Will we ever do a beta-beam design study beyond the present CERN-Frejus baseline?

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The short answer

- Yes,
  - If we get the resources and the time we need!

Outline

- What are we aiming for with the present EURISOL beta-beam design study?
- A few examples of what we are doing within the present study (see also talk by M. Benedikt and A. Fabich)
- When will we achieve it?
- Can we go further?

FLUX

- The Design Study is aiming for:
  - A beta-beam facility that will run for a "normalized" year of 10^7 seconds
  - An integrated flux of $5.5*10^{18}$ anti-neutrinos (^{6}He) and $16.5*10^{18}$ neutrinos (^{18}Ne) in ten years running at γ=100

with an Ion production in the target to the ECR source:

- ^{6}He= $2*10^{13}$ atoms per second
- ^{18}Ne= $8*10^{11}$ atoms per second

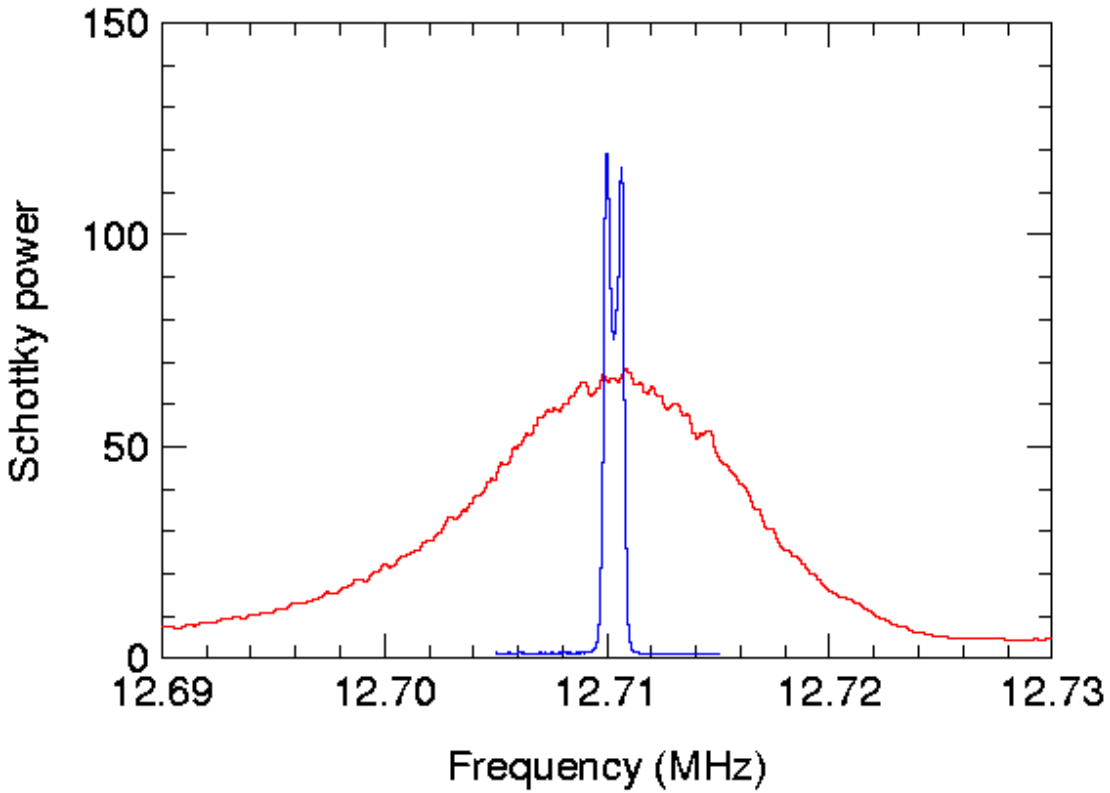
- Baseline 2: anti-neutrinos $15*10^{18}$, neutrinos $0.23*10^{18}$ in ten years

Basic ideas

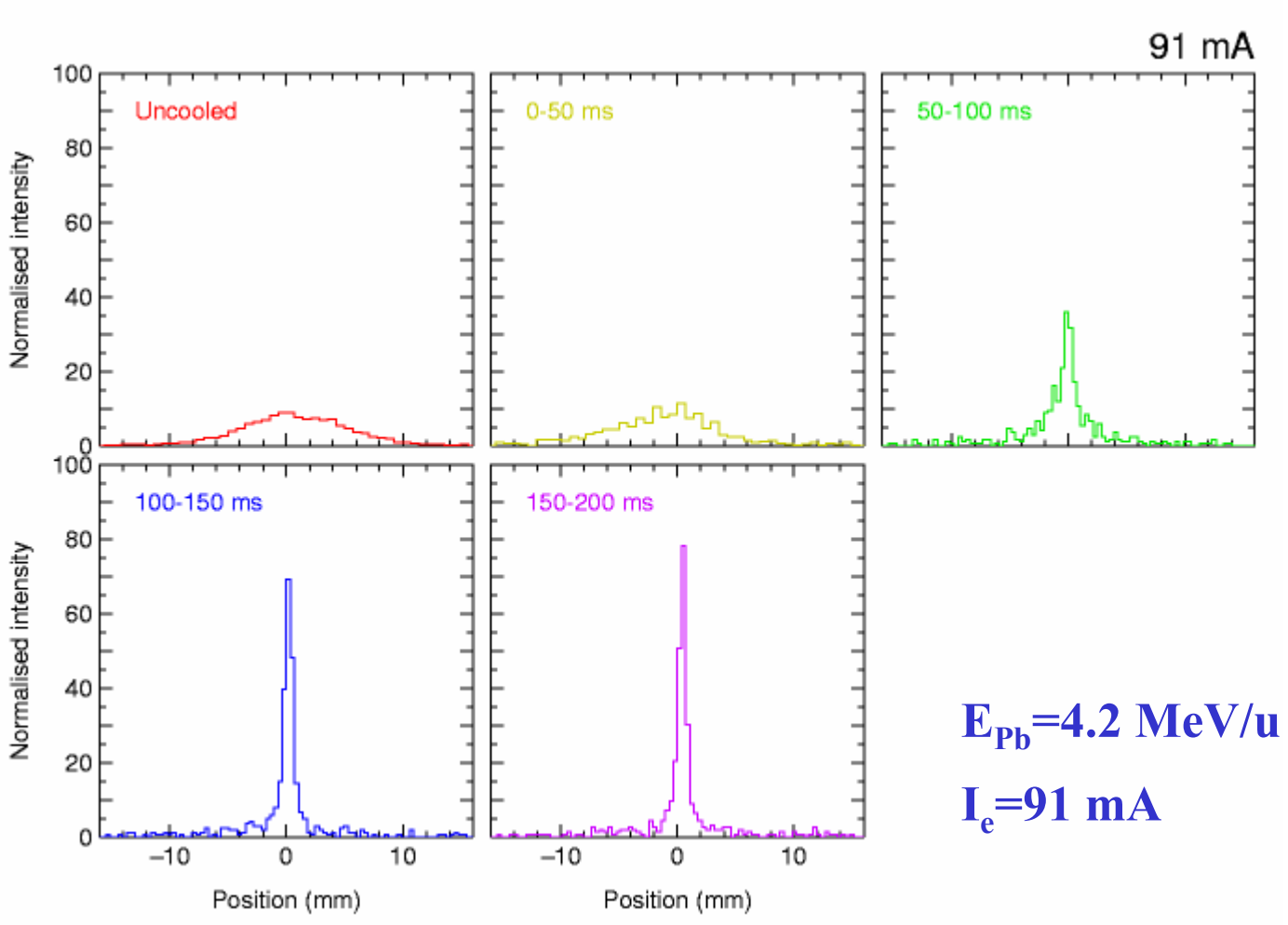
- **Use ^{19}Ne – production 20 times higher than ^{18}Ne (lifetime 10 times longer)**

- **Accumulation of ions in (or before) the RCS**
  - **Electron cooling of the ions in the RCS makes accumulation possible**
  - **The ions are continuously cooled in all dimensions which gives space for the injection of more ions**

Longitudinal cooling of d^+



Transverse cooling of Pb^{54+}

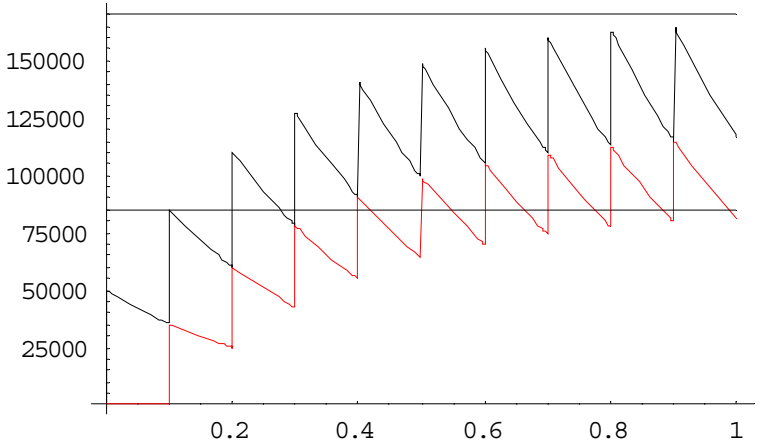


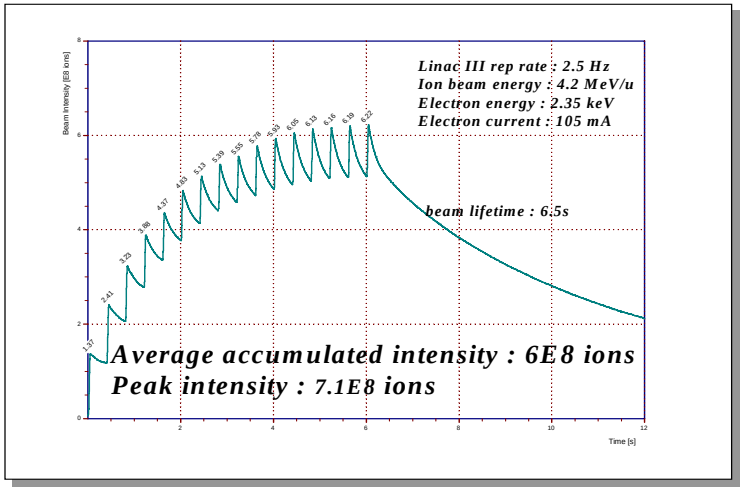
E_{Pb}=4.2 MeV/u

I_e=91 mA

Stacking

Multiturn injection with electron cooling





Half life [s]	0.1	1	10
T_{vacuum} [s]	30	30	30
Intensity ions [every 100 ms in 30 microsceonds]	10^4	$5\ 10^5$	$5\ 10^5$
T_{cool}[ms]	100	100	100
Number of turns	10	10	10
Final emittance [micrometer]	0.1	0.1	0.1
Final number of particles in stack	$3\ 10^4$	$3\ 10^7$	$3\ 10^8$

Requirements

- **The electron cooling needs to be fast enough. The cooling time should be of the same order as the repetition time of the injected pulses (1/10 Hz).**
- **Transverse cooling is normally slower than longitudinal**
- **Cooling time depends on the initial emittance**
- **@ 100 Mev/u: $U_{e\text{-}gun} \approx 55$ kV, $I_{e\text{-}gun} = 1\text{-}2$ A**

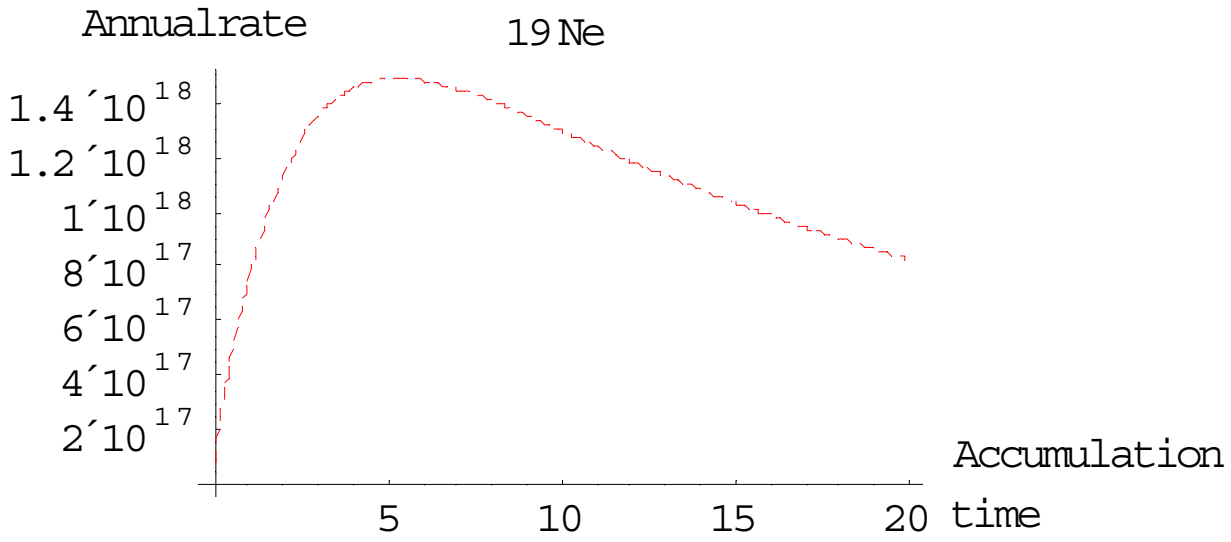
Limitations

- **Radioactive halflife of the ions. Balance between accumulation and decay is achieved after ≈ 3*$t_{1/2}$**
- **The full benefit of the accumulation is achieved by using more long lived ions, like ^{19}Ne with $t_{1/2}$=17 s**
- **Intensity gain also for the short-lived ^{18}Ne and ^{6}He**
- **Instabilities and space-charge limitations.**

Parameters to vary

- **Number of pulses accumulated in the EC-RCS**
- **Further accumulation in the PS or SPS? Or both?**
- **Number of accumulations in PS/SPS**
- **...**

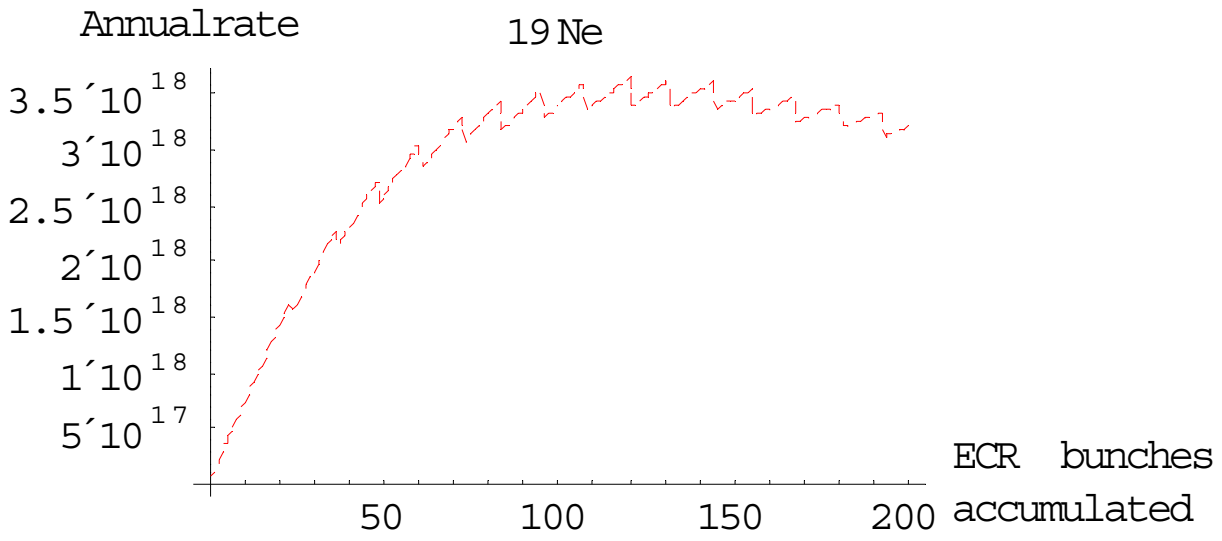
Accumulation of ^{19}Ne



The annual neutrino rate as a function of the accumulation time in the EC-RCS and stacked in **PS** at 10 Hz injection.

The annual rate depends on the combined effects of the whole accelerator chain.

Accumulation of ^{19}Ne



The annual neutrino rate as a function of the number of ECR bunches accumulated in the EC-RCS and stacked in **SPS**

Intensities, ^{18}Ne, ^{19}Ne

Machine	Total Intensity ^{18}Ne (10^{10})	Total Intensity ^{19}Ne with accumulation (10^{10})
Source	80	1600
ECR	2.3	47
RCS inj	1.1	1170
RCS	1.1	1160
PS inj	19	10300
PS	18	10200
SPS	18	10200
Decay ring	311	157000

Intensities ^{18}Ne, without and with accumulation

Machine	Total Intensity ^{18}Ne (10^{10})	Total Intensity ^{18}Ne with accumulation (10^{10})
Source	80	80
ECR	2.3	2.3
RCS inj	1.1	18
RCS	1.1	18
PS inj	19	18
PS	18	17
SPS	18	127
Decay ring	311	1120

Intensities ^{6}He, without and with accumulation

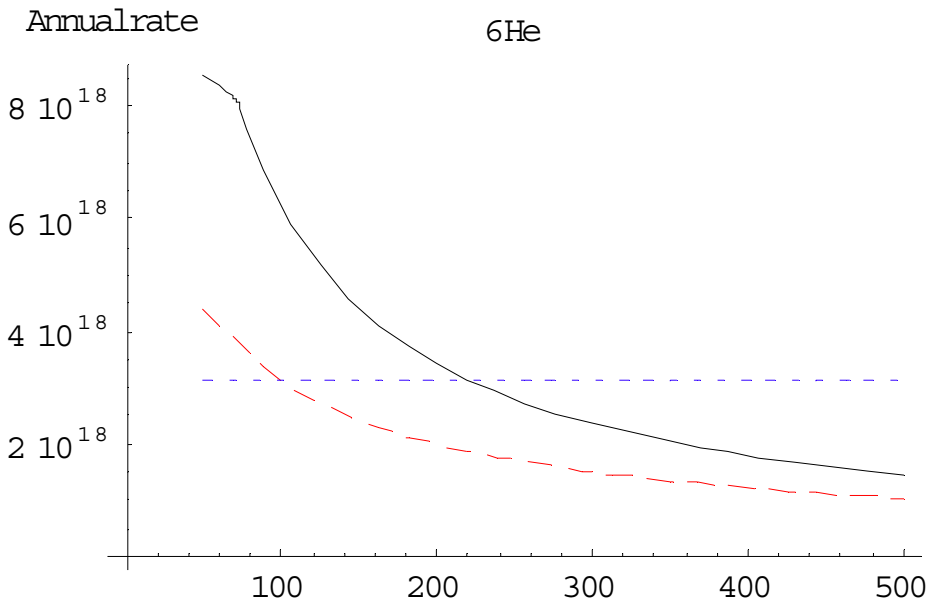
Machine	Total Intensity (10^{12}) without accumulation	Total Intensity (10^{12}) with accumulation
Source	20	20
ECR	1.9	1.9
RCS inj	0.93	10
RCS	0.90	10
PS inj	11	10
PS	9.6	8.6
SPS	9.1	27.5
Decay ring	97	190

Further investigations

- **Intensity limitations**
- **Emittances and cooling times. Need for special design of the electron cooler?**
- **Accumulation in RCS or in a separate cooler ring?**
-

So, will you something beyond the baseline?

Gamma and annual rate, ^{6}He



- Nominal duty cycle (saturates at 4 x)
- We must increase production!

Gamma and decay ring size, ^{6}He

Gamma	Rigidity [Tm]	Ring length T=5 T f=0.36	Dipole Field rho=300 m Length=6885m
100	938	4916	3.1
150	1404	6421	4.7
200	1867	7917	6.2
350	3277	12474	10.9
500	4678	17000	15.6

New SPS

Civil engineering

Magnet R&D

In 2008 we should know

- The EURISOL design study will with the very limited resources available give us:
  - A feasibility study of the CERN-Frejus baseline
  - A first idea of the total cost
  - An idea of how we can go beyond the baseline
    - Resources and time required for R&D
    - Focus of the R&D effort
      - Production, Magnets etc.

We need to know for 2008

- Is there a feasible detector design?
  - Site of the detector and cost
- Is there a physics case for the beta-beam
  - The CERN Frejus baseline?
  - Other options?
- For other options
  - What gamma, duty-factor and intensity do you require
- When will we know if there is a physics case?
  - Theta_13

Conclusions

- It takes time and costs money to do a design study
  - It takes even more time to spend money on a design study
    - Time to hire and train staff
    - Time to build prototypes and test them
- Thanks for all your input so far…
- We can only advance the beta-beam concept with your help!

- Your are very important!