Stochastic cooling system:
Start-up and project modes

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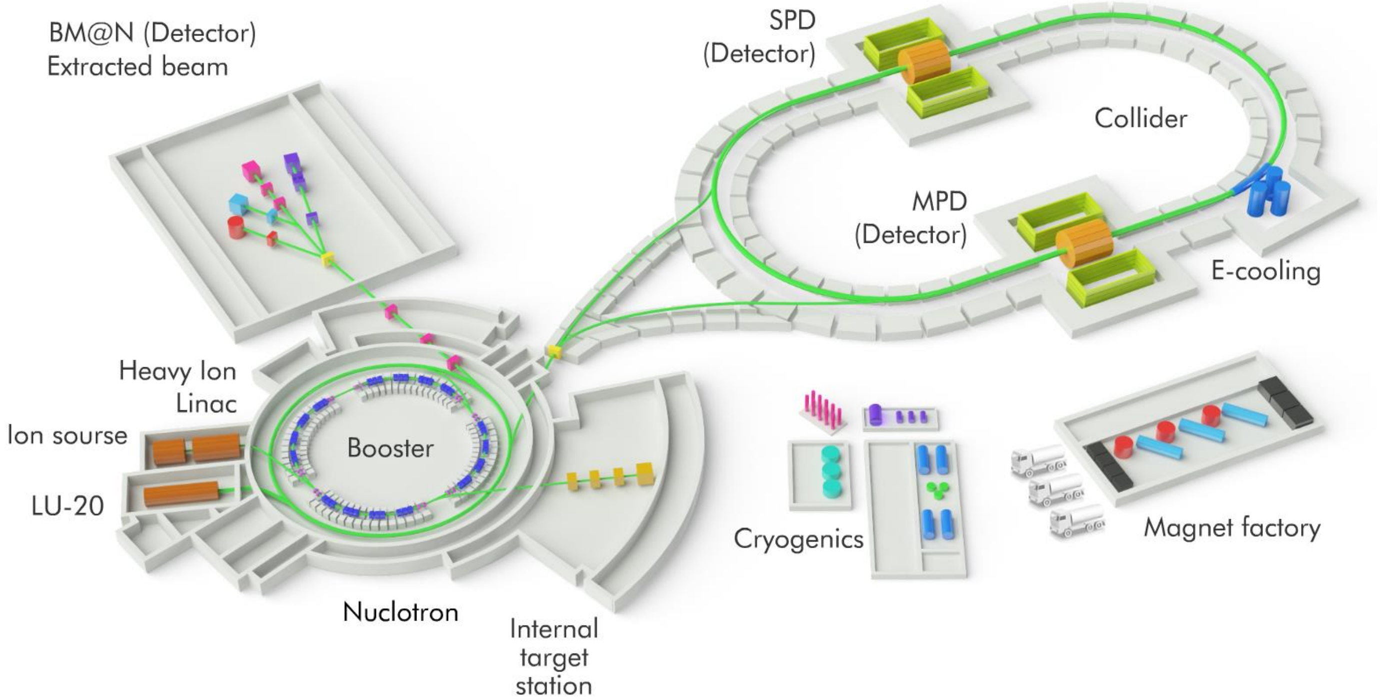
NICA MAC 2017

Nuclotron-based Ion Collider fAcility



Stochastic cooling system – one of the crucial elements of NICA project

Tasks:

- Beam accumulation(at low intensities)
- Longitudinal emittance reduction during the bunching
- Luminosity preservation(IBS counteration)

Start-up mode	Project mode
RMS bunch length 1,2 m	RMS bunch length 0,6 m
U_{RF} = 50 kV	U_{RF} < 1000 kV
h = 22	h = 66
Ions $^{179}Au_{97+}$	
$\varepsilon_{\perp max}$ = 1,1 π mm mrad	
Energy range 3-4,5 GeV/u	
Bandwidth 2-4 GHz	
Only longitudinal cooling	3-D cooling

Project mode

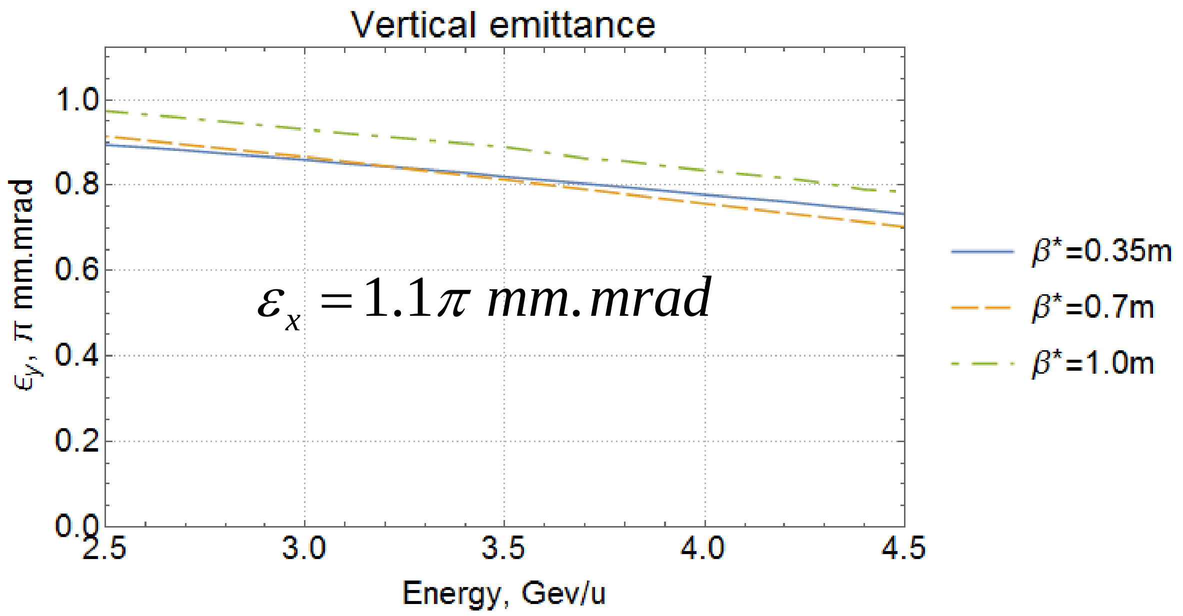
IBS calculations: BETACOOL

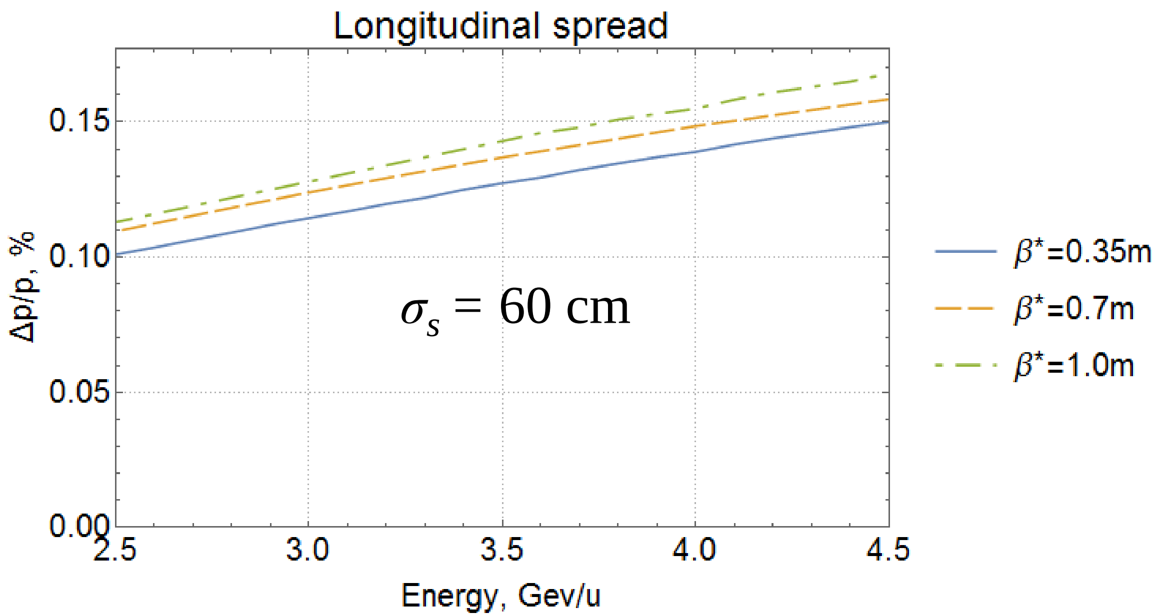
Structures compared: $\beta^* = 35, 70, 100\ cm$

3-D cooling

IBS simulation condition

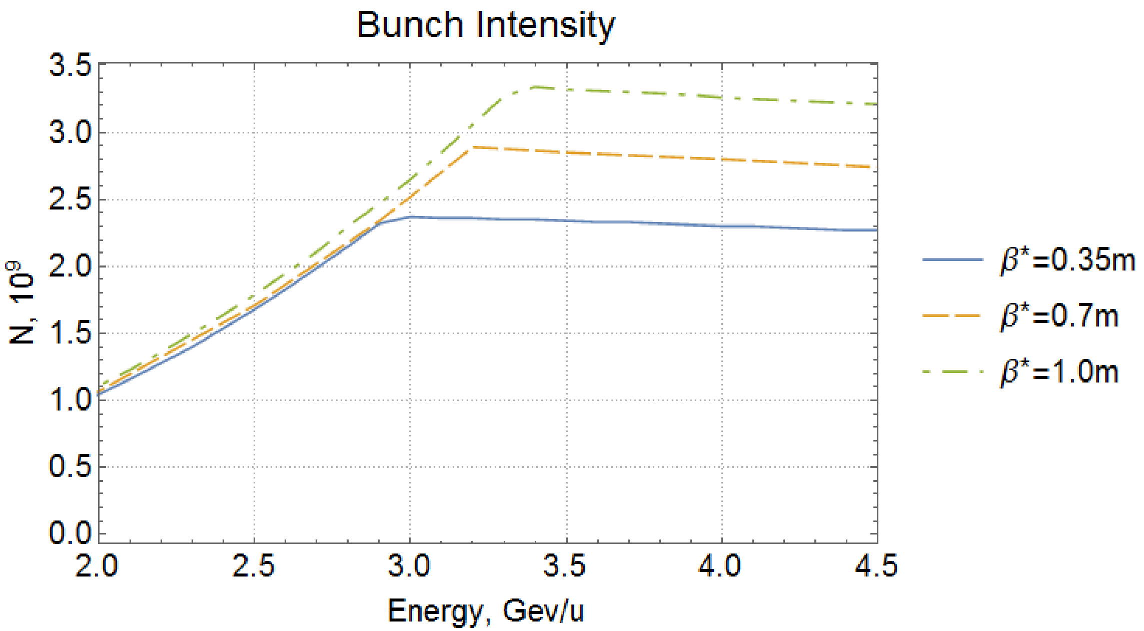
$$\tau_{IBS}^{x} = \tau_{IBS}^{y} = \tau_{IBS}^{z}$$



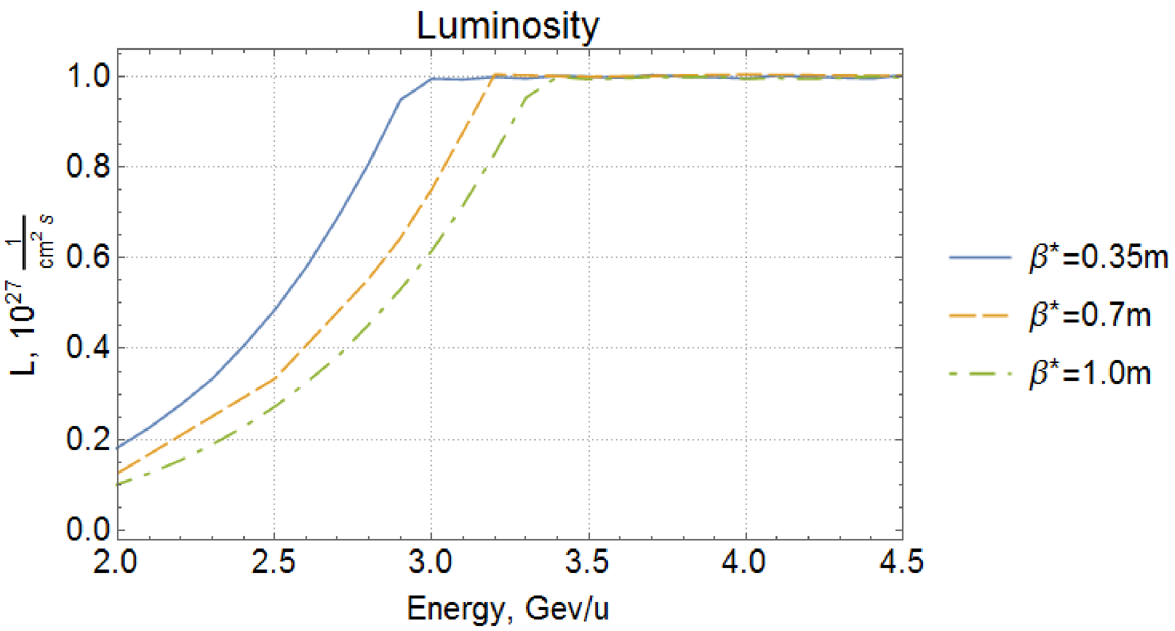


Luminosity

$\Delta Q = 0{,}05$



$L_{max} = 10^{27} cm^{-2} s^{-1}$

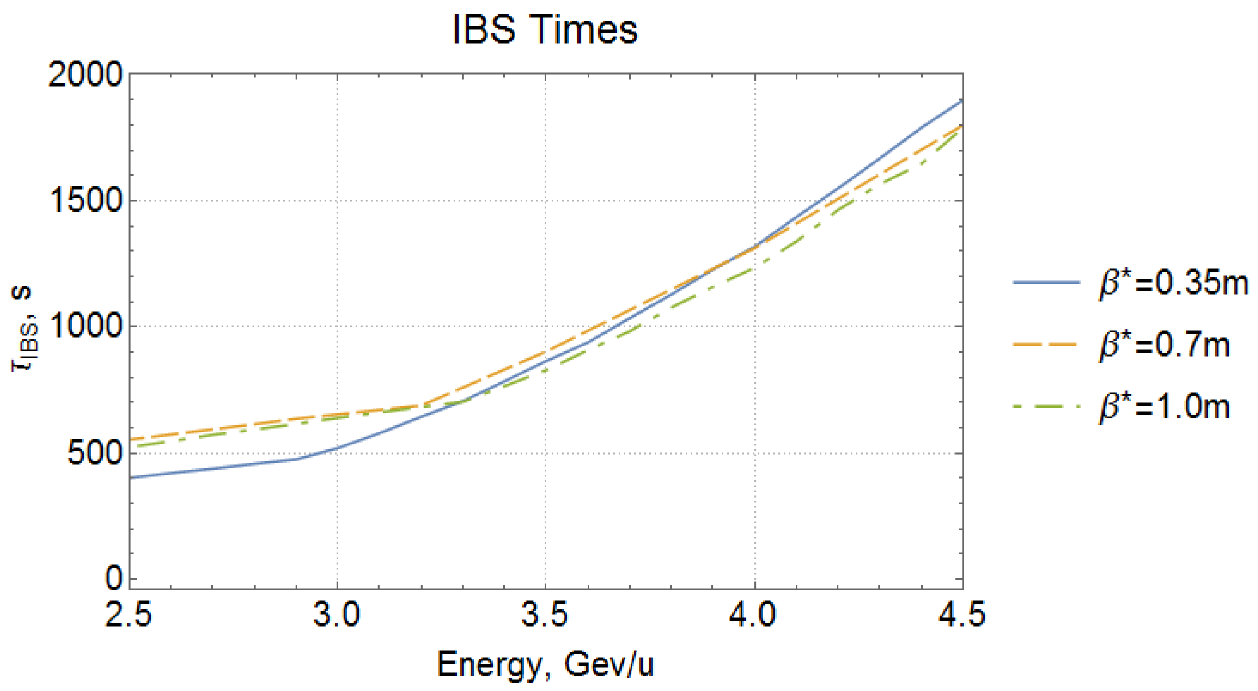


Project luminosity attainment

β^{IP}, m	0,35	0,7	1,0
E, GeV/u	3.0	3.2	3.4
N, 10^9	2.3	2.85	3.25

Intrabeam scattering

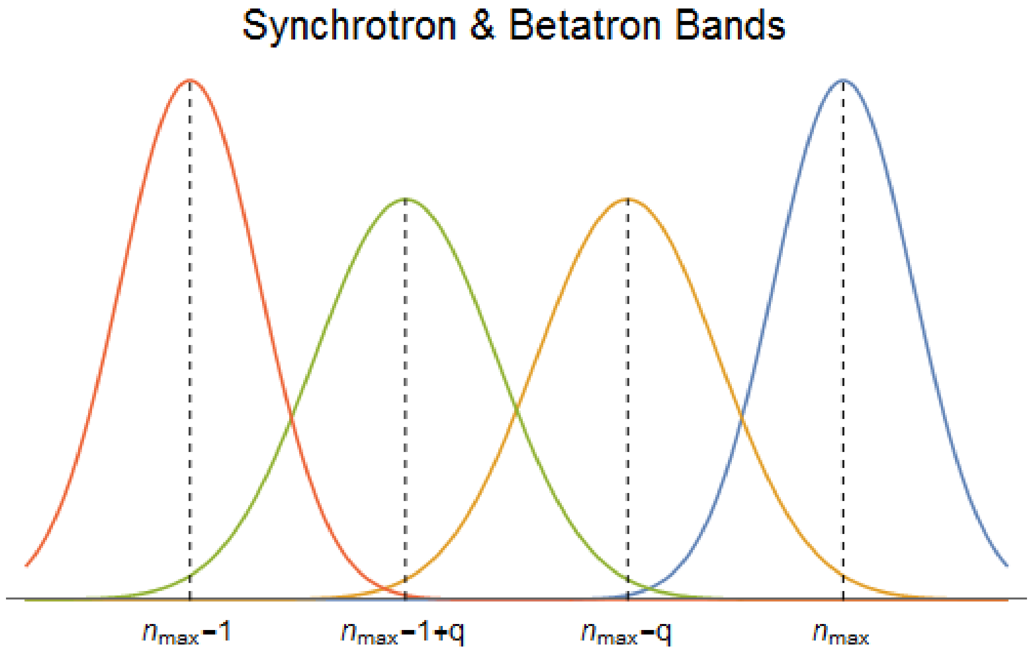
Requirement: cooling rates has to exceed IBS rates



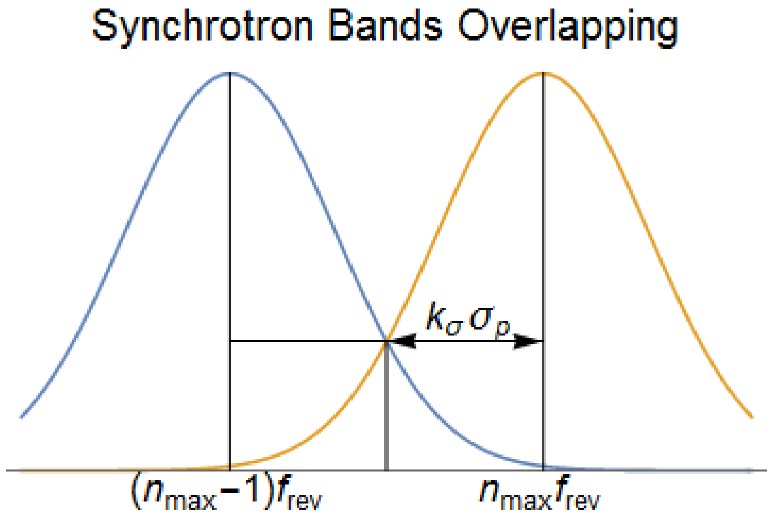
In the range from 3,3 to 4,5 GeV/u IBS times for compared structures does not significantly depend on β^{IP} and are about (700-1800 s)

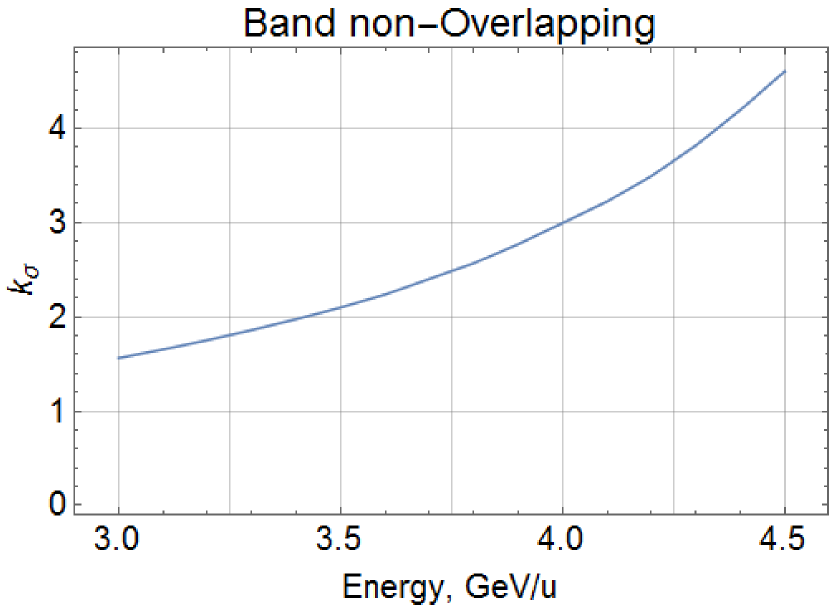
Bandwidth & Working Point

Bandwidth 2-4 GHz



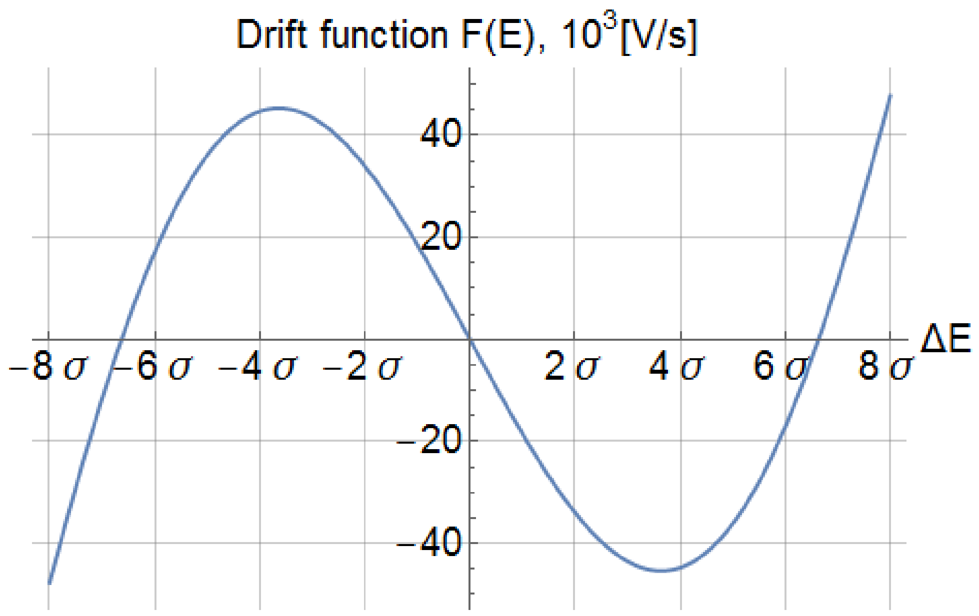
Preferable working point is $\frac{1}{6} < q < \frac{5}{12}; \quad \frac{7}{12} < q < \frac{5}{6}$

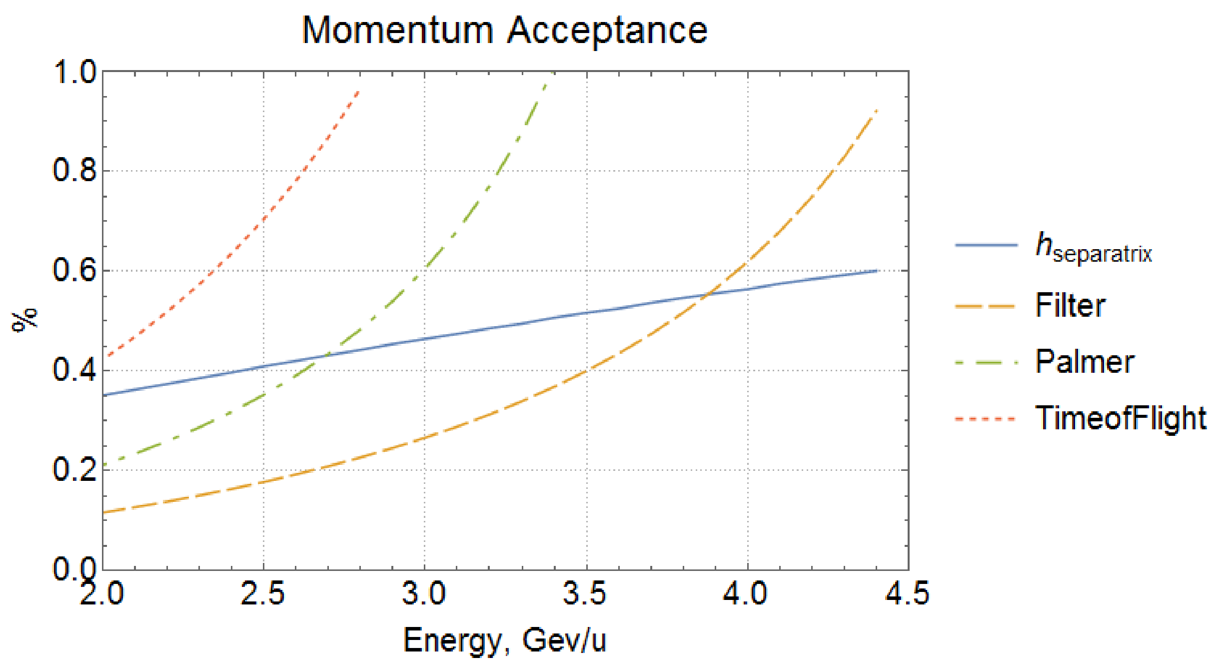




Having bandwidth 2 – 4 GHz we have the absence of overlapping 1.5 – 4.6 σ_p

Cooling Acceptance

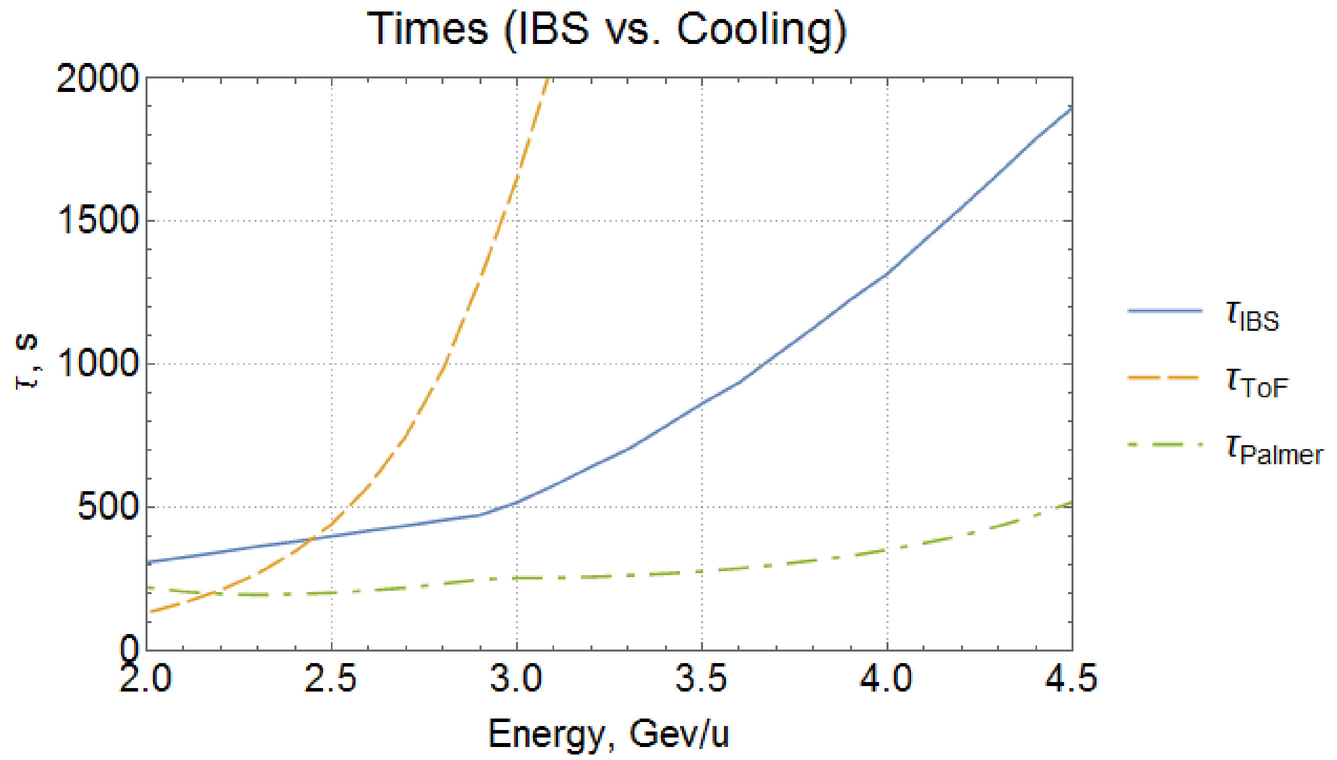




At energies below 3.9 GeV/u cooling by the filter method does not cover the whole separatrix, which leads to additional beam loss.

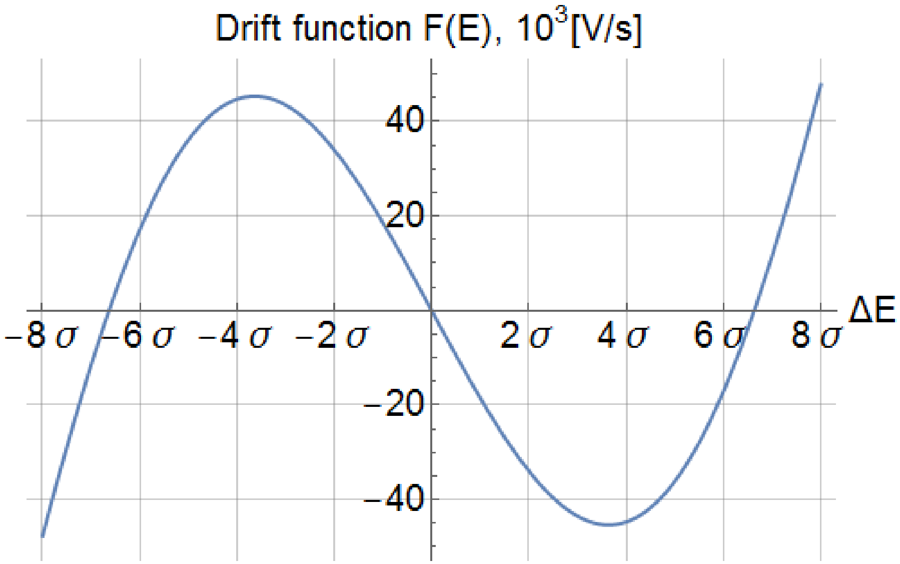
The Filter method is rejected for the project mode due to the low acceptance

Cooling times(at optimal gain)

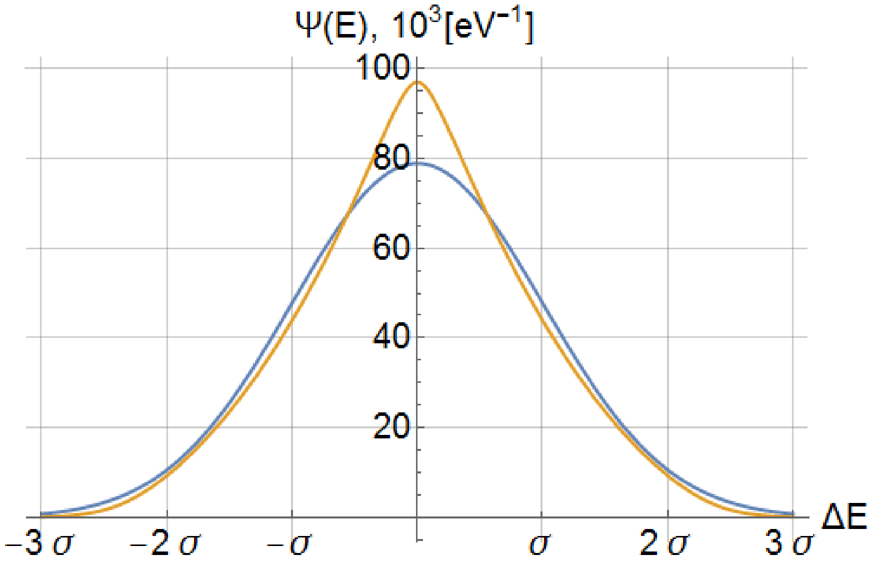


Time-of-Flight method does not provide faster cooling tempo than tempo of IBS heating.

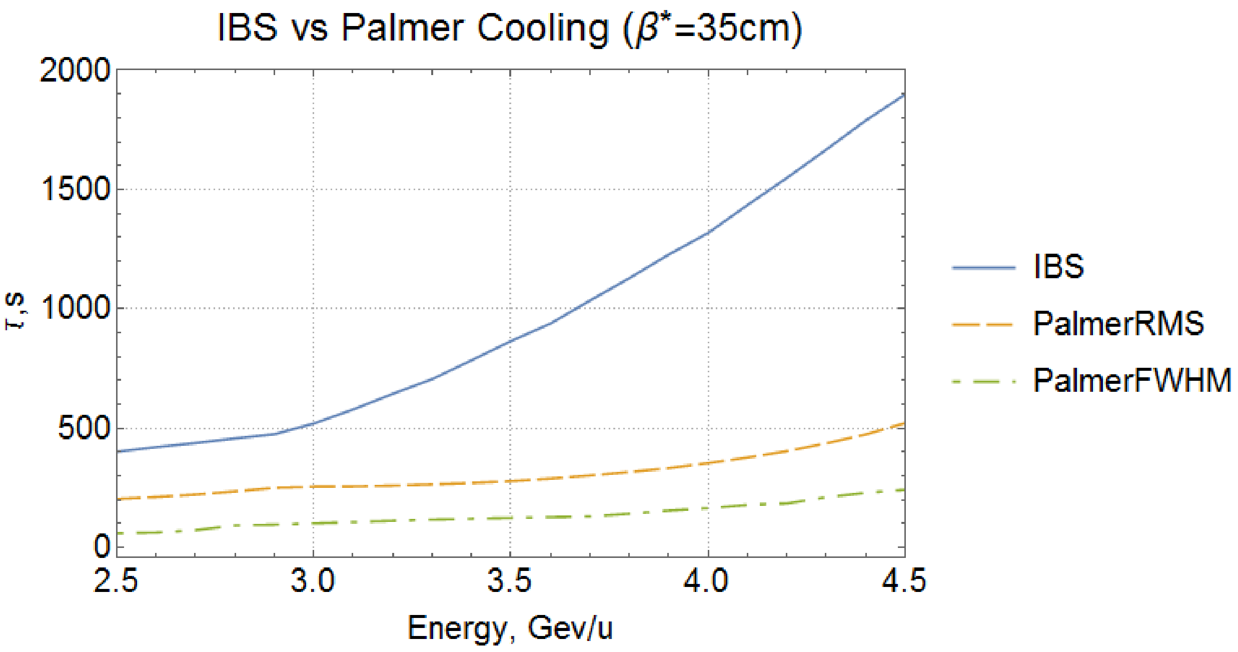
Only Palmer method satisfied the requirements and it is chosen for the project mode.

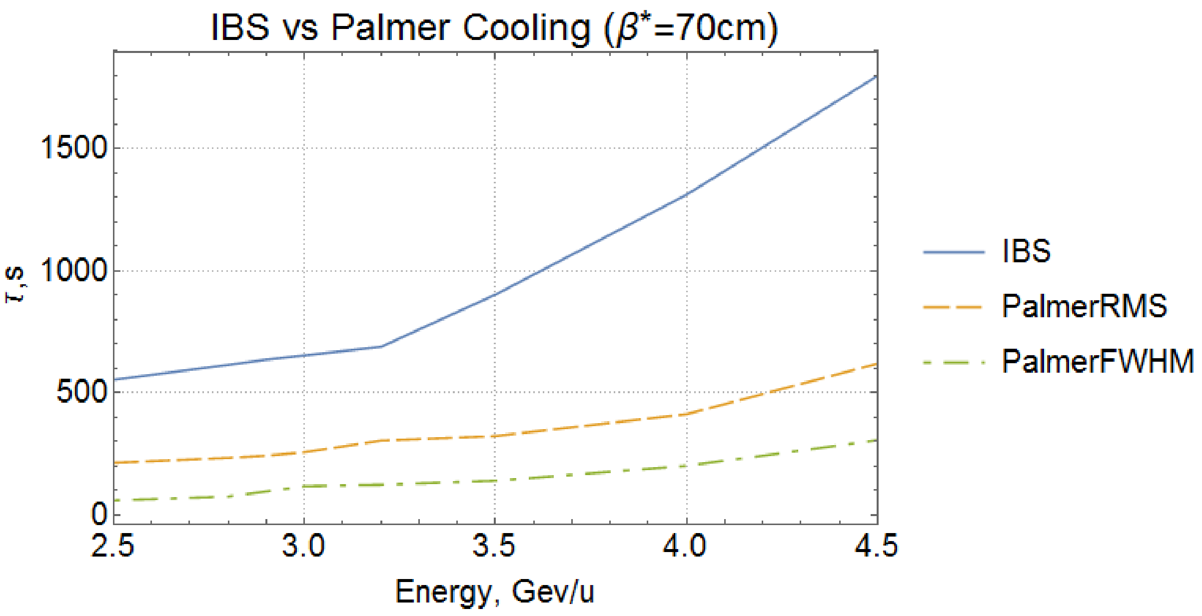


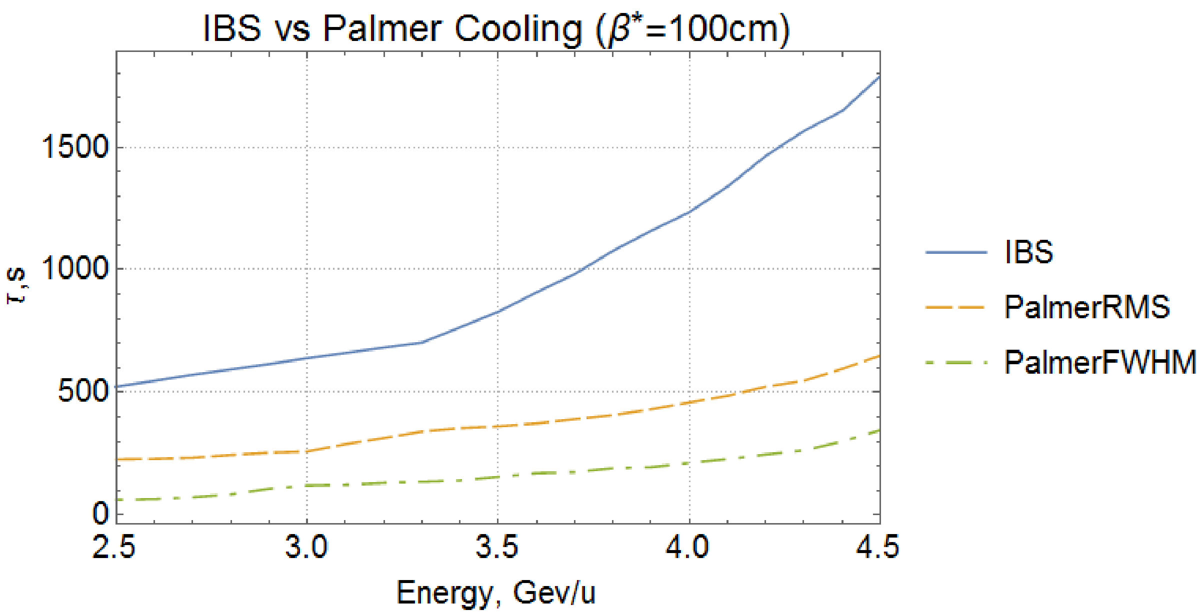
Drift force is not linear



The core is cooled faster than the tail







E=3Gev/u	β*=35cm	β*=70cm	β*=100cm
IBS/CoolRMS	2,034	2,543	2,464
IBS/CoolFWHM	5,110	5,584	5,302

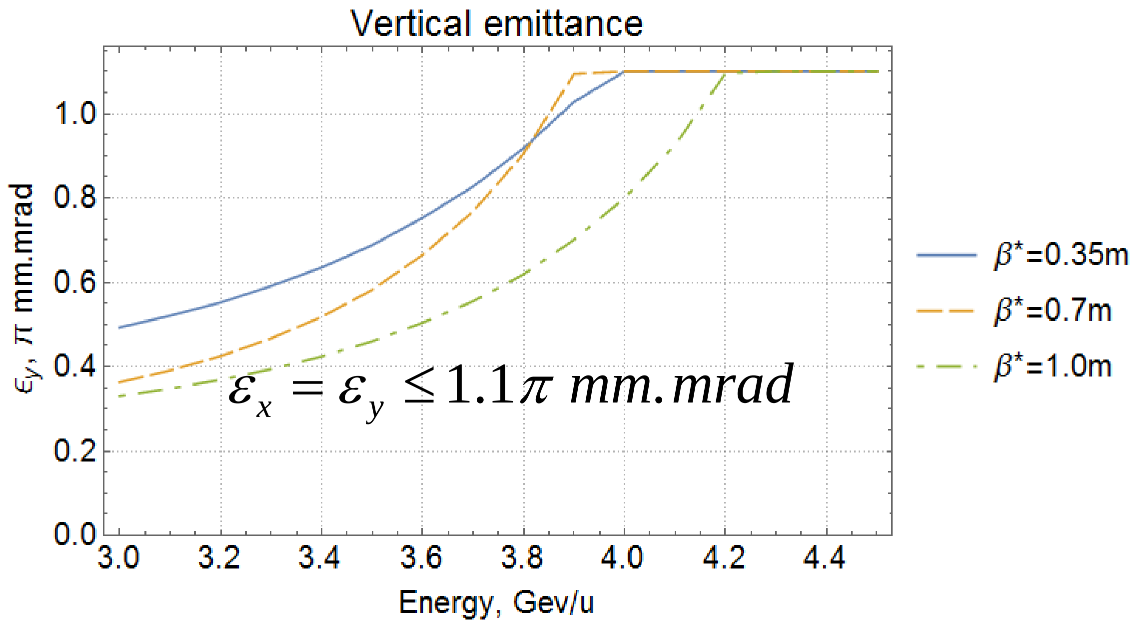
For the project mode the Palmer cooling rates 2-5 times exceed the IBS rates at any discussing choice of β–function in the interaction point

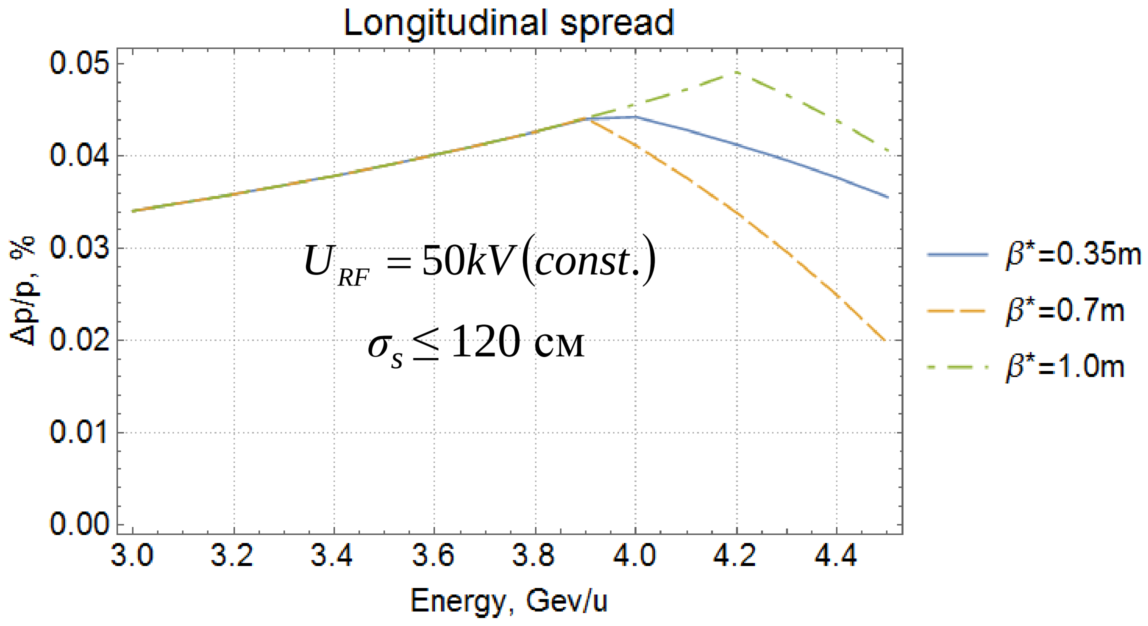
Start-up mode

Longitudinal cooling only

IBS simulation condition

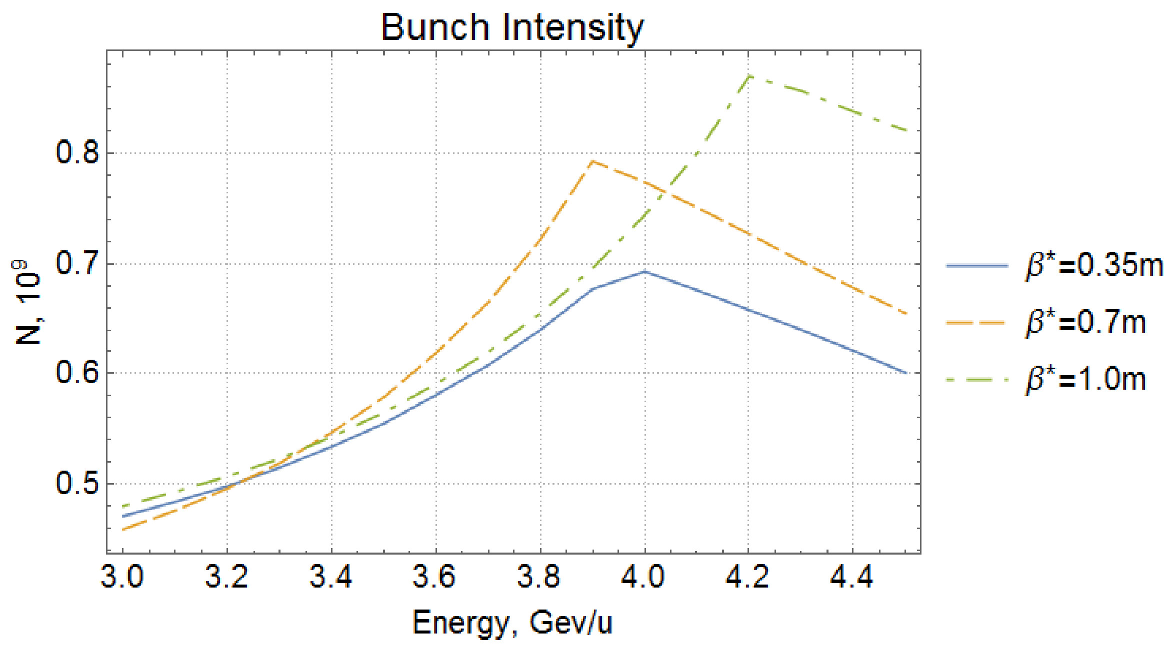
$$\tau_{IBS}^{x} \cong \tau_{IBS}^{y} \to \infty$$

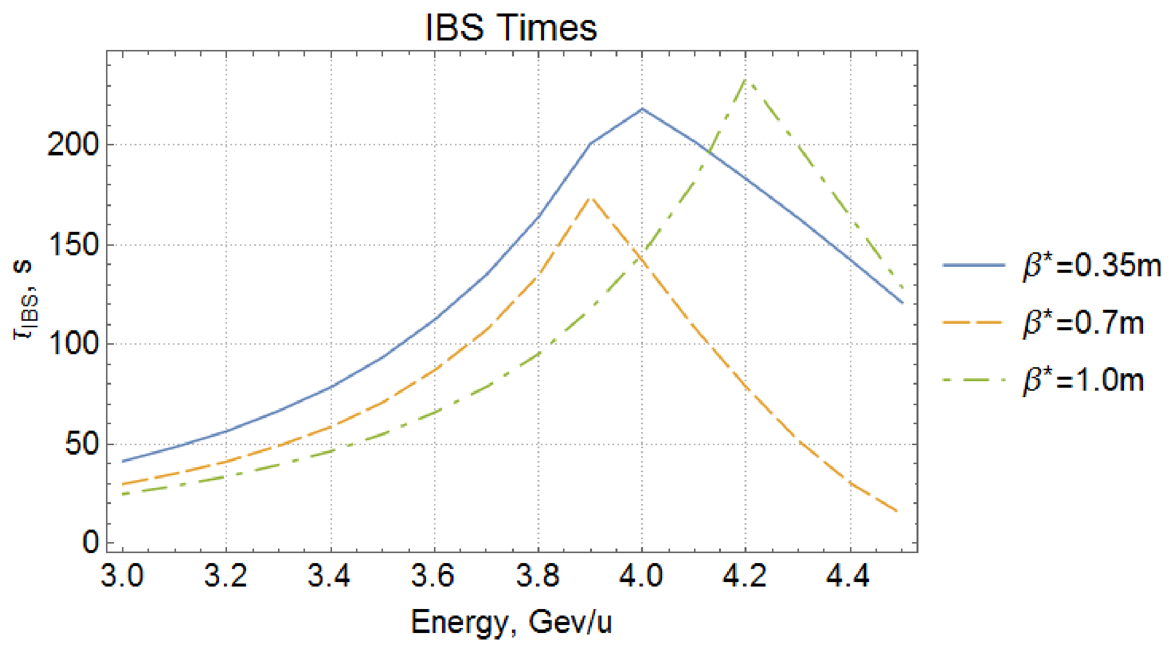




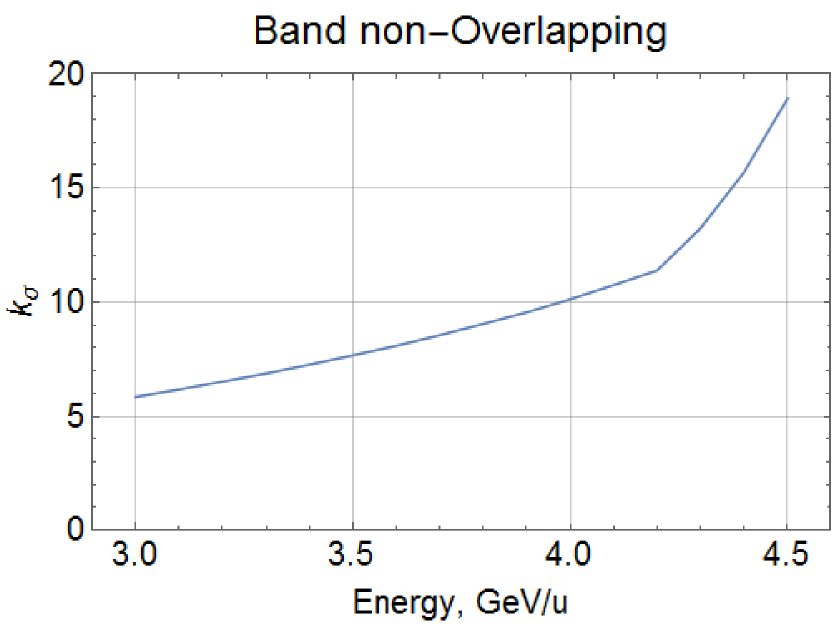
Intrabeam scattering

Required luminosity for start-up mode $L = 5 \cdot 10^{25} cm^{-2} s^{-1}$

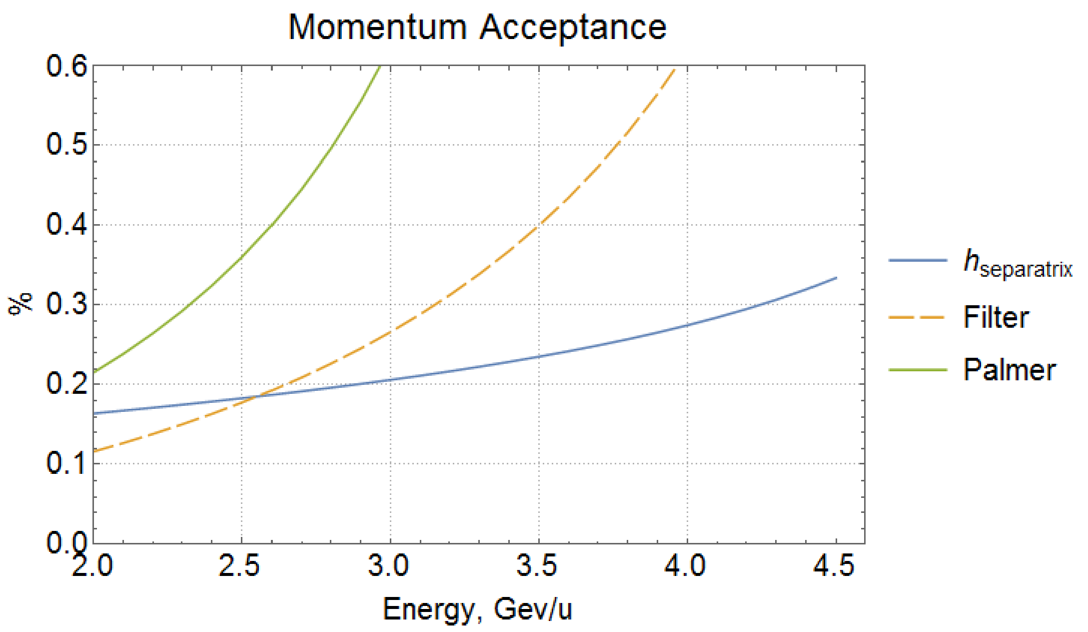




Bandwidth & Cooling Acceptance



Absence of band overlapping > 6σ_p



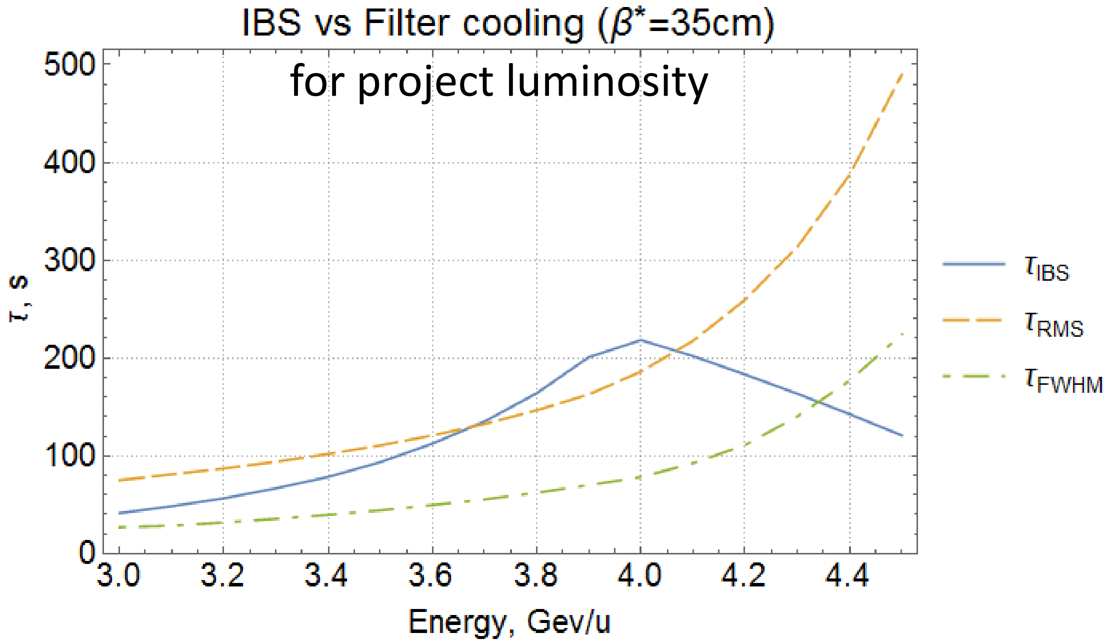
Separatrix covered:
Palmer: >1,7 GeV/u
Filter: >2,5 GeV/u

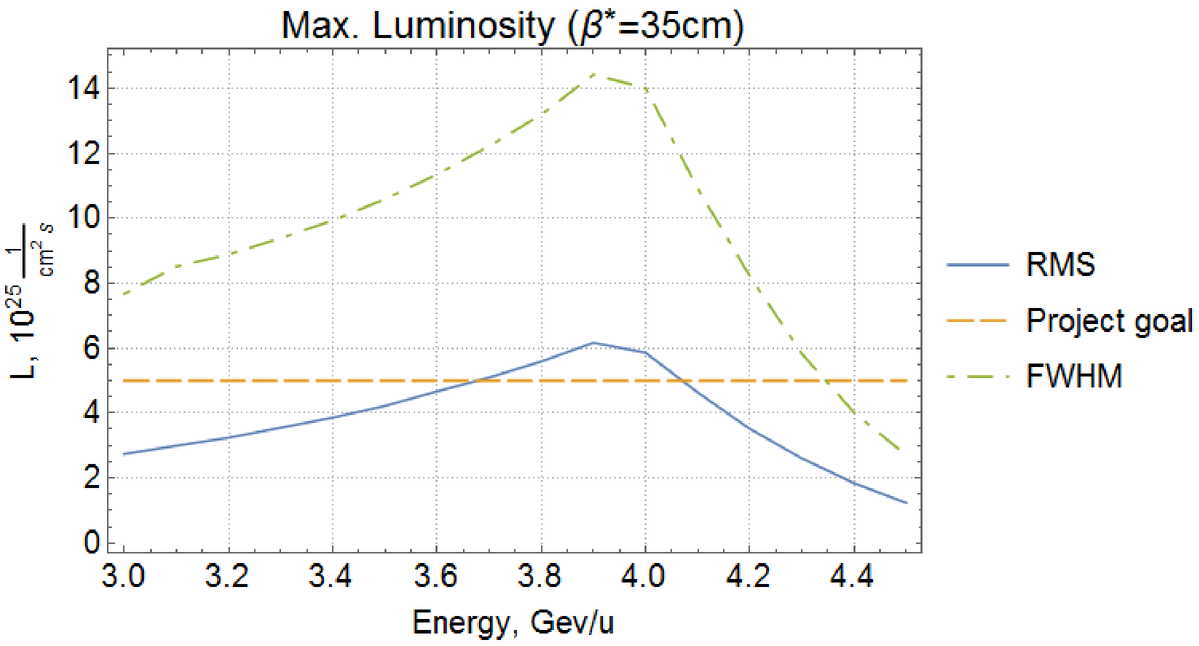
Palmer and Filter methods are allowed to be implemented by acceptance criterion.

Filter method provides faster cooling rates therefore it is chosen for the start-up mode.

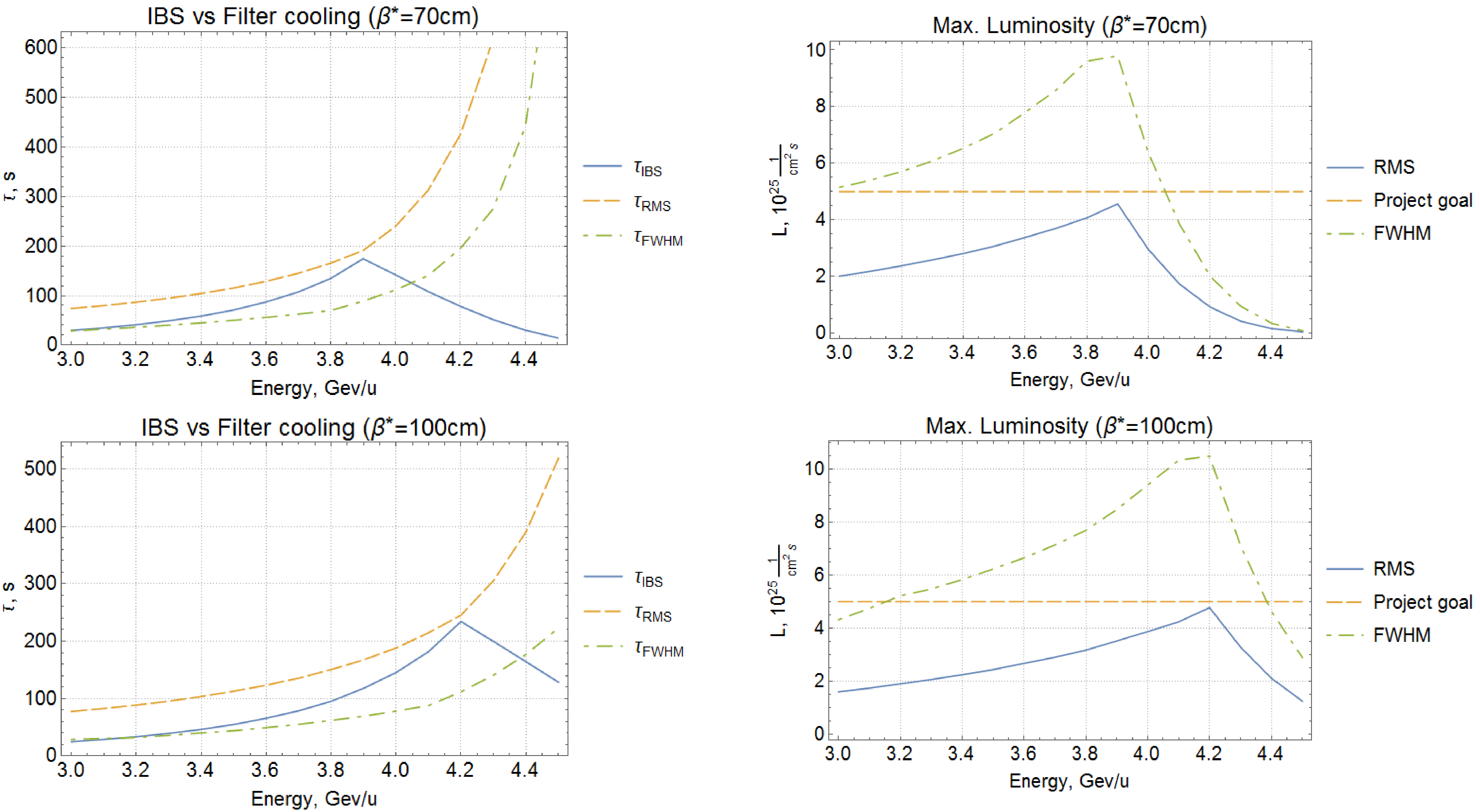
Luminosity (at equal IBS/Cooling rates)

$$\lambda_{cool} = \frac{1}{\tau_{cool}} \sim \frac{1}{N} \qquad \lambda_{IBS} = \frac{1}{\tau_{IBS}} \sim N \qquad N_{eq} = \sqrt{\frac{\tau_{cool}}{\tau_{IBS}}}$$



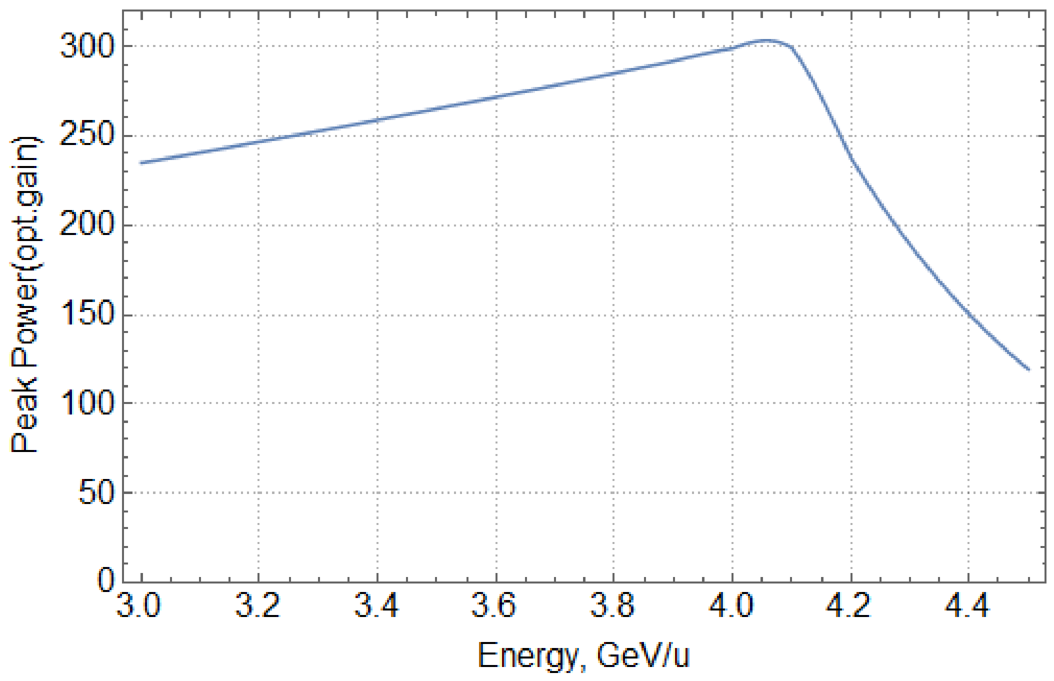


For the core of the distribution the stochastic cooling system provides the required cooling rates



IBS vs Filter cooling (β*=70cm)
τ, s
Energy, Gev/u
τIBS
τRMS
τFWHM
Max. Luminosity (β*=70cm)
L, 10^25 1/(cm^2 s)
Energy, Gev/u
RMS
Project goal
FWHM
IBS vs Filter cooling (β*=100cm)
τ, s
Energy, Gev/u
τIBS
τRMS
τFWHM
Max. Luminosity (β*=100cm)
L, 10^25 1/(cm^2 s)
Energy, Gev/u
RMS
Project goal
FWHM

Power & Gain



Mode	Start-up	Project
Long. cool. method	Filter	Palmer
Optimal gain, dB	69	91
Equipment losses, dB	67	37
Total gain, dB	136	128

Output peak power is chosen 500 Watt/channel

Gain is chosen 140 dB

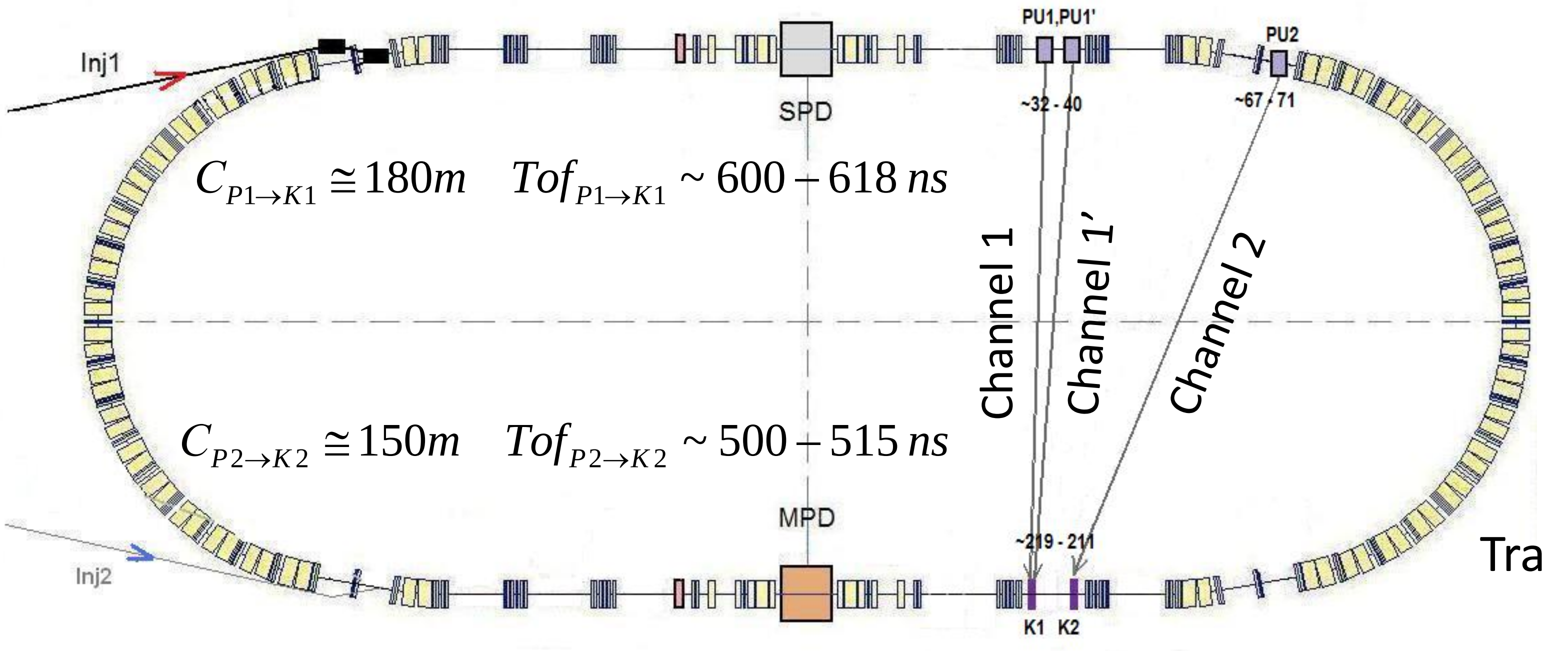
List of Equipment

Low power(<–30dBm): Pickups, Low noise Preamplifiers, Couplers

Medium power: Preamplifiers, Feeder Cable, Optical Comb Filter, Attenuators, Phase Shifters

High power(>30dBm): Main Amplifiers, Dividers, Kickers

Placement & Delay



Start-up mode:
Longitudinal channel 1
(Equipment own delay 452 ns)

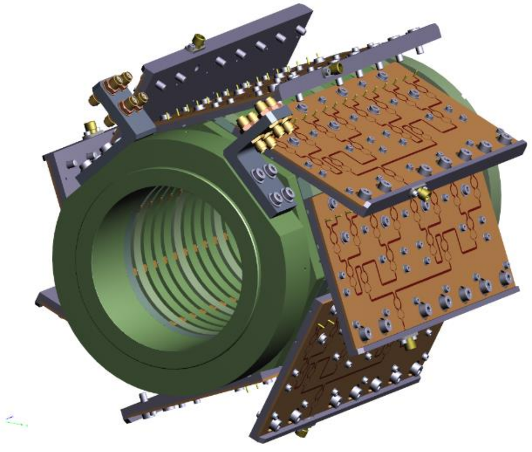
Project mode:
Longitudinal channel 2 (473 ns)
Transverse channels 1, 1’ with combined kicker
(405 ns, 418 ns)

Min. constant delay:	+ Variable delay:
Channel 1 – 595 ns	Range 32 ns
Channel 2 – 490ns	Precision 1 ps

There is a reserve in delay for all channels and modes

Pickups, Kickers & Main Amplifiers

FZJ Ring-slot couplers are chosen as Pickups & Kickers



Basic structure – 16 rings

High Impedance $Z_{//}^{PU} = 144\Omega$

Purchase list:

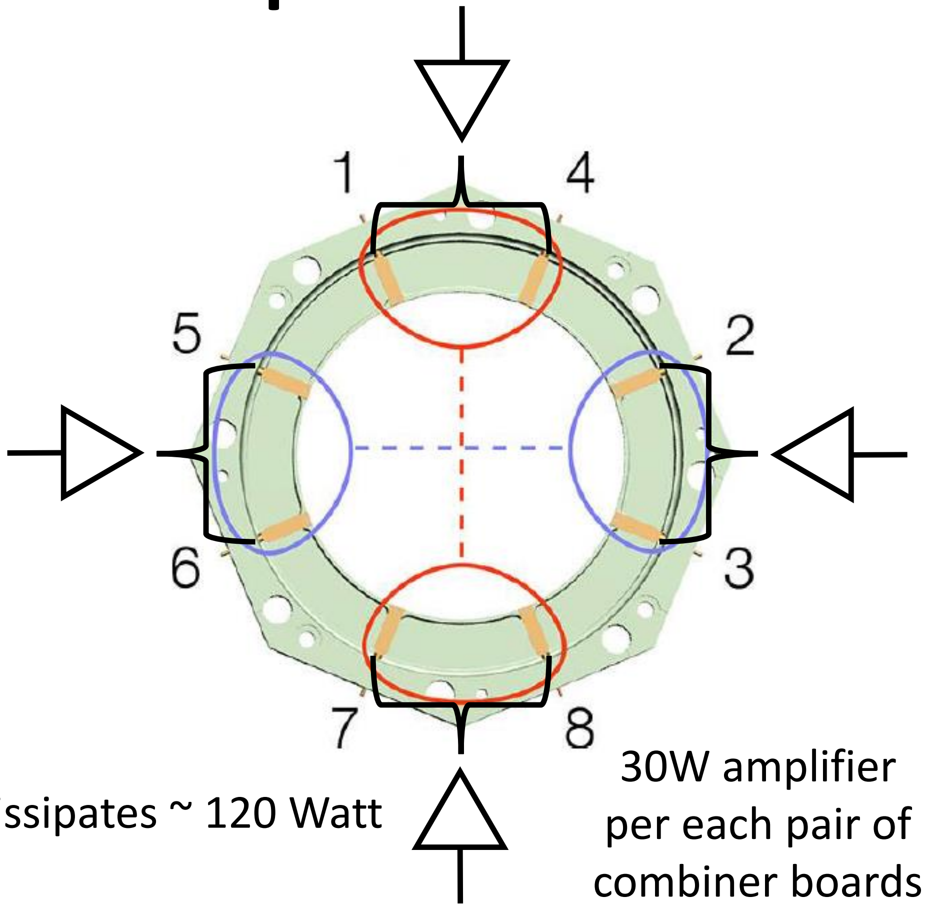
Pickup – 2 basic structures

Kicker – 4 basic structures

6 pickups & 4 kickers in total

16 amplifiers per kicker

100 amplifiers in total



Kicker dissipates ~ 120 Watt

30W amplifier per each pair of combiner boards

Negotiations with FZJ concerning pickups & kickers are on the way

Main 30W Amplifiers R&D is in progress (OKB TSP, Minsk)

Diagnostics

Signal Spectrum Analyzer

Schottky diagnostics

4-channel Vector Network Analyzer

BTF measurements

Equipment
is being purchased

Power meter

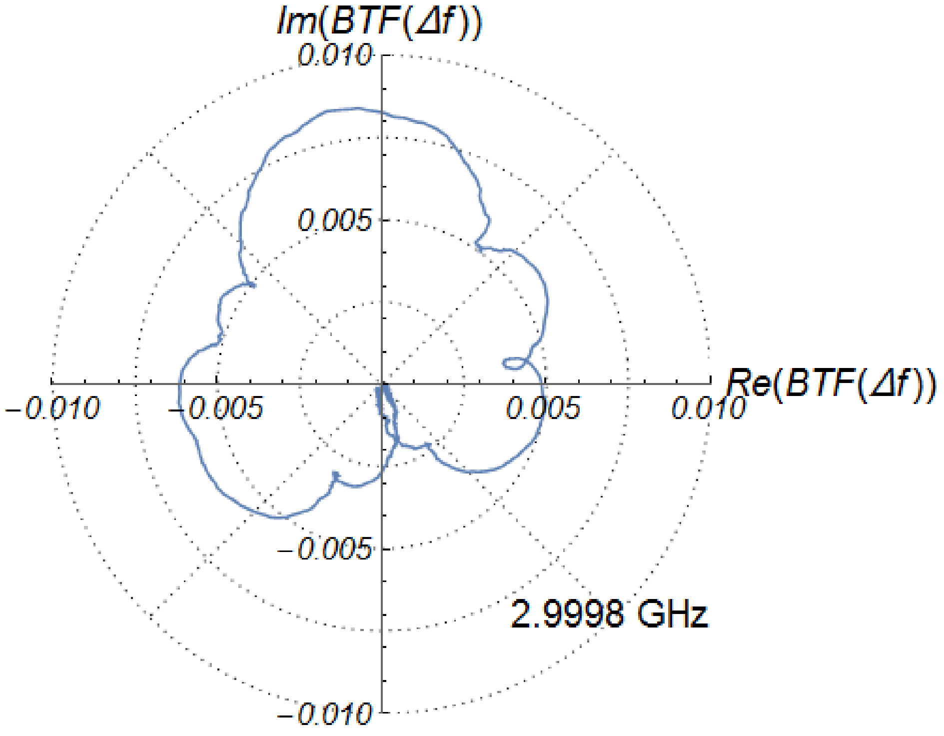
Status & Plans

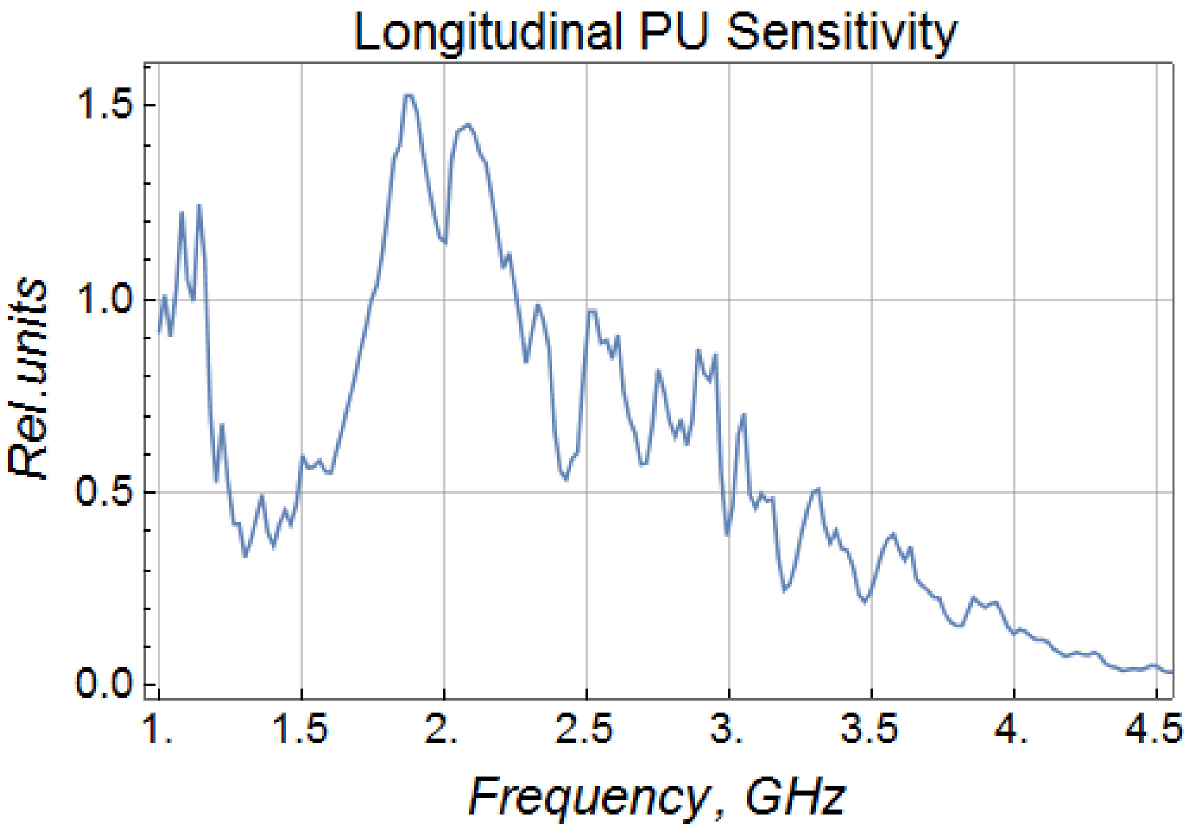
More detailed plan is in the database

Equipment	Status		Plans	
Diagnostics	Being Purchased		Finished by the end of 2017	
Optical Comb Filter	Components being purchased		Purchased (III 2017)	Assembled (I 2018)
4 Kickers	Test bench Production	Negotiations (FZJ)	First Tests (III-IV 2017)	Production + Assembly 1 unit/year starting 2018
6 Pickups	Negotiations (FZJ)		Production + Assembly 1 unit/year starting 2018	
Main amplifiers	R&D		R&D finished (end 2017)	16 units/yr starting 2018
Electronics	Being purchased		Purchase + Assembly 1 channel/year starting 2018	

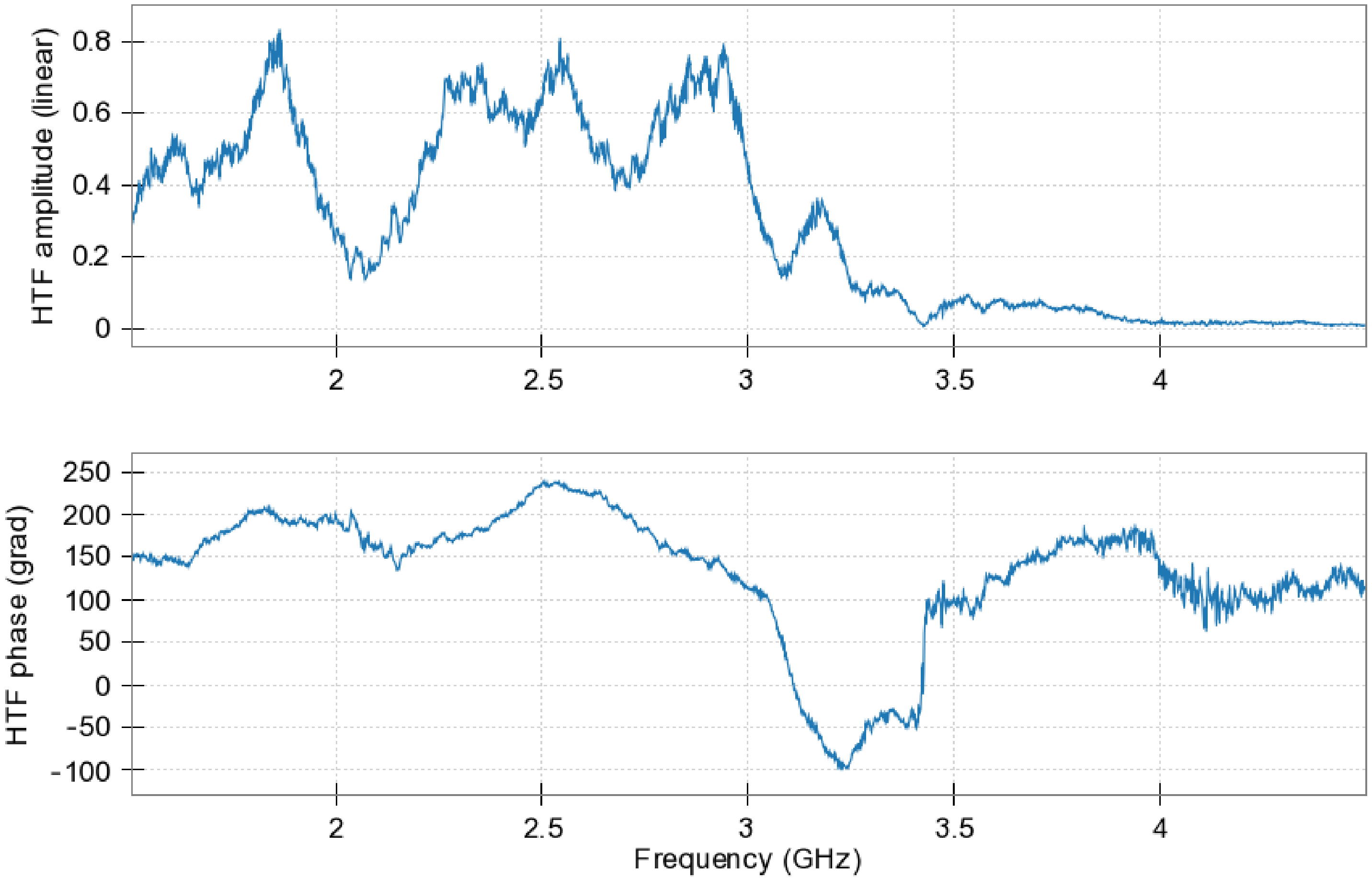
Recent results

Beam Transfer Function:
Nyquist diagrams of
41 harmonics measured





BTF measurements at FZJ



Conclusions

- Stochastic cooling system can provide the required luminosity at any discussing beta-function in the interaction point for both Start-up and Project modes.
- For longitudinal cooling in the Start-up mode the Filter method is chosen, Palmer method is chosen in the Project mode. Also main parameters are defined.
- For the Start-up mode the stochastic cooling system provides the required cooling rates for the core of the distribution. Evolution of the distribution function tails has to be investigated numerically.
- Equipment purchasing is started, main amplifiers R&D is in progress, negotiations with FZJ concerning pickups and kickers are on the way.

Thank you for attention