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ESS NEUTRINO SUPER BEAM

Funded by the Horizon 2020 Framework Programme of the European Union

Studies on beam collimation system for the ESSnuSB accumulator

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Abstract

- The ESSnuSB, a neutrino facility based on the European Spallation Source, aims at measuring, with precision, the charge-parity (CP) violating lepton phase at the 2nd oscillation maximum. The ESS linac will have to be upgraded to provide an additional 5 MW beam for the ESSnuSB to produce an unprecedented high-intensity neutrino beam. An accumulator ring is employed to compress the 2.86 ms long pulse from the linac to around 1.5 μs in order to satisfy the target requirements and improve the physics performance.

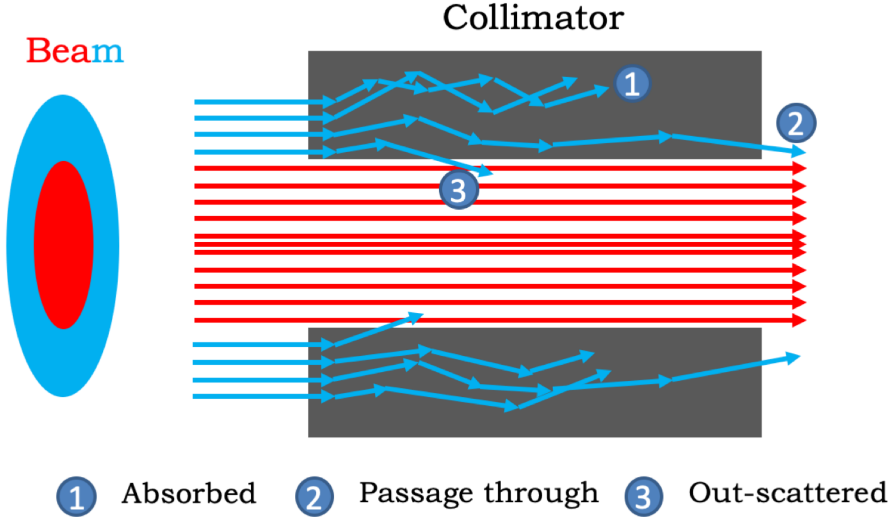
- In the operation of a high-intensity proton accumulator, the most important issue is to minimize the uncontrolled beam loss to reduce component activation in order to make hands-on maintenance possible. For this purpose, a two-stage collimation system is designed, which consists of a thin scraper to scatter halo particles and secondary collimators to absorb those scattered particles. Phase advances between scraper and secondary collimators, together with the material, thickness of collimators, have been detailed studied and numerical simulations have been performed to evaluate the performance of the collimation system.

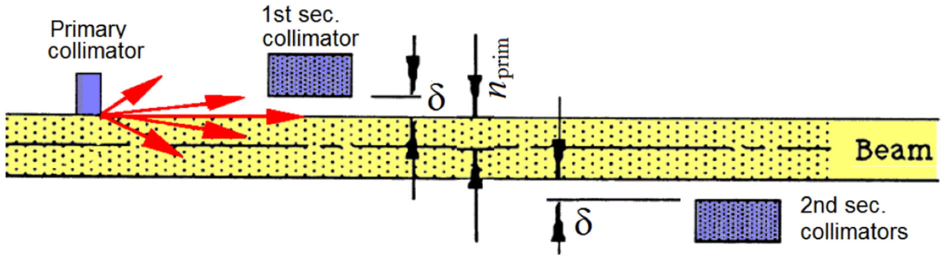
Beam collimation system

- Beam collimation system to localize beam loss, with high efficiency, to a specific region which has strong shielding
- The goal for the ESSnuSB accumulator: total beam loss < 10^{-4}, collimation efficiency > 90%

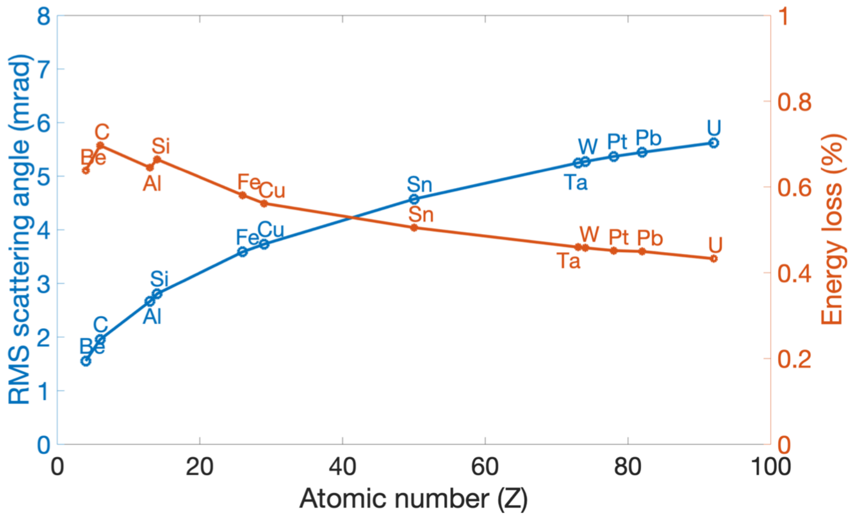
Two-stage collimation system

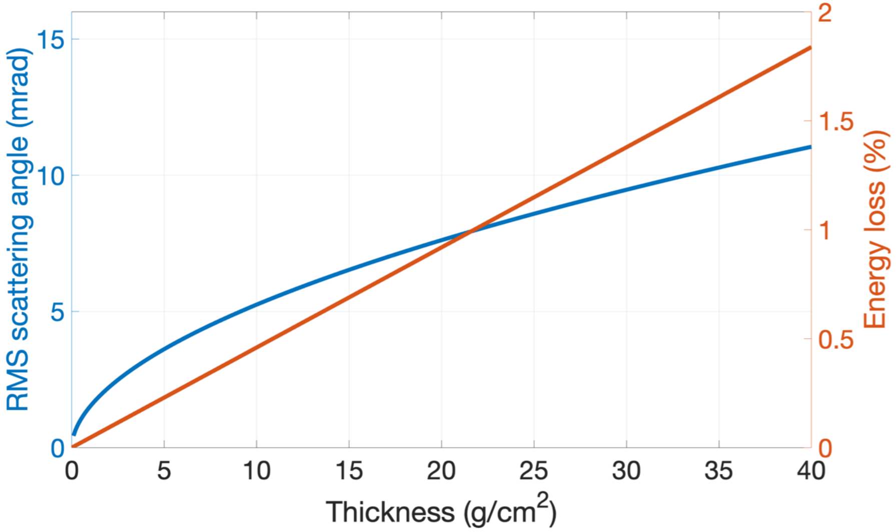
- A scraper located before thick collimators
- Optimal phase advances between scraper and thick collimators
- Particles always hit the scraper before they reach thick collimators
- The impact parameter of the scattered particles significantly enlarged





Material and thickness



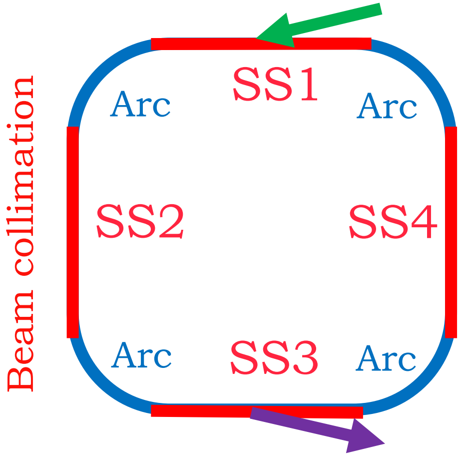


- The ideal material: small energy loss and large mCs deflection angle
- Other factors: availability, radiation and heat damage, melting point, thermal conductivity
- Tantalum, Tungsten, Platinum are good choice

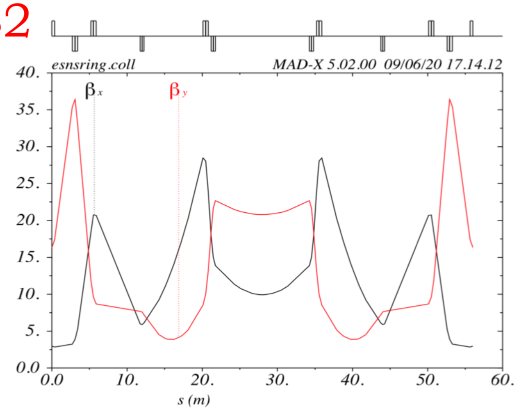
- The choice of scraper thickness is a balance between scattering angle and energy loss
- A thick scraper also increase the probability of large scattering angle
- Thickness of 5-20 g/cm^2 (3 mm to 12 mm for tantalum) is good
  - RMS scattering angle: about 4 to 8 mrad
  - Energy loss: about 0.5% to less than 1%

Location and shape

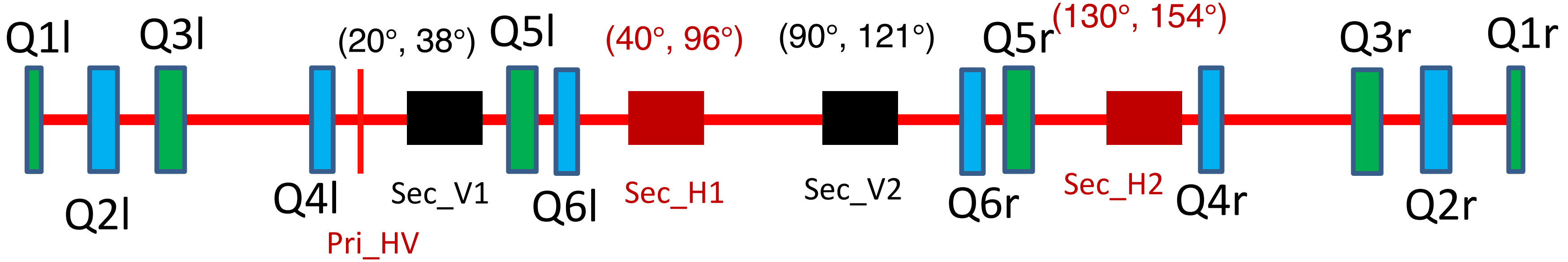
ESSnuSB accumulator



SS2



SS2

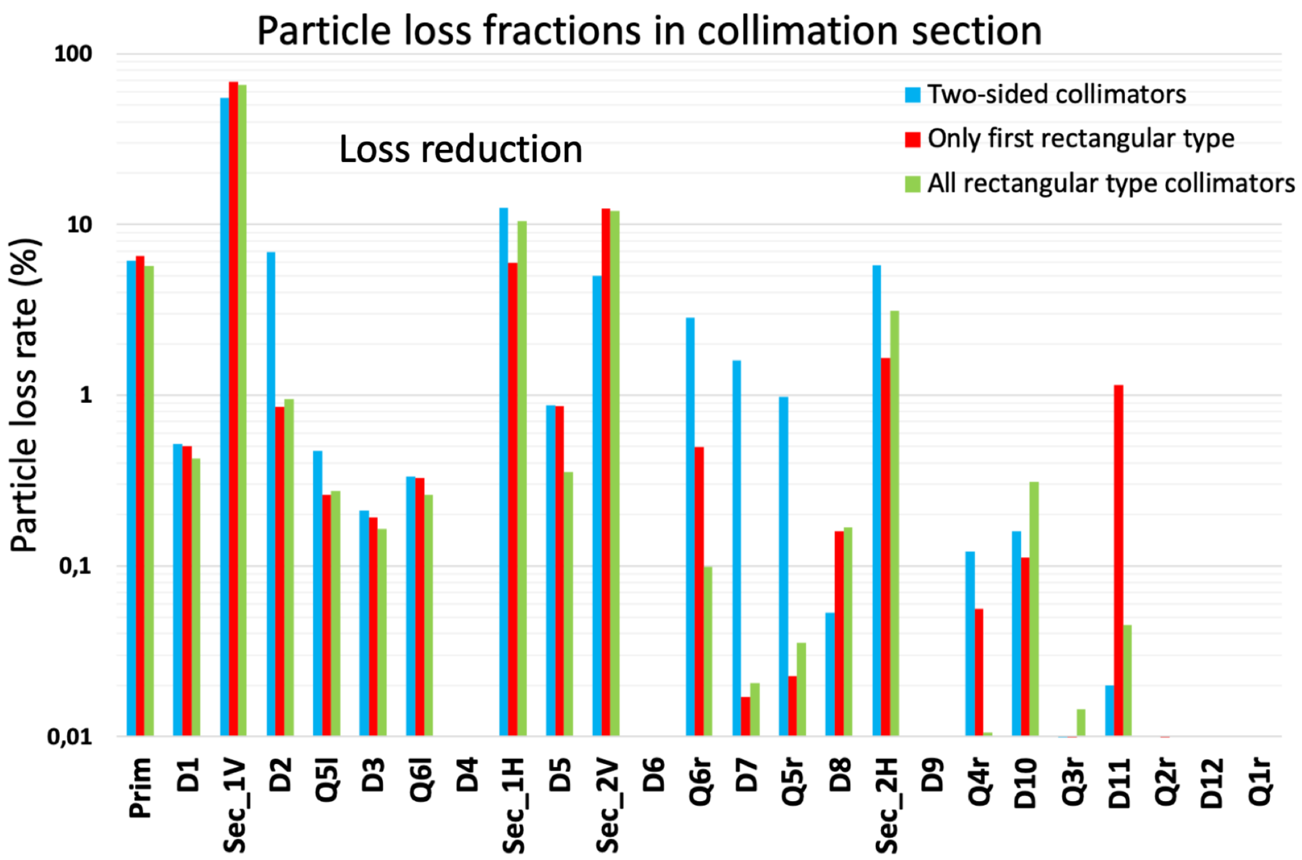


- Collimation system consists of one scraper and four secondary collimators
- Scraper is located after Q4l, where $\beta_x = \beta_y$
- Location of secondary collimators (compared to the scraper):
  - Sec_V1 (20°, 38°), Sec_H1 (40°, 96°), Sec_V2 (90°, 121°), Sec_H2 (130°, 154°)
- Shape of scraper: "L" type
- Shape of secondary collimators:
  - All two-sided shape
  - First collimator rectangular, others two-sided shape
  - All rectangular shape

Numerical simulations

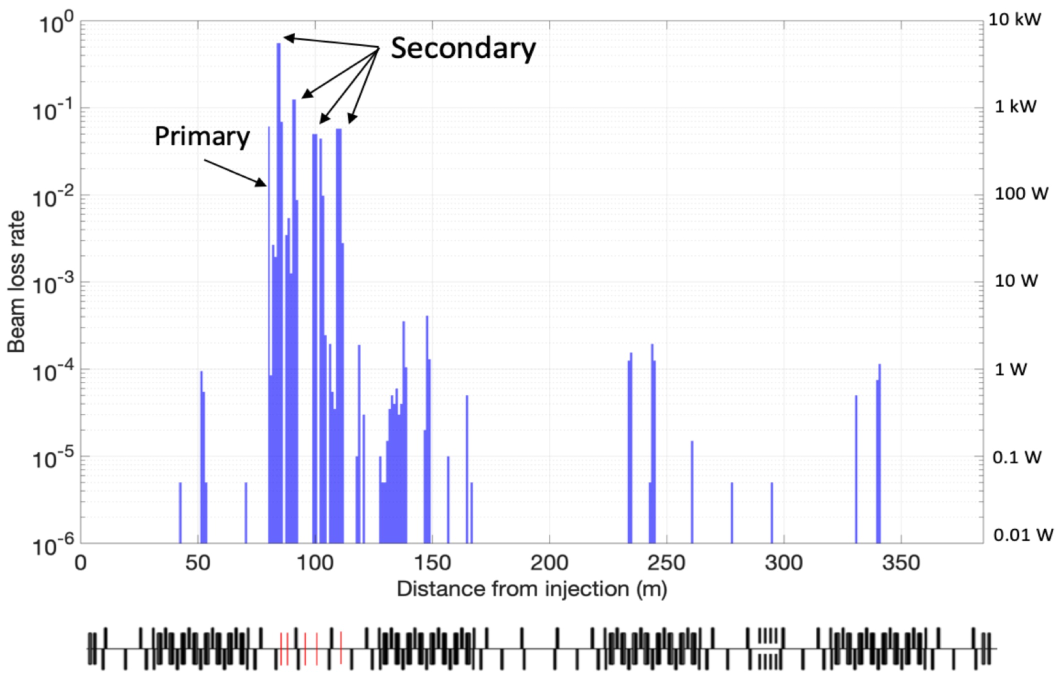
Main configuration

Parameter	Value
Ring acceptance	200 π mm mrad
Scraper/Secondary collimators:	
Acceptance	70 /120 π mm mrad
Material	Tantalum / Tungsten
Thickness (length)	6 mm / 1.5 m



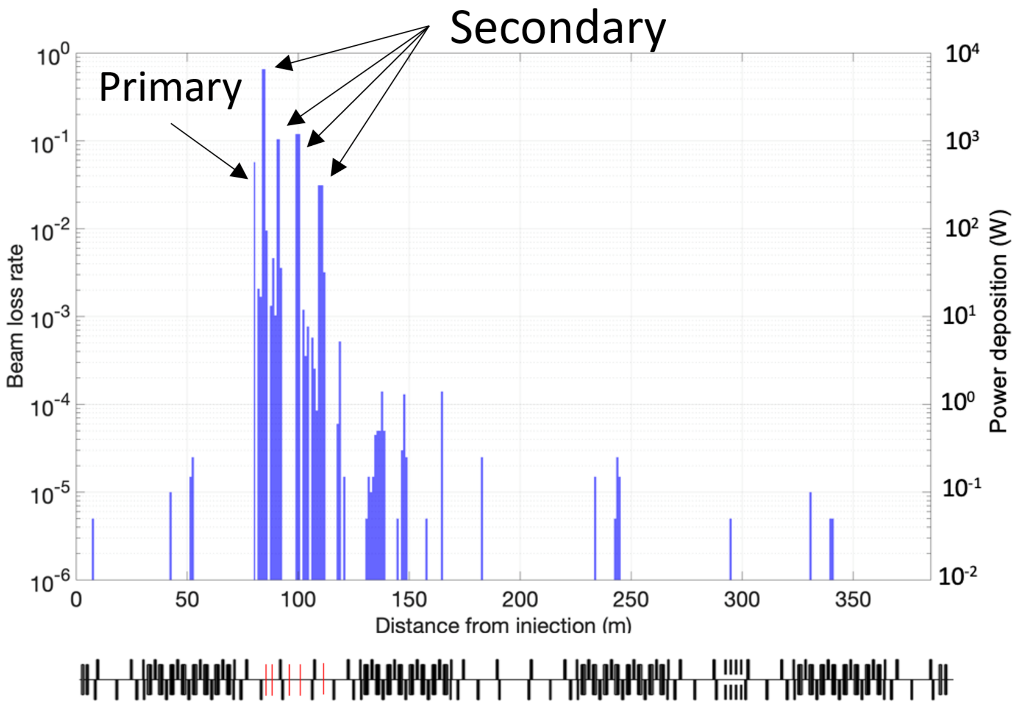
Collimator efficiency

Two-sided shape collimators



Collimation Efficiency: 84.71%

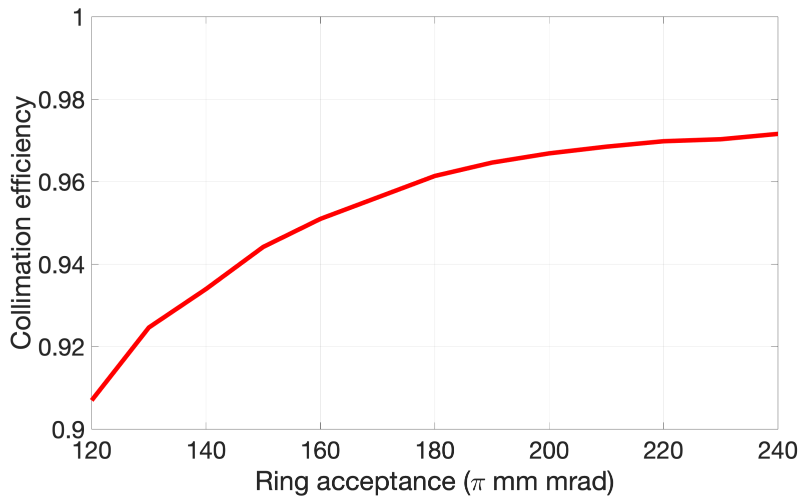
Rectangular shape collimators



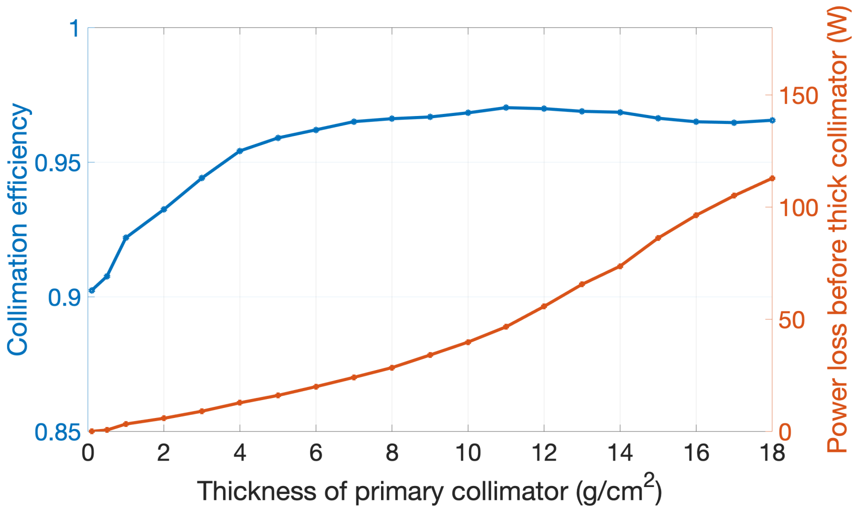
Collimation Efficiency: 96.83%

Further study and conclusion

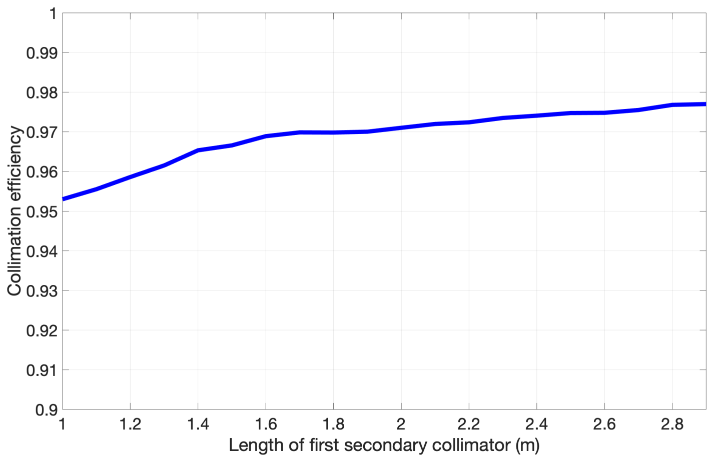
Collimation efficiency vs. Ring betatron acceptance



Collimation efficiency vs. thickness of primary collimator



Collimation efficiency vs. length of first secondary collimator



- A basic betatron collimation system has been set up for the accumulator
- Different configurations have been studied
- Numerical simulations have been performed to evaluate the collimation efficiency
- The collimation efficiency can reach about 97% with rectangular-shape collimators, and more than 99.8% beam lost in the collimation section