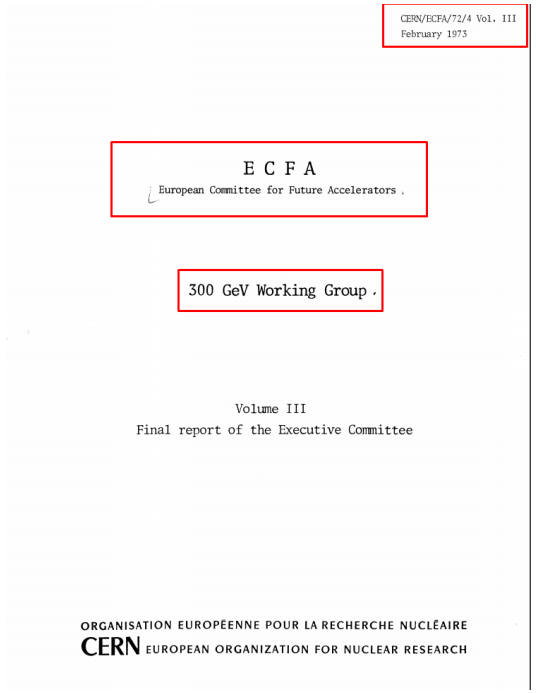
First ideas on a VVLE (Very Very Low) Energy Beam

From the challenges of designing a high-energy beam….



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CERN EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

In the framework of CERN neutrino platform project at the CERN SPS North Area, two new beam lines have been designed as extensions of the existing secondary beam lines, able to provide low energy particles in the momentum range of 0.4 to 12 GeV/c. The layout of these *very low energy* beam lines, their design parameters as well as outlook on their expected performance, are summarized in this paper.

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…to the challenges of designing a max 2 GeV/c beam !

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Presentation outline

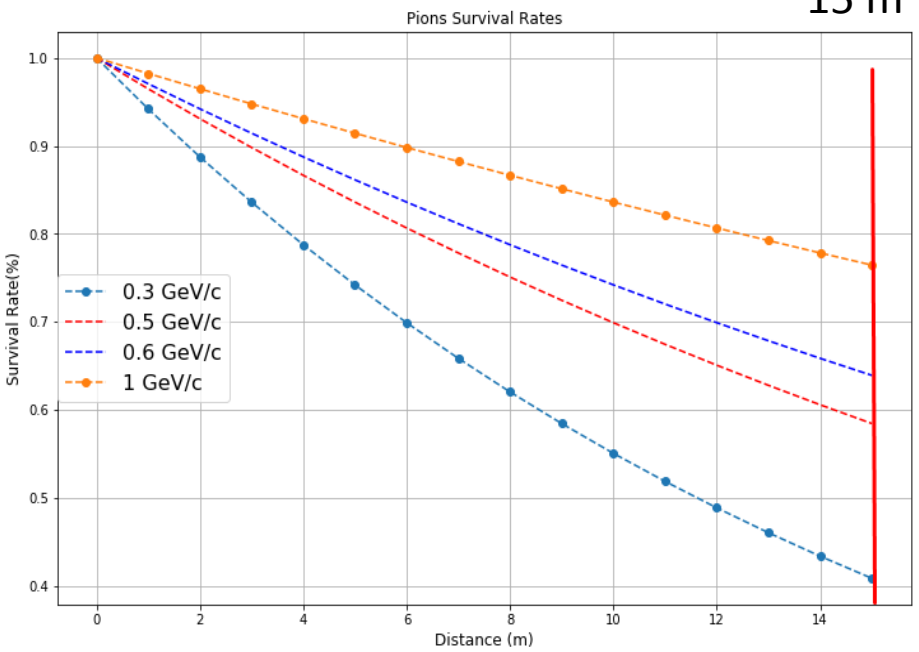
- Design considerations
  - Factors to be taken into consideration
  - Technical possibilities
- First implementation ideas

- Summary / Conclusions

Design considerations (1) - hadrons

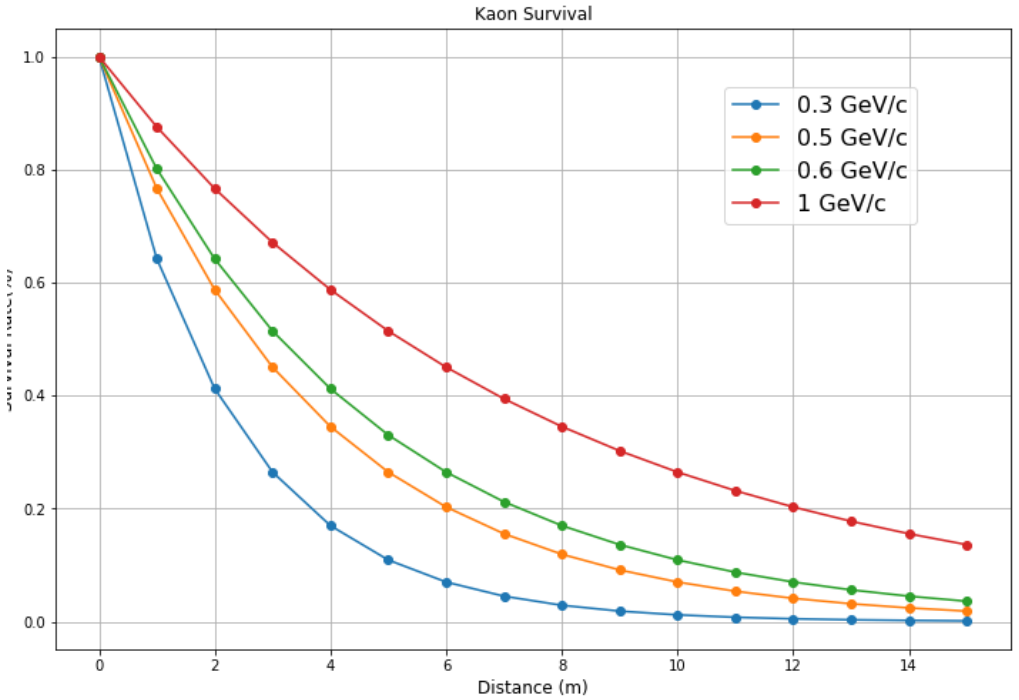
- Overall length of the beam line a **key factor**

15 m



- Pions
  - → 75% of the pions @ 1 GeV/c make it to the end
  - → Even 40% of the 0.3 GeV/c pions survive

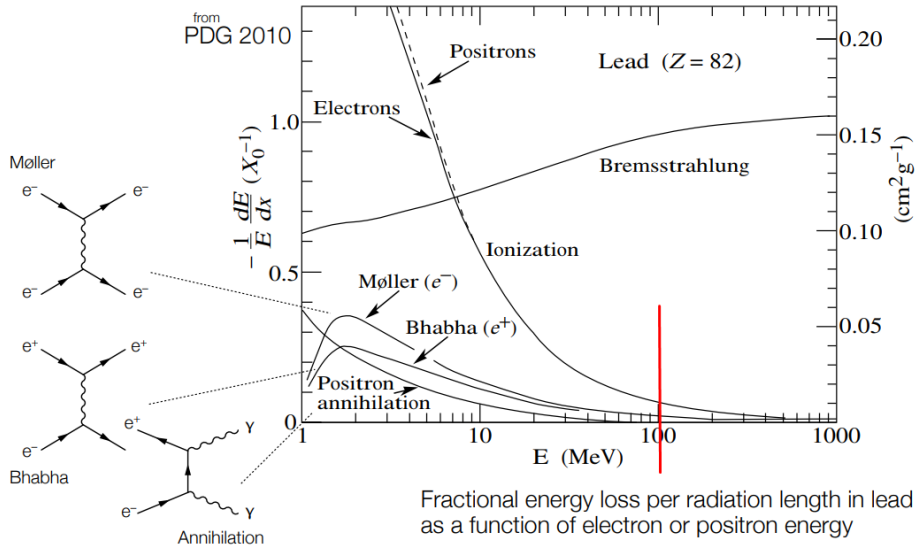
- Kaons
  - → Less than 20% of the kaons (even @ 1 GeV/c make it to the end)



Design considerations (2) - electrons

- No decays…..but…
- Material on the line a **key factor**
- Even 10% of X0 → 6.3% momentum loss due to Bremsstrahlung.
  - For sub-GeV/c electrons ionization starts to become also important
- Not a showstopper but…

…in case of big bending angles or many strong magnets in the beam line, *synchrotron radiation* could become important.



Fractional energy loss per radiation length in lead as a function of electron or positron energy

Design considerations (hadrons / electrons) (1)

- Due to the length consideration : Low energy particles must be created **close to the experiment – a transport of max 15 m** (or less)

…this can be a *dirty* process.

- Background on the experiment : a **key factor – especially for slow readout and difficult-veto detectors**

*** Especially for Kaons, one must start with **protons** from at least **~4-5 times higher the "wanted" energy and create a 'secondary' or 'tertiary' beam.***

Design considerations (hadrons / electrons) (3)

- If a second (or third) generation beam solution is chosen :

  ……since the low energy particles are always generated in large transverse angles….

- Rate always is ~3-4 orders of magnitude less than the first generation beam – **Large acceptance can become a key factor**

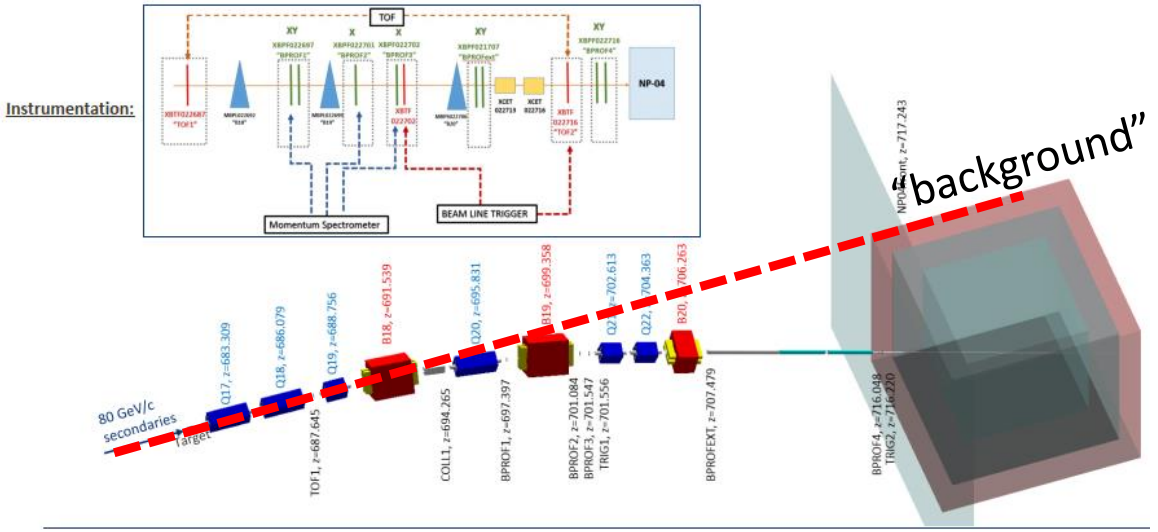
→ Large aperture magnetic elements and detectors a sine qua non.

On top : A ***momentum selection process*** → choose the 'Good' particles as much as possible – 'clean' the wrong momentum particles

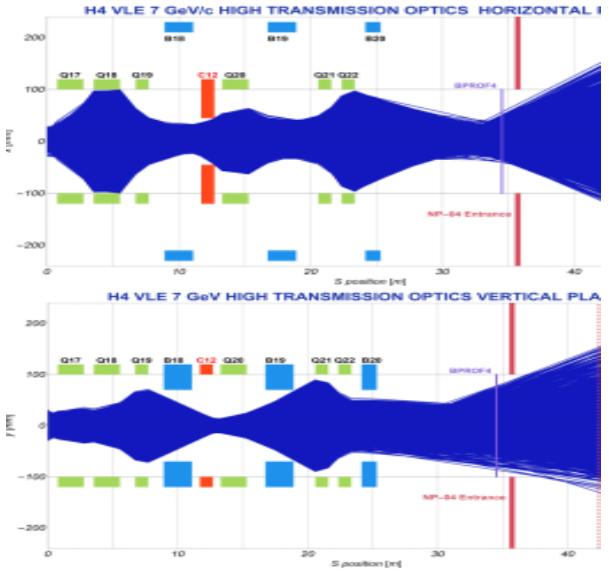
Technical possibilities – an example : H4-VLE

- Putting all the previously described requirements together
  ….for a higher momentum range….
- Two low-energy constructed and commissioned in 2018 for serving NP-02 and NP-04 detectors.
  …Details on the conceptual design :
  Phys. Rev. Accel. Beams **20**, 111001

- Momentum range: 0.3 – 7 GeV/c *(12 GeV/c for NP-02)* ✓
- 29 m length *(40 m for NP-02)* ✓
- Large acceptance via existing magnetic elements ✓
- Offset beam – detector (+ shielding → Background reduction) ✓
- Momentum selection (7% full acceptance) + reconstruction (2% resolution) ✓
- Particle identification and tagging, on an event-by-event basis ✓
  …. ~15% X0.

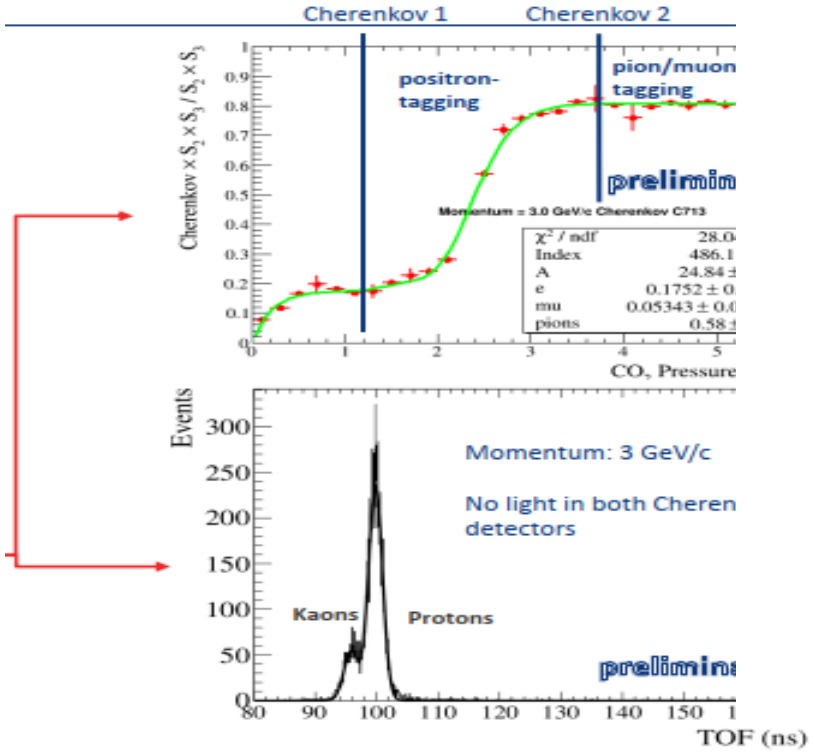


Produced tertiaries are accepted, momentum selected and transported to the experiment.



Measured performance

p (GeV/c)	e	μ	π	K	p
1	CH1	TOF	TOF	/	TOF
2	CH1	TOF	TOF	/	TOF
3	CH1	CH2	CH2	TOF	TOF
4	CH1	CH2	CH2	TOF	TOF
5	CH1	CH1	CH1	CH2	!CH
6	CH1	CH1	CH1	CH2	!CH
7	CH1	CH1	CH1	CH2	!CH



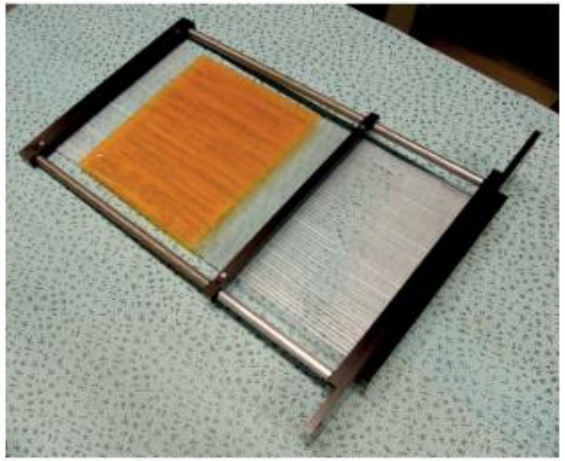
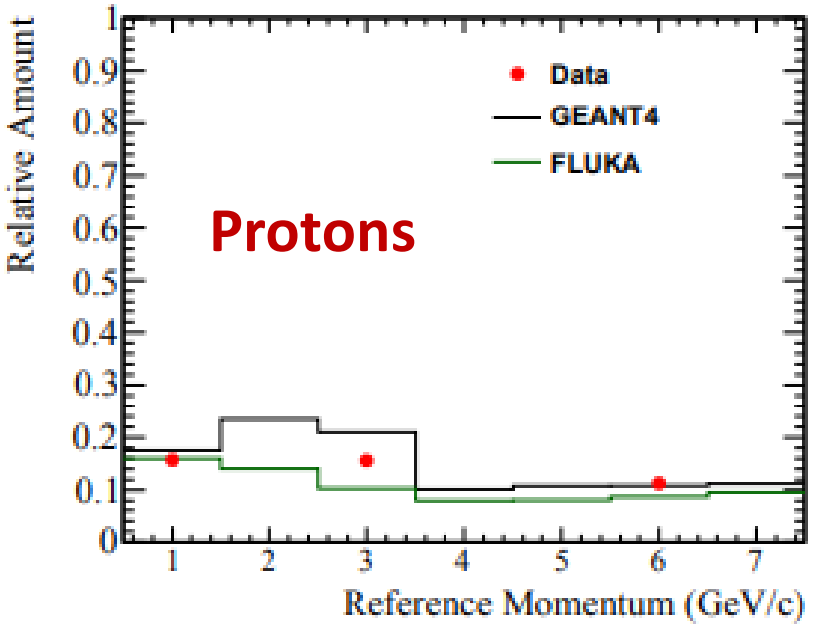
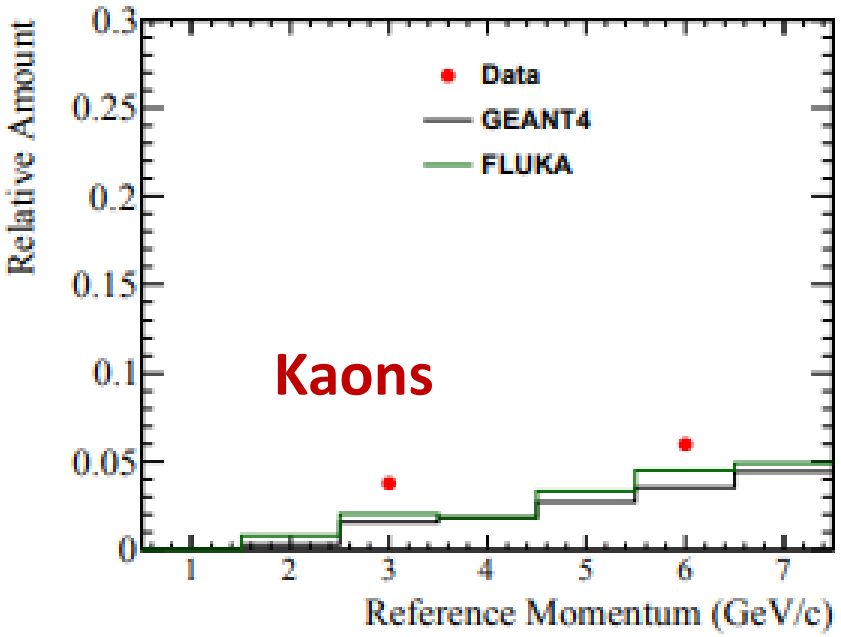


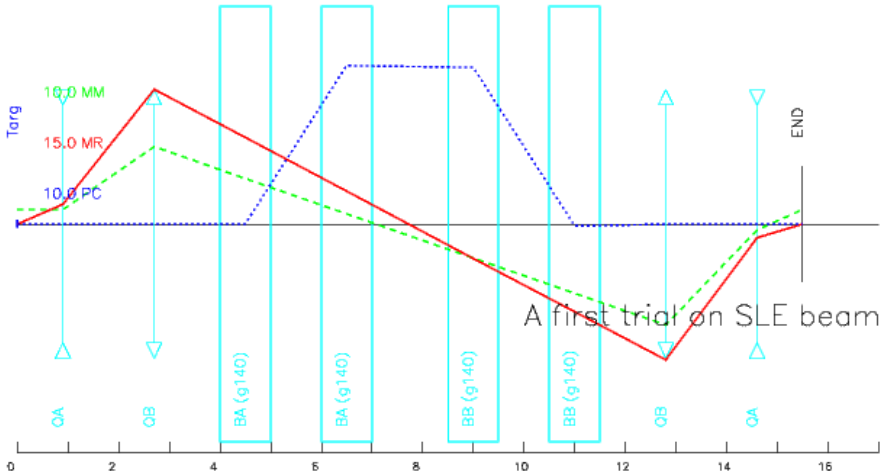
Figure 12: XBPF module, used as beam profile monitors. The fibers are readout by 192 SiPMs coupled with CITIROC ASICs, that transfer the signal to the back-end VFC as discussed in the text.



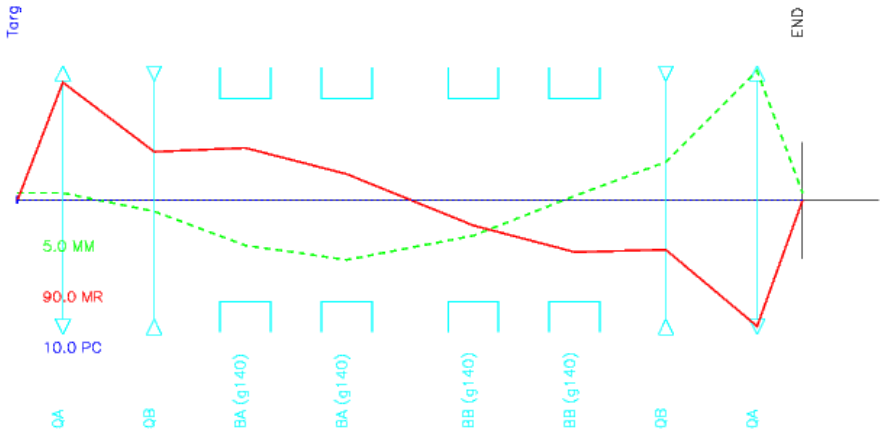


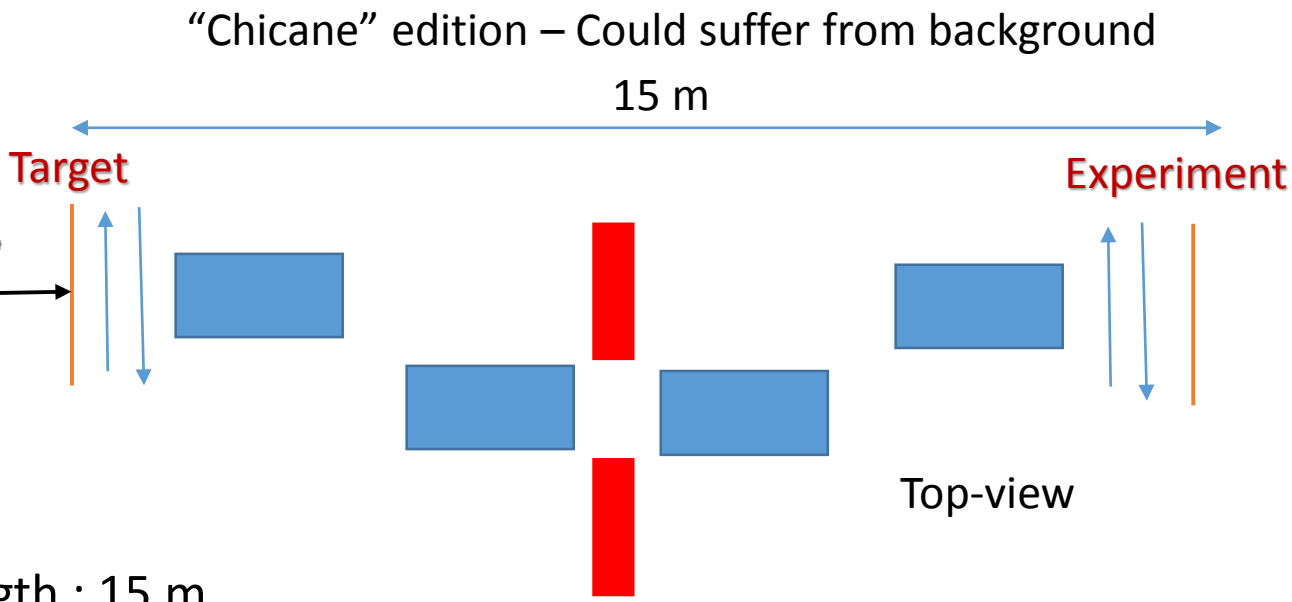
Imagining a VVLE beam line – Back of the envelope calculations

- Assuming a maximum of 1 GeV/c

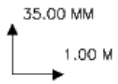


A first trial on SLE beam – Achro versio





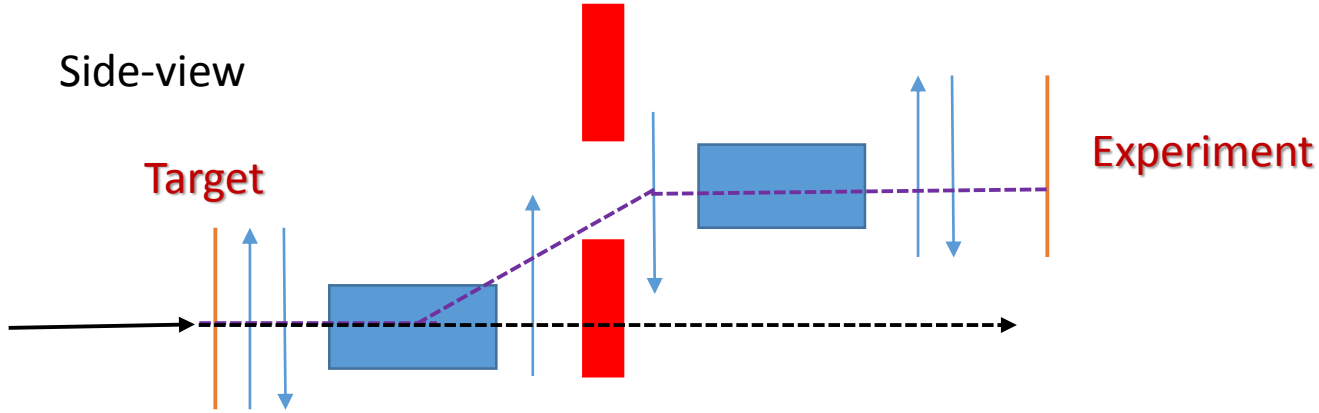
Total length : 15 m
Using existing MBPS dipoles (1 m)
Using existing QPL quads (1m)
Only needs 3 (!) power supplies
Very large angles & acceptance – second order effects prominent ?



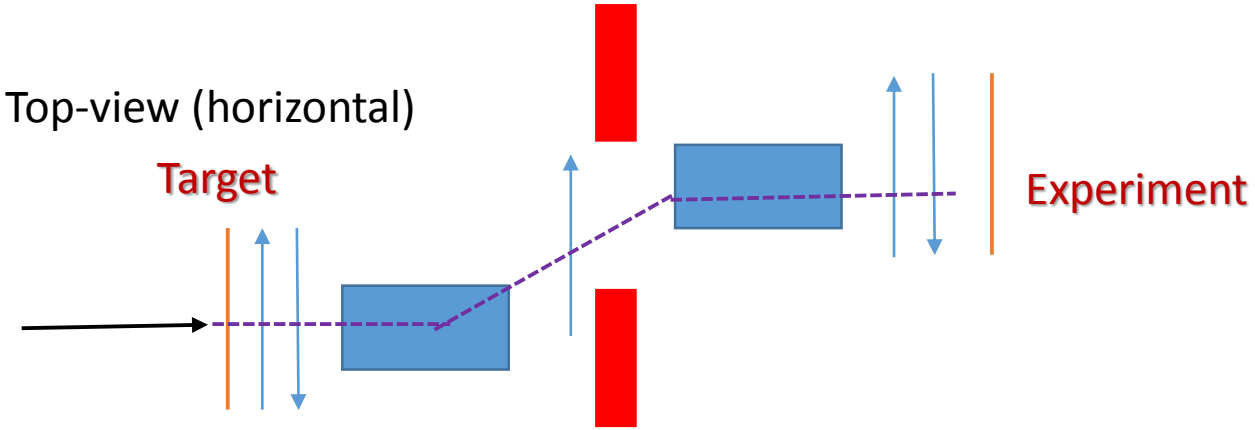
Imagining a VVLE beam line – Back of the envelope calculations – Other variants

‘Field focus’ edition – Suffers less from background

Side-view



Top-view (horizontal)



- ~ same order of magnitude length
- existing MBPS dipoles (1 m)
- Detector out of the “direct” high energy background
- More quadrupoles : More ‘chromatic’ abberations (second order effects)
- Fewer bends (less control of the focusing in the horizontal)
- Smaller acceptance ?

If spot-size is not important, and some first-order dispersion is allowed, other variances can be also imagined.

→ Reduced length ?

Summary

- The design considerations and challenges of a VVLE beam have been presented
- Low energy tertiary beams (even in the sub-GeV range) have been designed and operating at CERN since long.
- Dedicated design & optimization studies would be necessary in order to be able to estimate better the possibilities and performance of such a beam line – along with the experimental requirements.