
# Resonance Extraction Research Based on China Spallation Neutron Source

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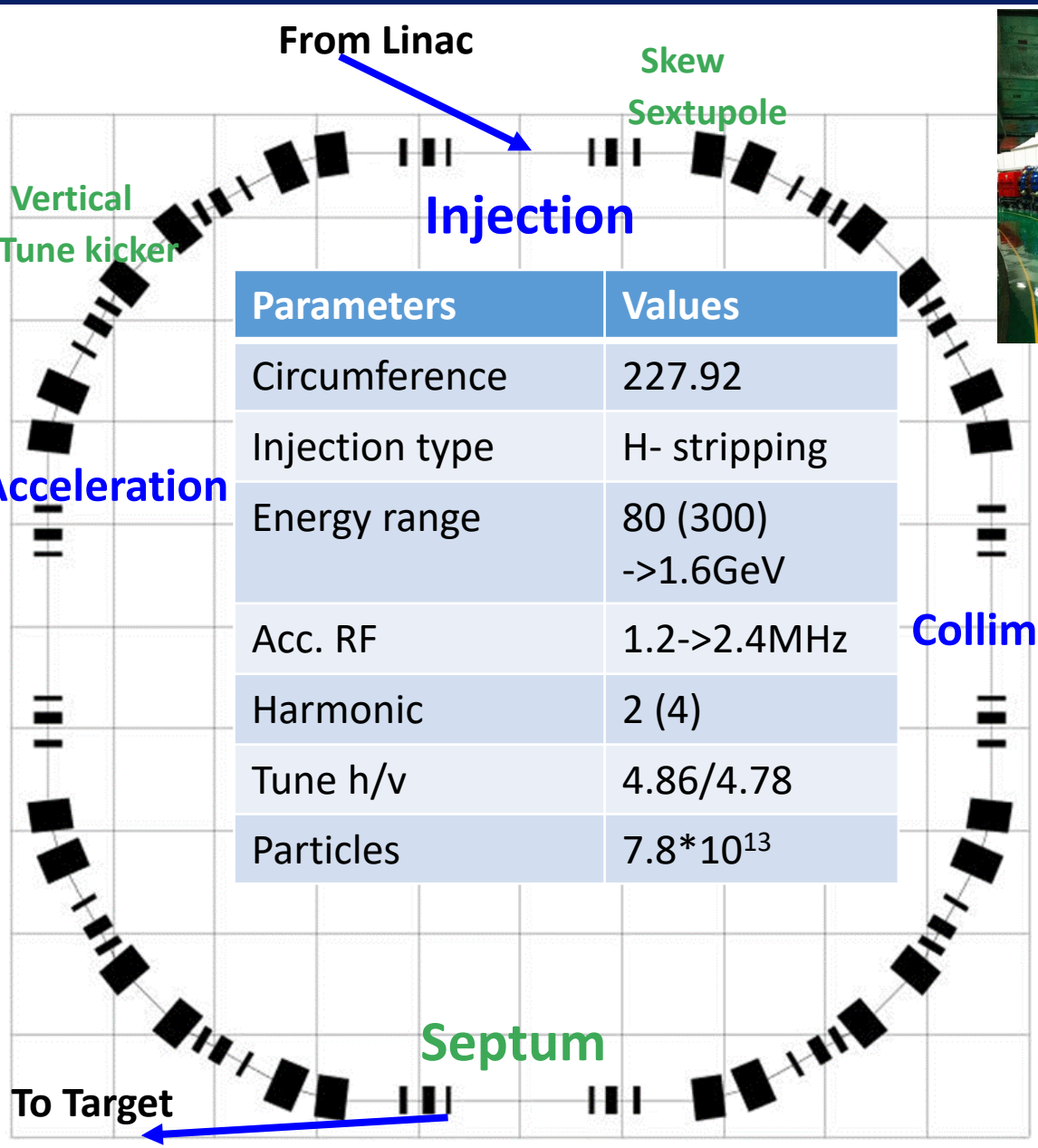
# Motivation:

- CSNS-I has achieved its design goal 100kW in 2020
- The beam power of the CSNS is steady increased, and will reach 500kW at CSNS II
- Besides neutron scattering, **photon radiography** is also an exciting application
- At least 20 frames@10us is required
- At least $10^{10}$ particles per frame, about **0.03%** extraction rate per turn

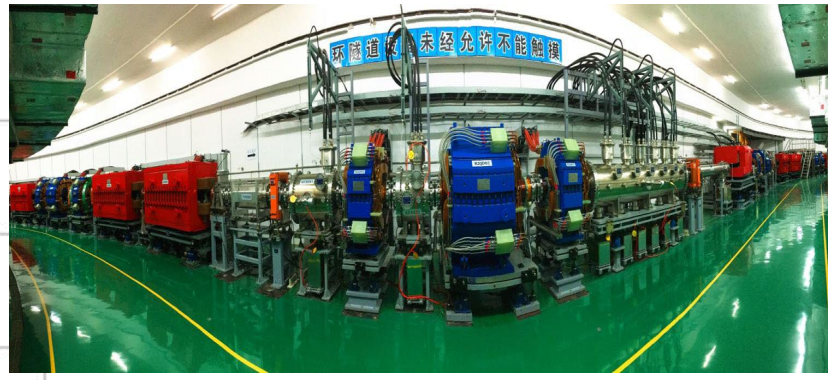
# Outline:

- Typical beam parameters
- Simulation of the 3rd order resonance extraction
- Parameters of the skew quadrupoles, septum and RF kicker
- Conclusion and outlook

# China Spallation Neutron Source (CSNS-RCS): Overview




| Parameters | Values |
|---|---|
| Circumference | 227.92 |
| Injection type | H- stripping |
| Energy range | 80 (300) ->1.6GeV |
| Acc. RF | 1.2->2.4MHz |
| Harmonic | 2 (4) |
| Tune h/v | 4.86/4.78 |
| Particles | $7.8*10^{13}$ |



- Septum & Skew Sextupole is reserved
- Vertical Tune kicker is the exciter for tune measurement

**Third order resonance extraction**

- Tune variation('Quad driven') or transverse excitation('knock-out')
- Bunched beam

# Time structure of extraction beam in the RCS:

- RF Freq. 1.02~2.44MHz 978~409ns
- Bunch Length 489ns~65ns
- 818ns corresponding to 227.92m
- 20 turns extraction can meet the requirements 20 frames@10us;
  $10^{10}$ particles per bunch

# Basics of the 3rd order resonance extraction:

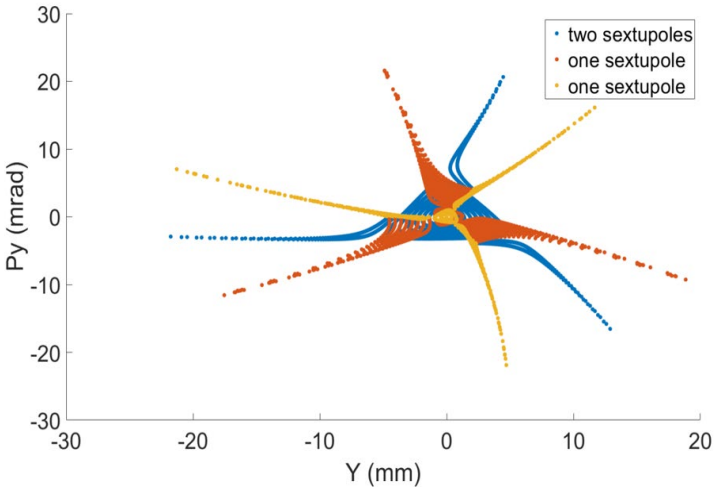
$$|\vec{Y}_{UFP}| = 8\pi|\frac{Q_r - Q_p}{S_v}|$$

$Q_p \equiv Q_m + \xi\delta$ on-axis tune of the particles

$S_n = \frac{1}{2}\beta_{x,n}^{3/2}(k_2L)_n$ normalized strength of skew sext.

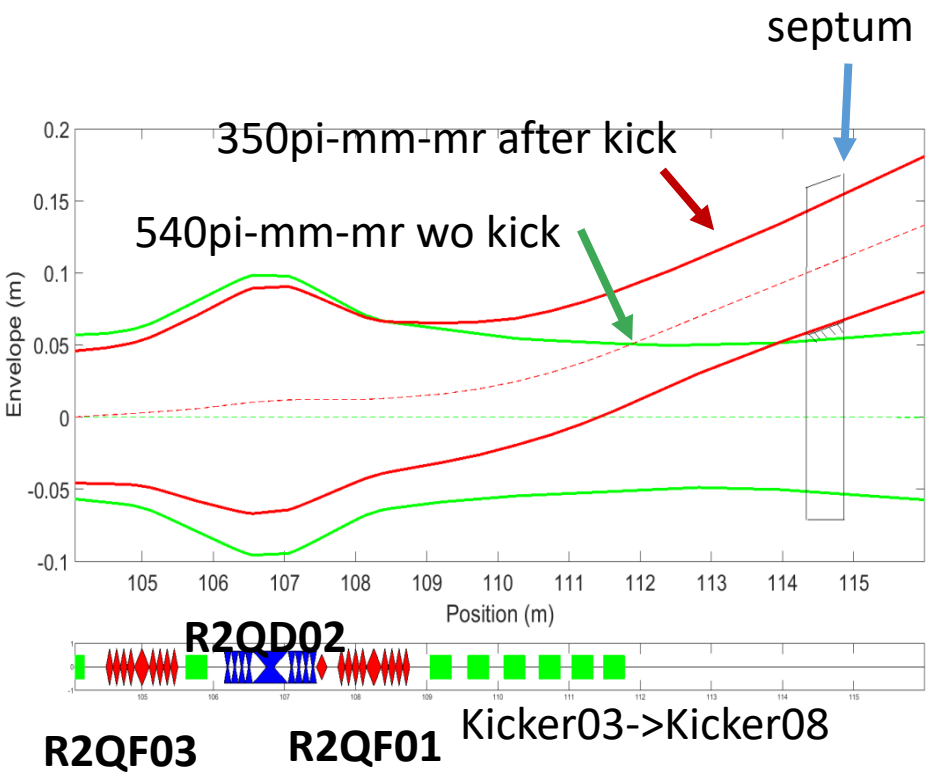
$S_v e^{3i\psi_v} = \sum_n S_n e^{3i\psi_n}$ virtual strength of skew sext.

$A_{stable} = \frac{\sqrt{27}}{4}|\vec{Y}_{UFP}|$ stable phase space area



# Extraction mode for beam supply:

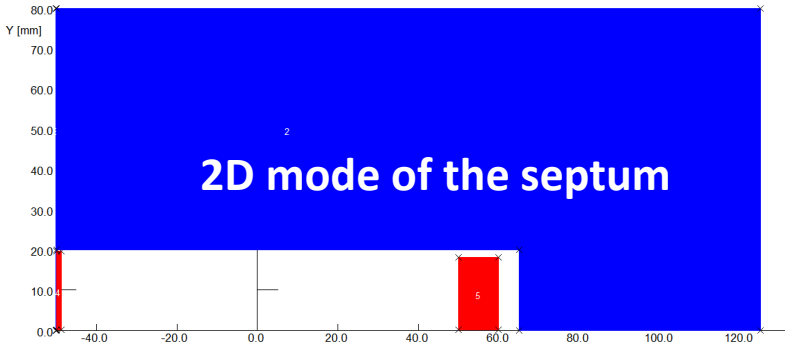
- The beam is deflected about 20mrad to enter Lambertson at vertical plane by 8 kickers in beam commissioning
- The 8 kickers is shut down in the proton radiography mode
- A magnetic septum with 20mrad is planed in proton radiography mode and will be removed in beam commissioning mode
- Necessary beam control and deflection in both modes, optimal performance and functionality for each specific operation.

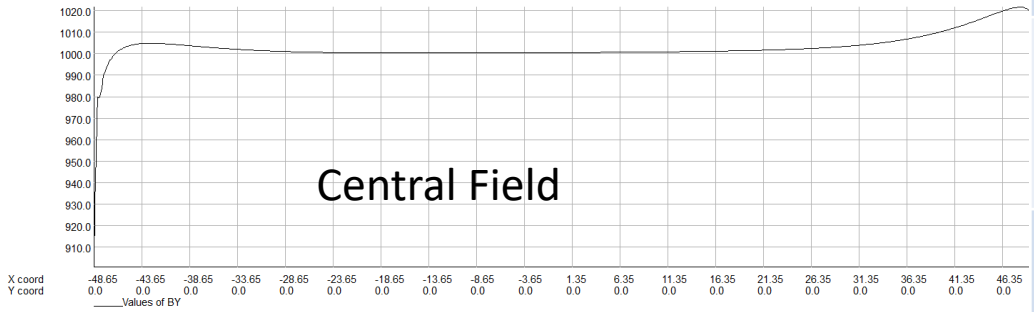


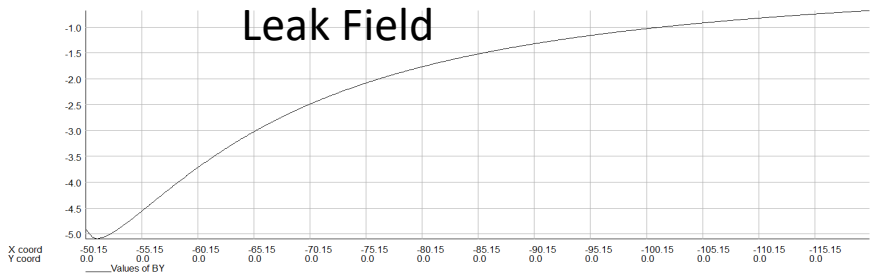

Two extraction mode

- Beam commissioning for 500kW
- Radiography mode

# Preliminary design of the septum:



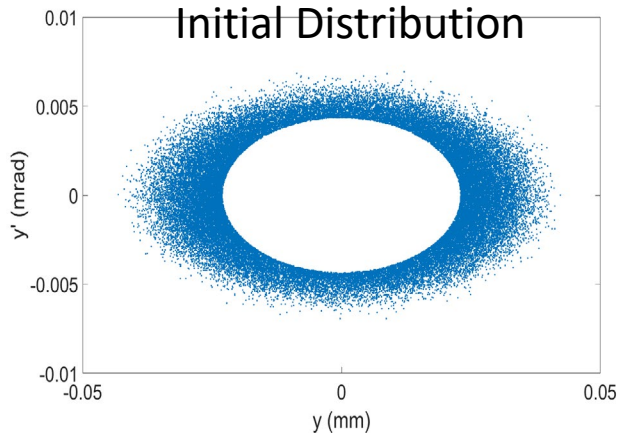



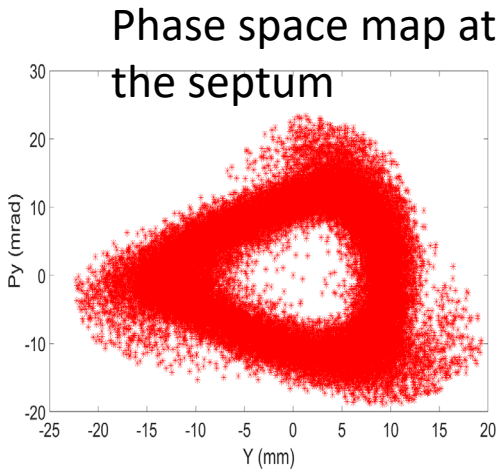

The design of two septa is superior to that of a single septum magnet.

| Parameters | SEP1 | SEP2 |
|---|---|---|
| Field | 0.1T | 0.3T |
| Length | 1m | 0.5m |
| Thickness | 1.5mm | 5mm |
| Good Field Region | 100mm*40 mm | 100mm*50 mm |
| Leak Field | <1% | <1% |
| Current density | 66A/$m^2$ | 62.5A/$m^2$ |
| Inductance | 12.8uH | 5.56uH |

The Leak field of the 2 septa is under 1%

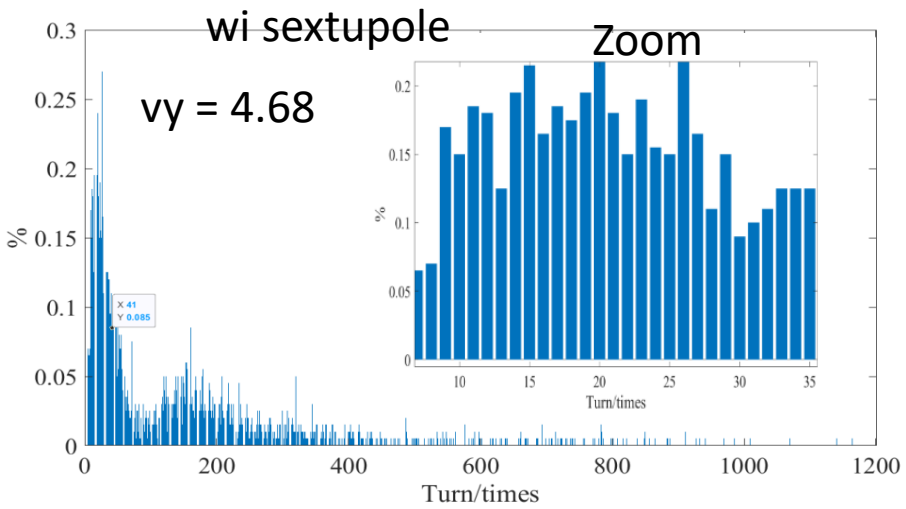
# Simulation Parameters:

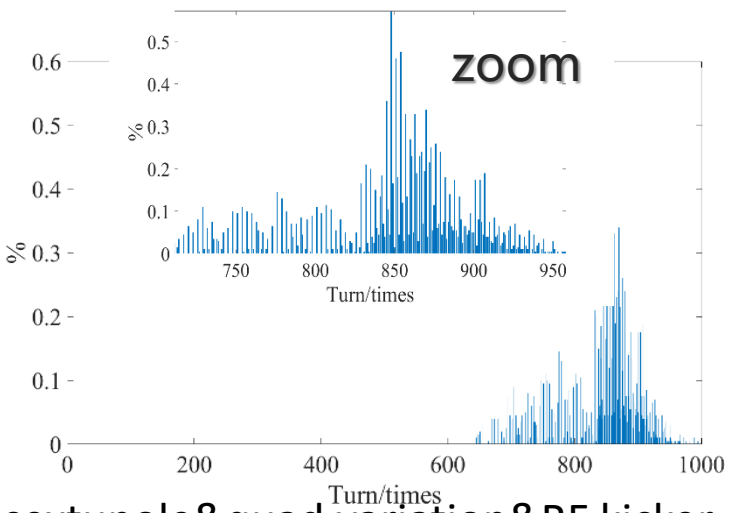


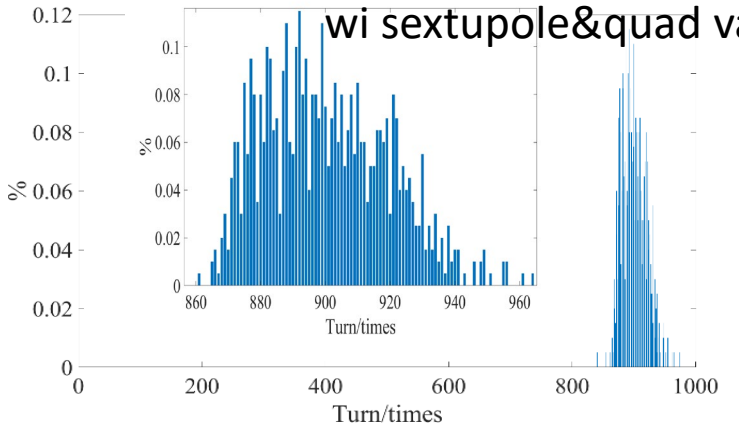

- initial particle distribution is from PyOrbit
  - painting injection
  - Dual harmonic cavities
  - Injection energy is 300MeV
  - tracking turn is 22000
  - Considering space charge effect
- Optimization of beam resonance extraction by removing the central beam
- Tracking about 1000 turns by tuning septum ,skew sextupole, Quadrupole, RF Kicker

# Simulation Result:




wi sextupole&quad variation&RF kicker




By tuning skew sextupole&Quad, the extraction rate can exceed 0.03% per turn

Parameters of skew sextupole and RF kicker

| devices | parameters | values |
|---|---|---|
| skew sextupole | Length (m) | 1 |
| | Strength (T/m*m) | 80 |
| | Rate of change (T/(m*m*us)) | 0.1 |
| septum | Central Field (T) | 0.1 |
| | Length(m) | 1 |
| | Thickness(mm) | 1.5 |
| | Gap(mm) | 40 |
| | Leak Field | <0.01 |
| RF kicker | Max. kick angle (urad) | 4.0 |
| | Frequency of RF kicker(MHz) | 0.83 |

# Conclusion:

- Proton radiography is a perspective application for CSNSII
- 20 frames @10us , particles exceeding $10^{10}$ is a application mode , requiring 0.03% extraction rate for CSNS-RCS at 500kW
- A new septum is designed to deflected extracted beam before Lambertson
- By tuning skew sextupoles , quadrupoles (tunes), and RF kicker, the extraction rate meet the requirement

# Challenges:

- The particles may not be very uniform during 20 frames
- 0.03% extraction rate seems high for 3$^{rd}$ order resonance extraction

# Thanks for your attention