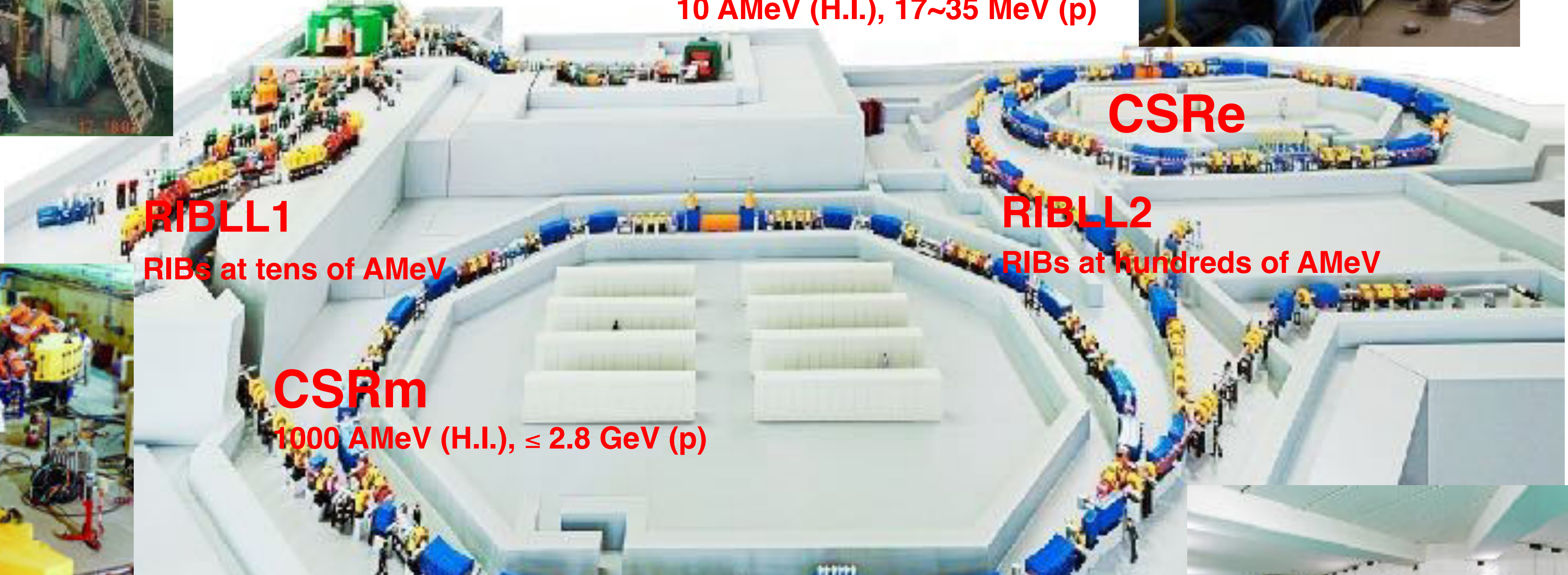
age ~11b year

outline

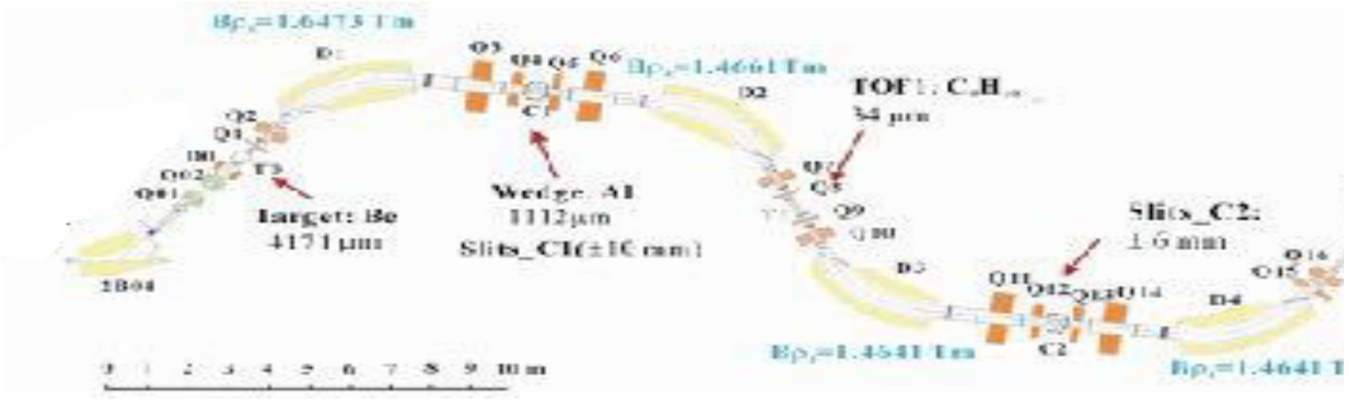
1 Rapid neutron capture process
- -sites of r-process
- -common envelop jet supernovae

2 Measurement of reaction rate on $^{59}Fe(n,\gamma)$
- -setup
- -preliminary results
- -HIAF in future

Heavy Ion Research Facility in Lanzhou (HIRFL)

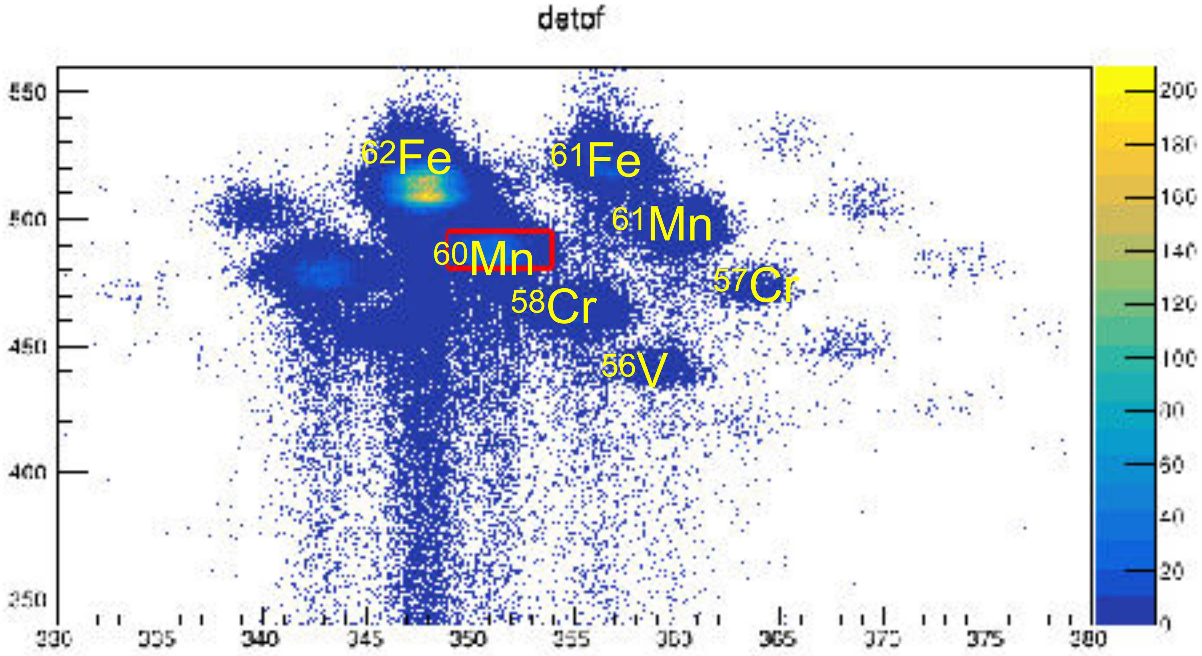


Radioactive Ion Beam Line in Lanzhou (RIBLL)



- Primary Beam: ^{64}Ni@60MeV/u
- Fast Beam(PF): ^{60}Mn

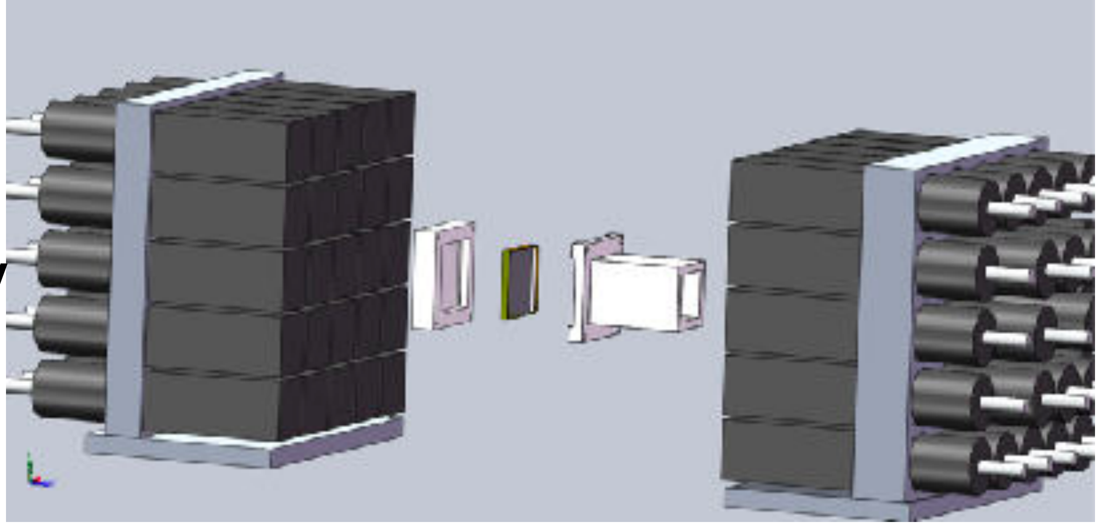
  ^{60}Mn $\xrightarrow{\beta decay}$ ^{60}Fe (NLD&γSF)
- Intensity: ~1.2pps
- Purity: ~11%
- Beam time: ~200 hr

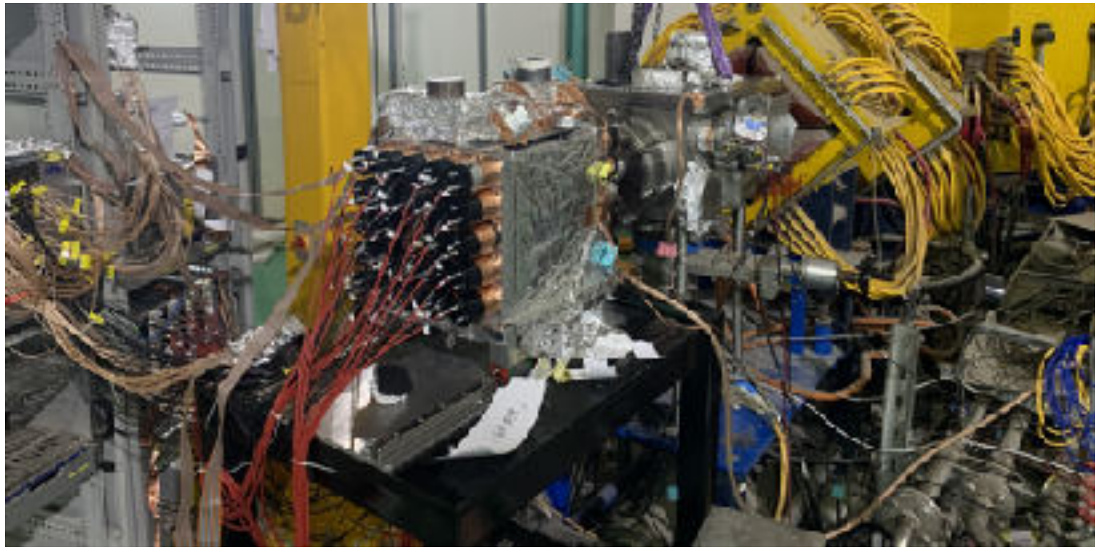


LAMBDA (LArge-scale Modular BGO Detector Array)

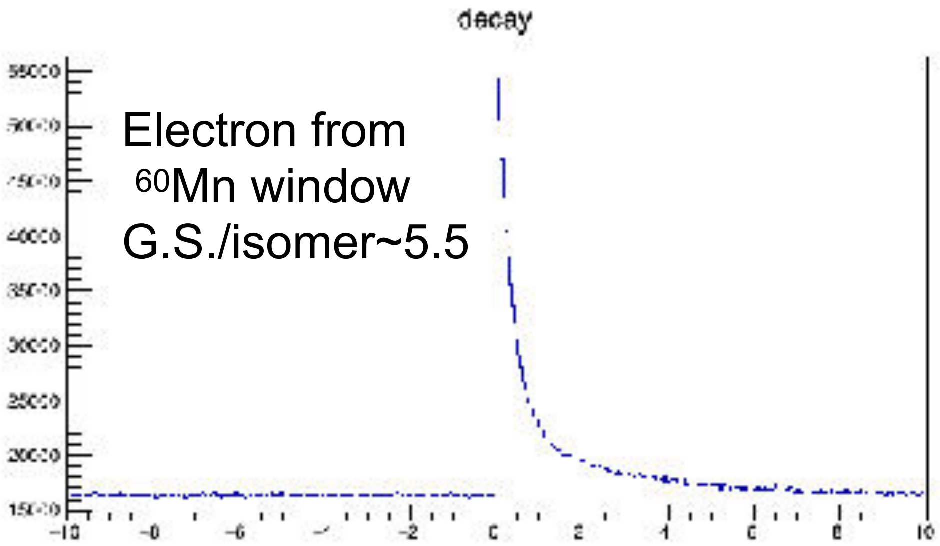
49 BGO modules

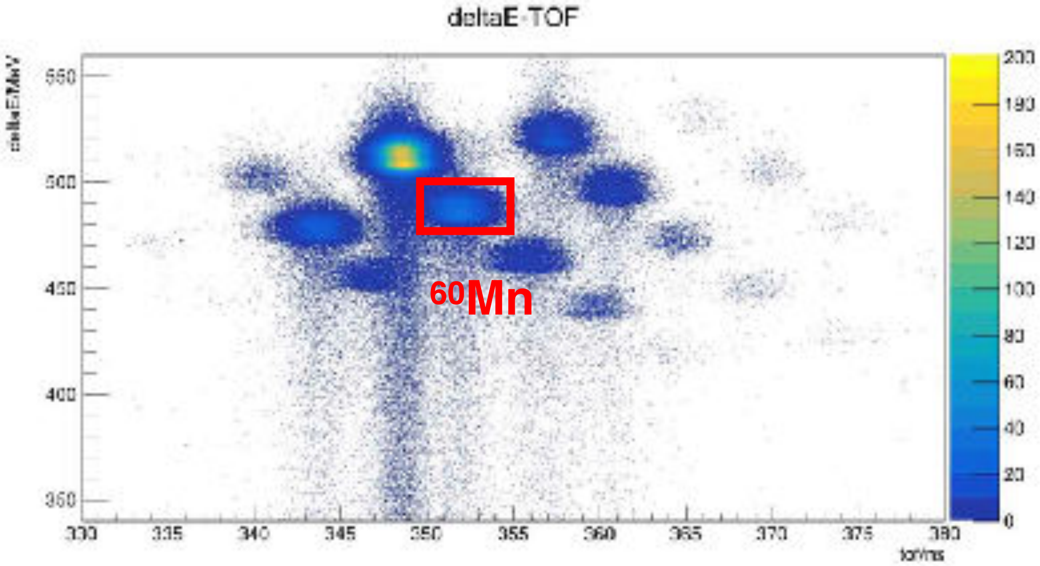
-Size:6cm×6cm×12cm
-Energy resolution: 9.7%@662keV
-Total efficiency: 90%@1MeV 80%@10MeV

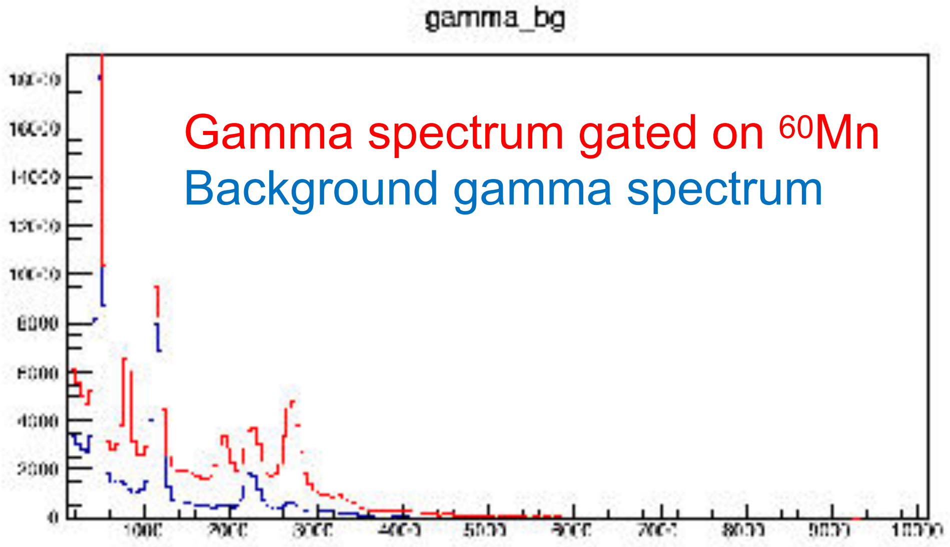


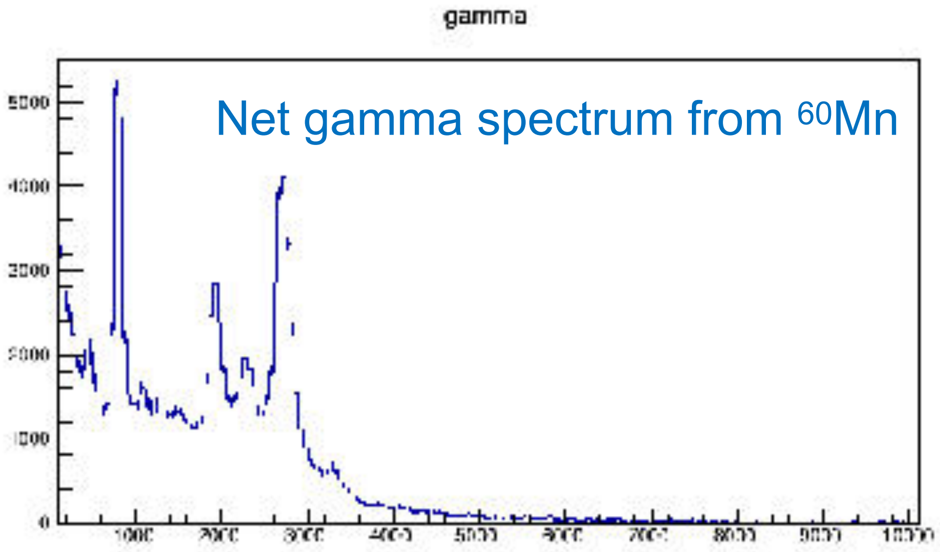


^{60}Mn β-Oslo experiment







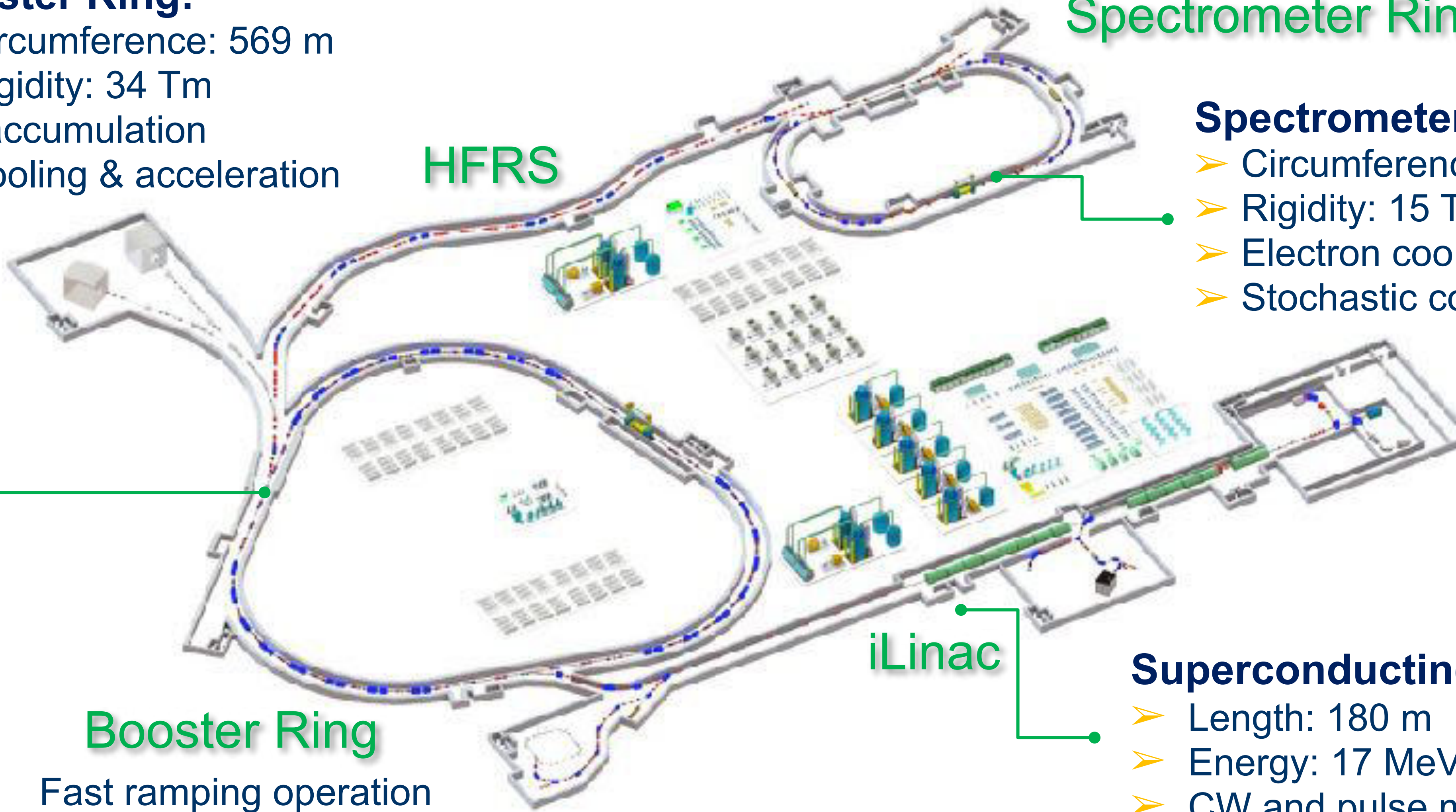



RUSSIA
KAZAKHSTAN
MONGOLIA
KYRGYZSTAN
TIBET
INDIA
NEPAL
BHUTAN
BANGLADESH
MYANMAR
VIETNAM
LAOS
THAILAND
PHILIPPINES
Urumqi
Turpan
Kashgar
Dunhuang
Golmud
Xining
Lanzhou
Yinchuan
Hohhot
Beijing
Shijiazhuang
Tianjin
Taiyuan
Jinan
Qingdao
Dalian
Shenyang
Changchun
Harbin
Zhengzhou
Xi'an
Nanjing
Hefei
Suzhou
Shanghai
Hangzhou
Wuhan
Yichang
Chengdu
Chongqing
Lhasa
Nanchang
Changsha
Guiyang
Fuzhou
Taibei
Xiamen
Lijiang
Dali
Kunming
Guilin
Guangzhou
Shenzhen
Macau
Hong Kong
Nanning
Haikou
Sanya
Yellow River
Yangtze River

HIRFL

HIAF

Booster Ring:
- Circumference: 569 m
- Rigidity: 34 Tm
- Aaccumulation
- Cooling & acceleration



Fast ramping operation

Spectrometer Ring:
- Circumference: 277.2 m
- Rigidity: 15 Tm
- Electron cooler
- Stochastic cooler

45 GHz, 20 KW
ECR ion source

Superconducting Ion Linac:
- Length: 180 m
- Energy: 17 MeV/u ($^{238}U^{34+}$)
- CW and pulse modes


2018, Ground-breaking Ceremony

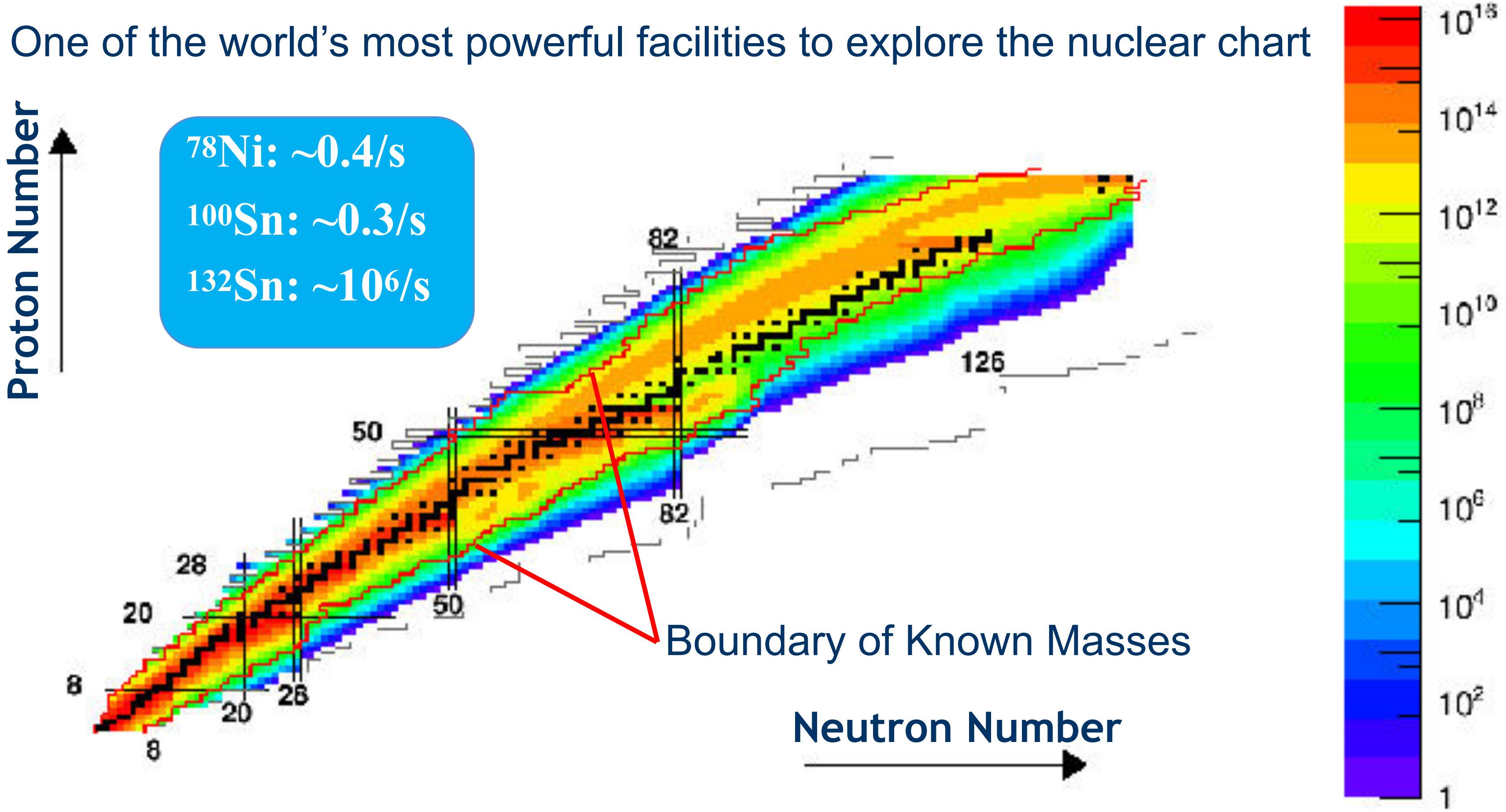

December 2018


November 2020


November 2023

Nuclides Available (Daily Production Yield) at HIAF

One of the world's most powerful facilities to explore the nuclear chart



Prolific sources of nuclides far away from the stability line will be provided using various reactions. The limits shown are the production rate of one nuclide per day, which enable the "discovery experiments"

Thanks

Shilun Jin
Institute of Modern Physics, CAS
jinshilun@impcas.ac.cn