The EHN1 Beams

Outline

General layout of the North Area

The target station

Principles of the EHN1 beams (N.D.)

Particles and beams

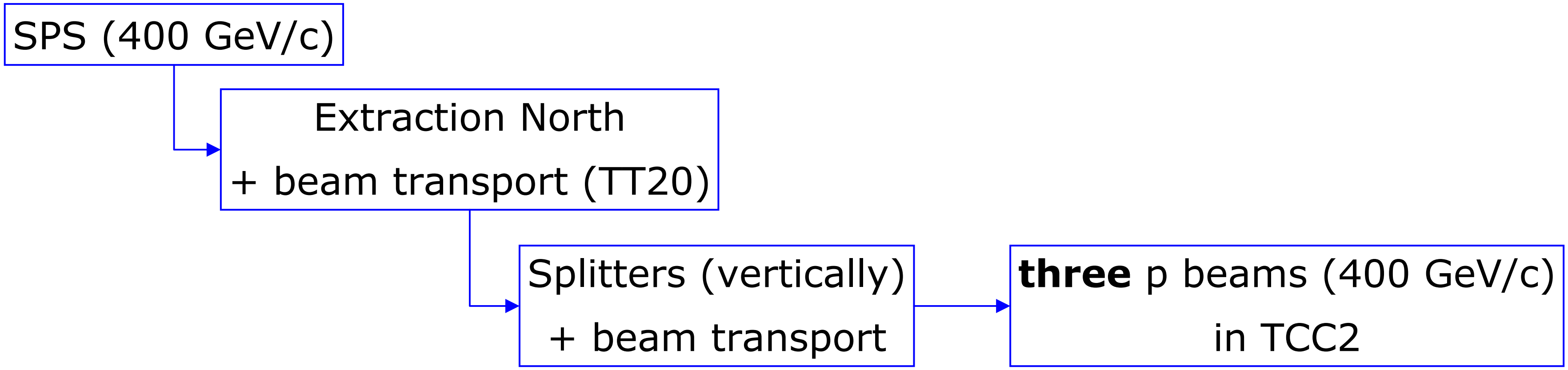
- tertiary beams

Operational aspects

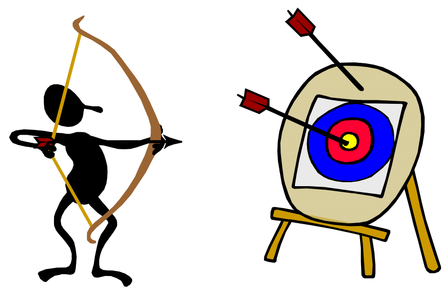
- beam tuning

Ilias Efthymiopoulos AB/ATB-EA
SPS/EA Training Lecture Program
March 2003

General - The North Experimental Areas at the SPS



- The three proton beams are directed onto the **primary targets**: T2, T4, T6
- The proton intensity on each target can go up to 10^{13} protons/pulse
  - limited by target construction (i.e. cooling, etc.)
- Possible options:
  - primary proton beam with high intensity in ECN3 (even without the T4 target)
  - attenuated **primary proton beams**
    - **ECN3** T4: P41/P42, T6: P61/P62
    - **EHN1** T2: H4, T4: H8
  - **secondary beams**:
    - **EHN1** T2: H2 & H4, T4: H6 & H8
    - **ECN2** T6: M2



Generalities

The EHN1 beams

Target	Beam	Characteristics
T2	H2	High-energy, high-resolution secondary beam. Alternatively can be used to transport: attenuated primary beam of protons, electrons from γ-conversion, polarized protons for Λ decay, enriched low-intensity beam of anti-protons, or K^+ <u>Main parameters</u>: P_{max}= 400 (450) GeV/c, Acc.=1.5 μSr, $\Delta p/p_{max}$= ±2.0 %
	H4	High-energy, high-resolution secondary beam. Alternatively can be used to transport: primary protons, electrons from γ-conversion, polarized protons for Λ decay, enriched low-intensity beam of anti-protons, or K^+ <u>Main parameters</u>: P_{max}= 330 (450) GeV/c, Acc.=1.5 μSr, $\Delta p/p_{max}$= ±1.4 %
T4	H6	High-energy secondary beam. <u>Main parameters</u>: P_{max}= 280 GeV/c, Acc.= 2.0 μSr, $\Delta p/p_{max}$= ±1.5 %
	H8	High-energy, high-resolution secondary beam. Alternatively can be used to transport an attenuated primary proton beam <u>Main parameters</u>: P_{max}= 400(450) GeV/c, Acc.= 2.5 μSr, $\Delta p/p_{max}$= ±1.5 %

… The EHN1 beams

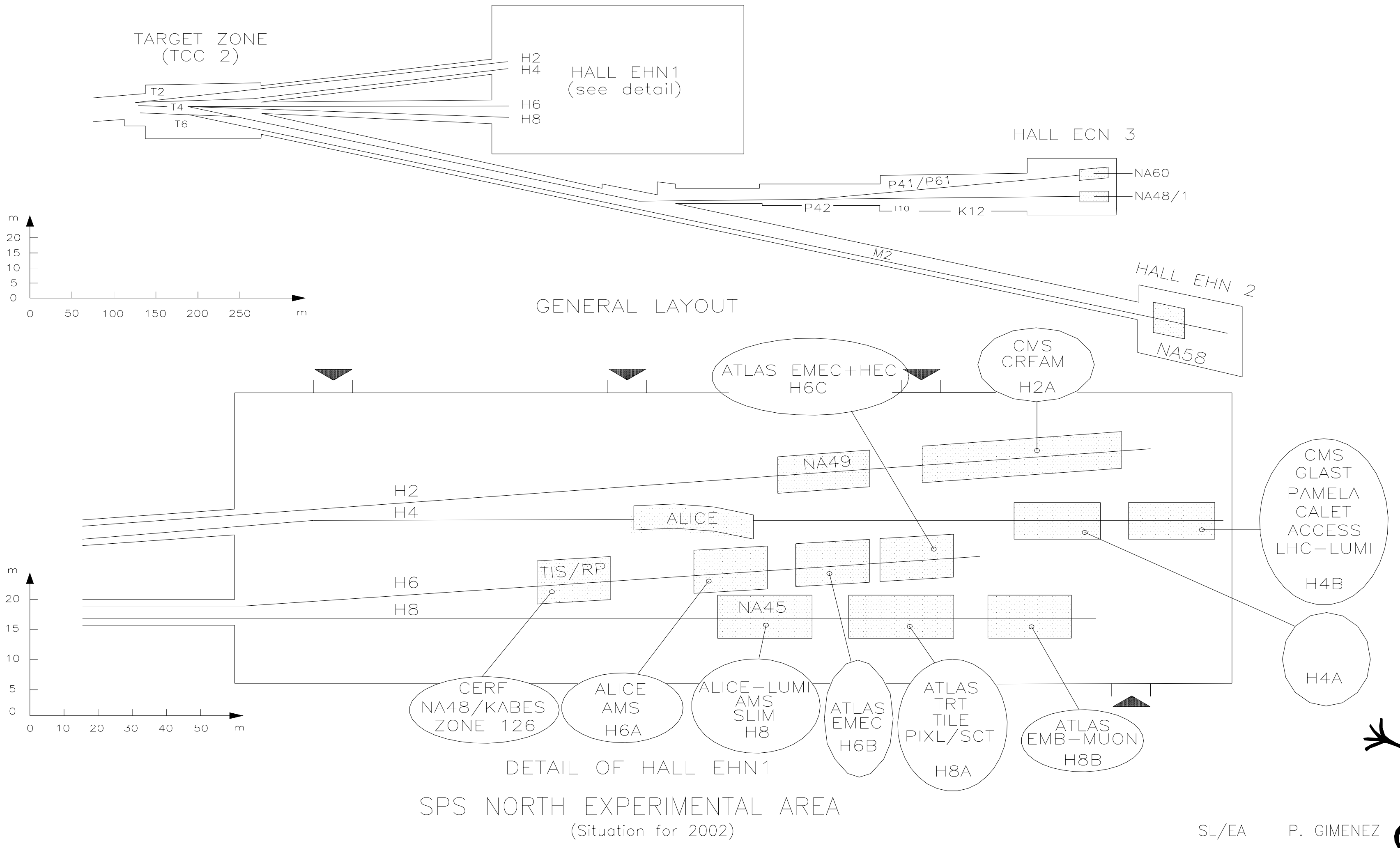
- The North Area was originally designed to house long-lasting experiments
  - demands for high quality of beams: high intensity, high energy, high resolution
- In the recent years most of the users are “tests”, in particular of LHC detectors
  - H2, H4 beam lines mainly CMS
  - H6, H8 beam lines mainly ATLAS
  - H4, H6 beam lines ALICE tests
- The test users have very different requirements from the big experiments
  - wide energy range from the highest accessible the the very low energies,
  - sometimes high (or very high) rates
  - all possible particles with as good as possible separation and identification

and all that during the few (or even one!) weeks of their allocated time!

- Few heavy-ion experiments and heavy ion users are also present
  - NA49 in H2 and NA45 in H6
  - tests for ALICE detectors (H8, H4, and/or H2)

Rapidly changing environment, quite demanding on beam conditions

… The EHN1 beams



Generalities

The target station

The target box

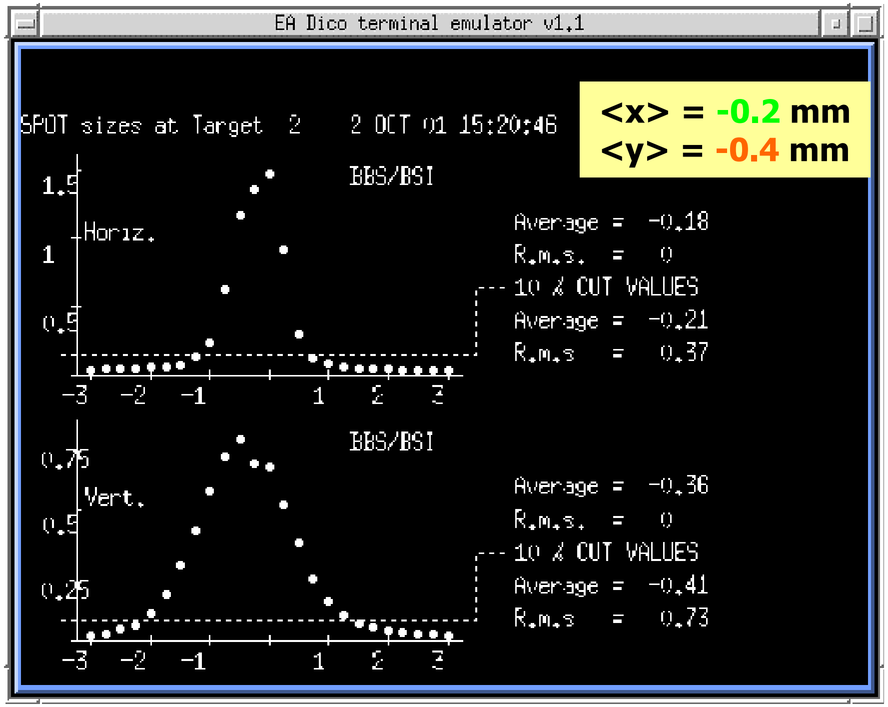
The target head

T2 target				
Position	H (mm)	V (mm)	L (mm)	Material
0	EMPTY			
1	160	2	300	Be
2	160	2	500	Be
3	160	2	180	Be
4	160	2	100	Be
5	120	2	40	Be

T4 target				
Position	H (mm)	V (mm)	L (mm)	Material
0	EMPTY			
1	160	2	300	Be
2	3	2	300	Be
3	160	2	200	Be
4	160	10	100	Be
5	120		40	Pb

Beam position monitors

- TBIU (upstream) , TBID (downstream)



- mounted on same girder as the target head for better alignment
- beam steering onto the target using BSM located ~30m upstream of the target

Wobbling

AIM

- Have the maximum flexibility in the use of a given target station

- Produce "several" secondary beams from the same target
  - when the primary beam hits the target basically "all" the particles are produced in a large variety of angles and energies
  - the most energetic particles are in the forward direction

should not forget:

- The very intense primary proton beam has to be dumped in a controlled way

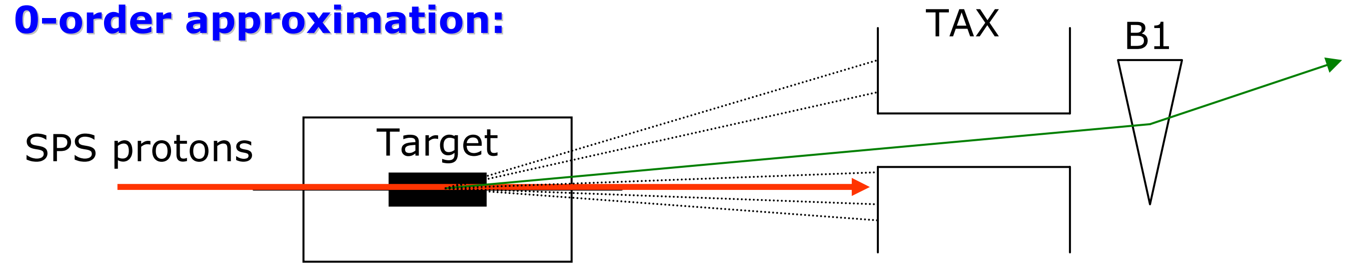
- The secondary beams of the chosen momentum have to go in the directions foreseen by the designer (i.e. inside the vacuum tube of each beam line)

Solution:

- "**wobbling**" : hit the target under variable angle

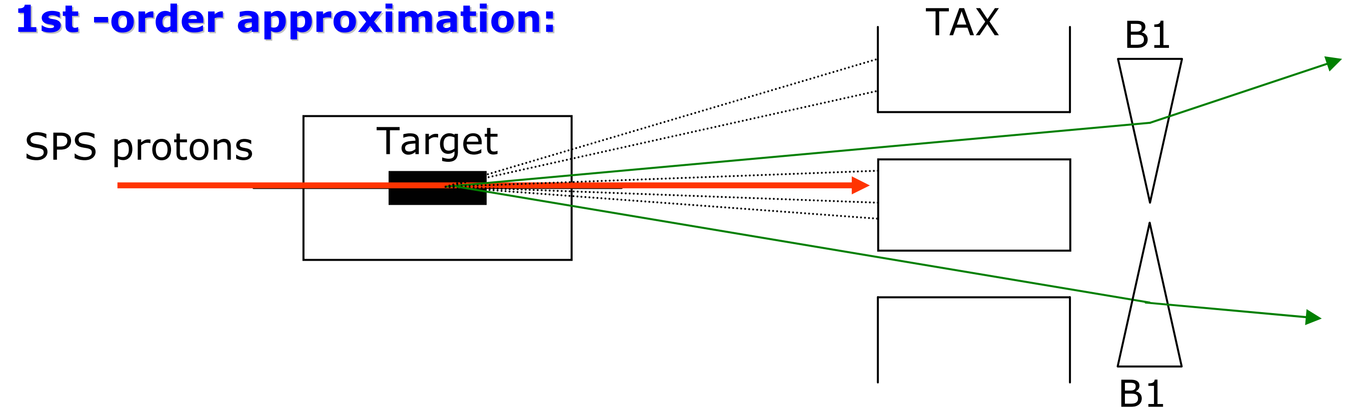
… Wobbling

0-order approximation:



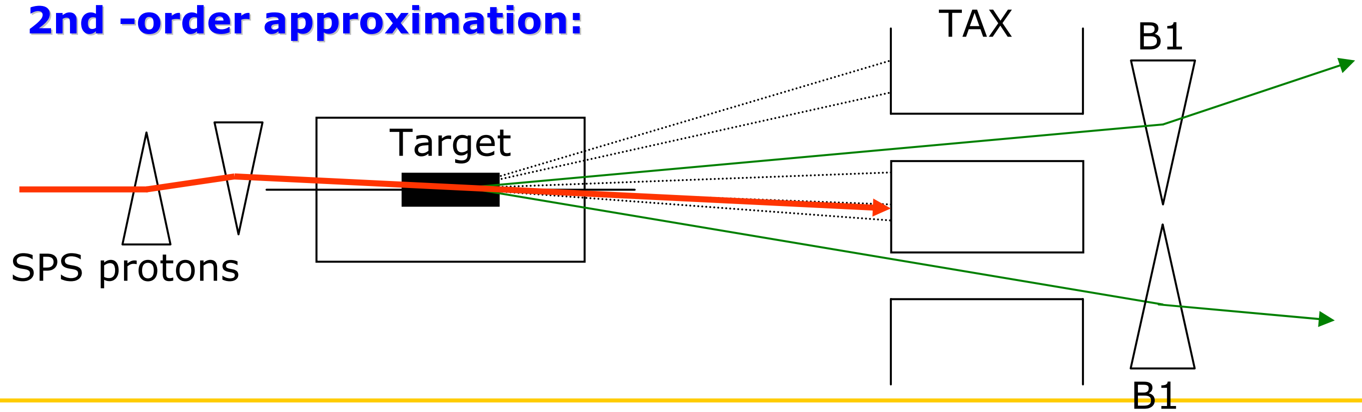
- single secondary or primary beam
- fixed production angle

1st -order approximation:



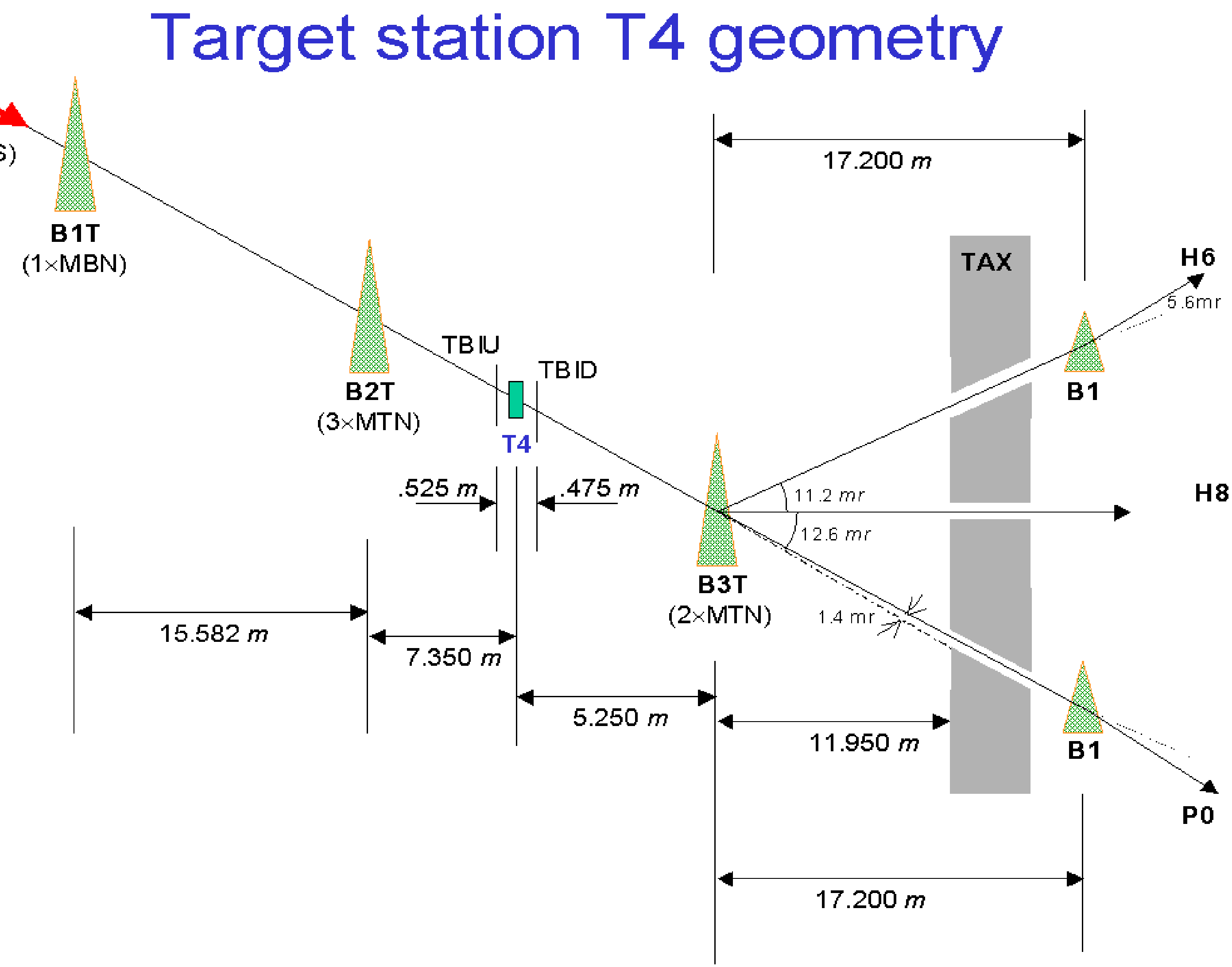
- two secondary beams
  - one could be the primary beam
- fixed production angles

2nd -order approximation:

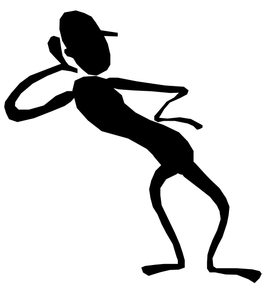


- two secondary beams
  - one could be the primary beam
- variable production angles

T4 target wobbling



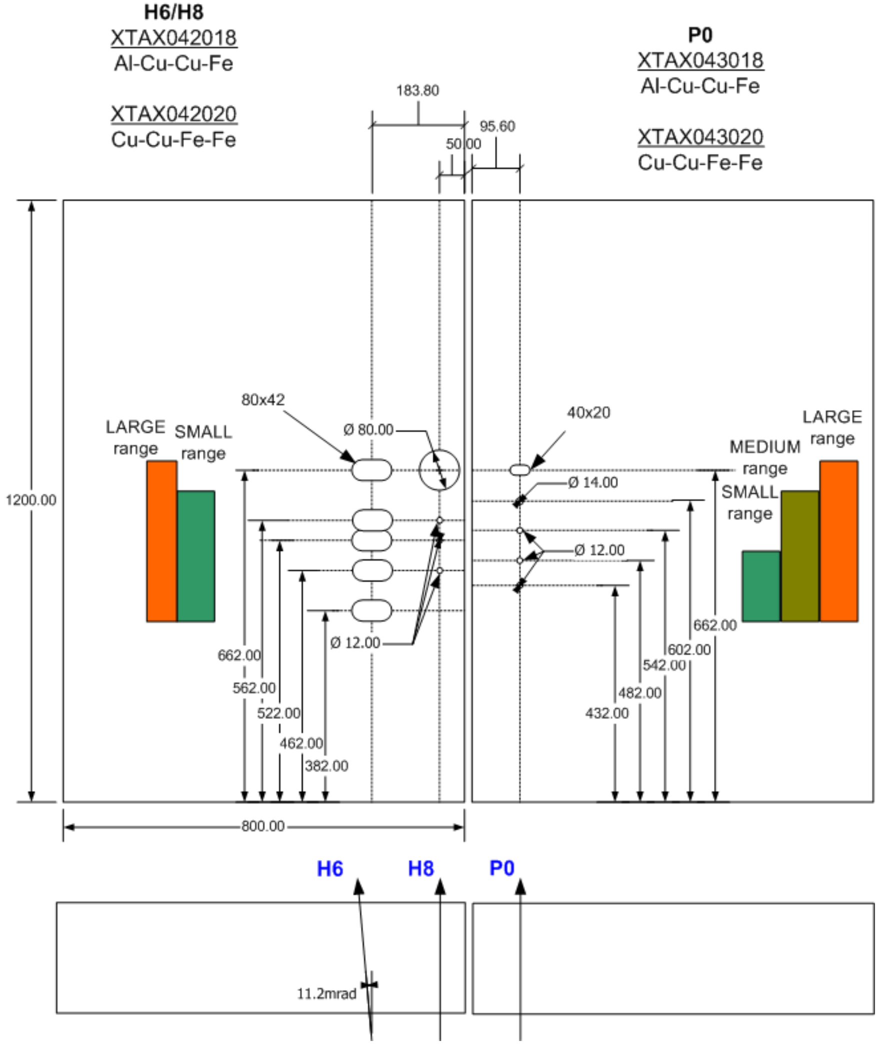
The target station

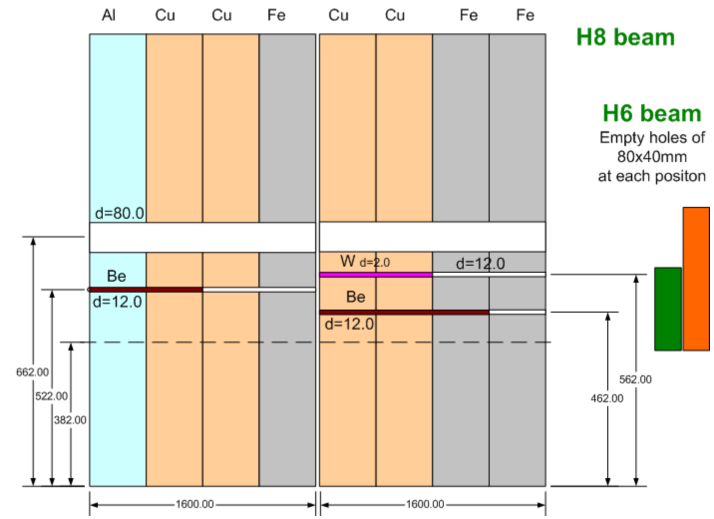


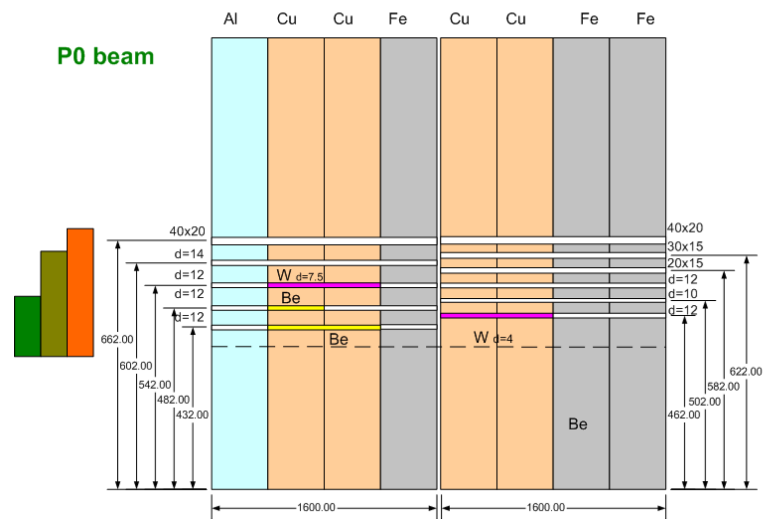
TAX - Target Attenuator

T4 Target TAX Blocks

Update 2000



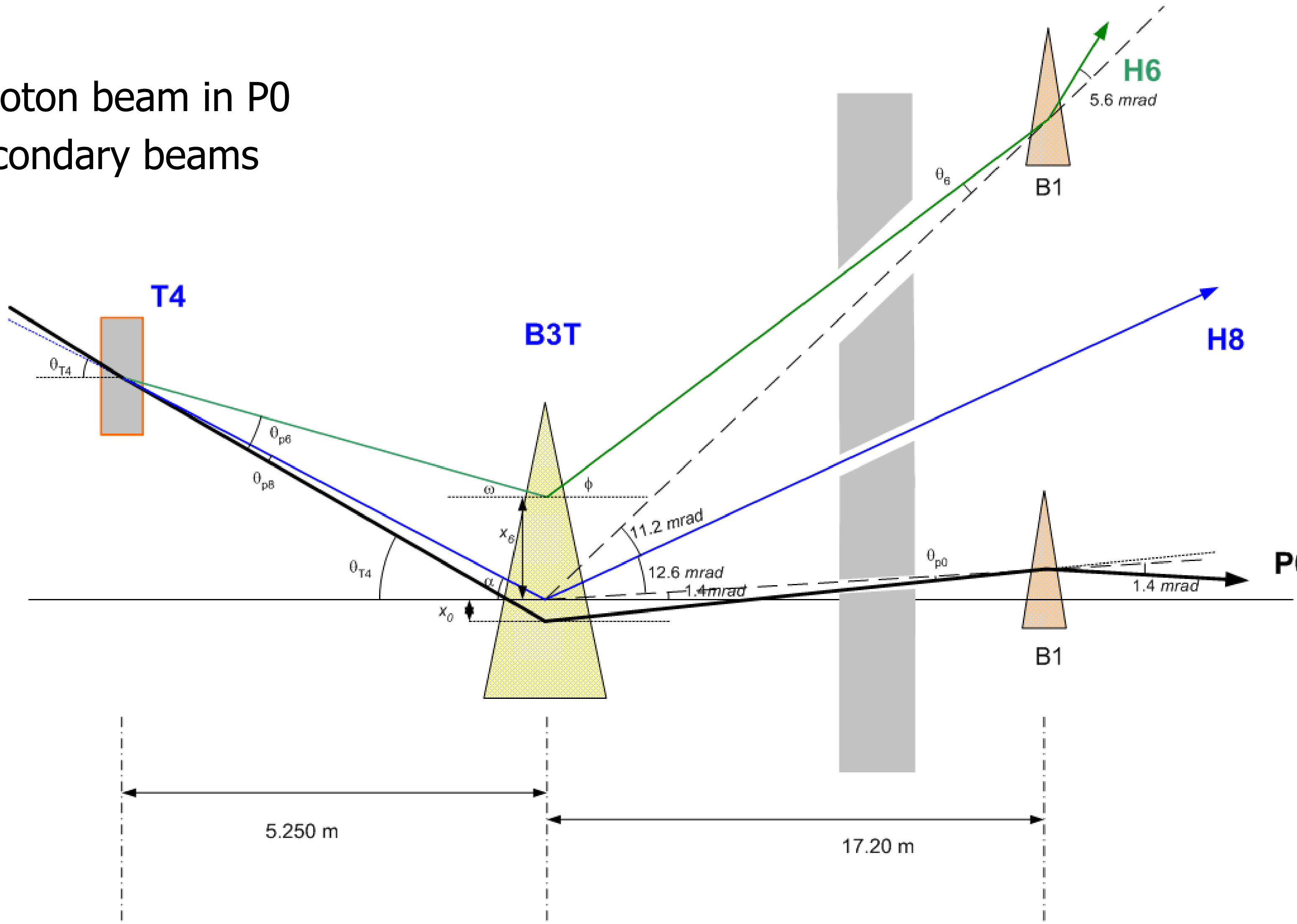




Wobbling - T4 target

Example 1:

- primary proton beam in P0
- H8, H6 secondary beams



The target station

… Wobbling - T4 target

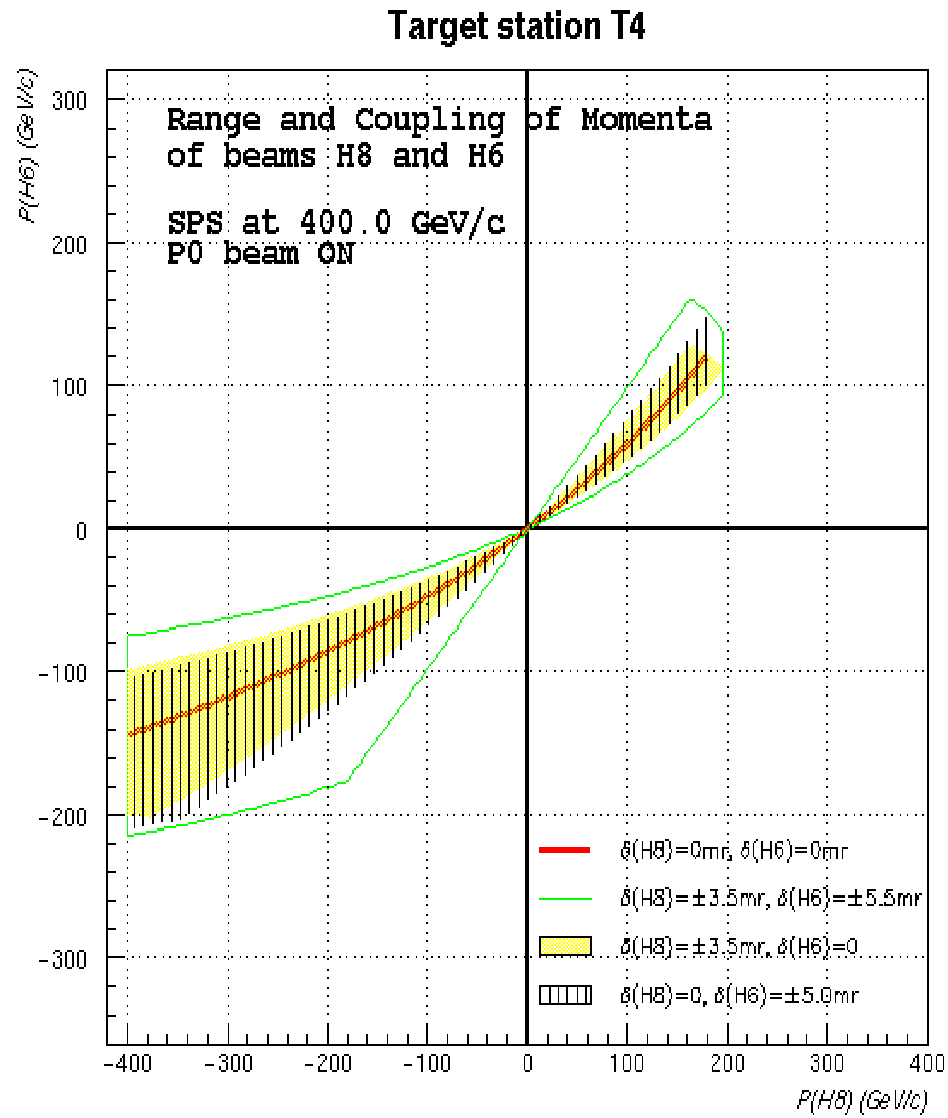
Example 1:

- primary proton beam in P0
- H8, H6 secondary beams

Presently the most frequent case

“standard wobbling” settings:

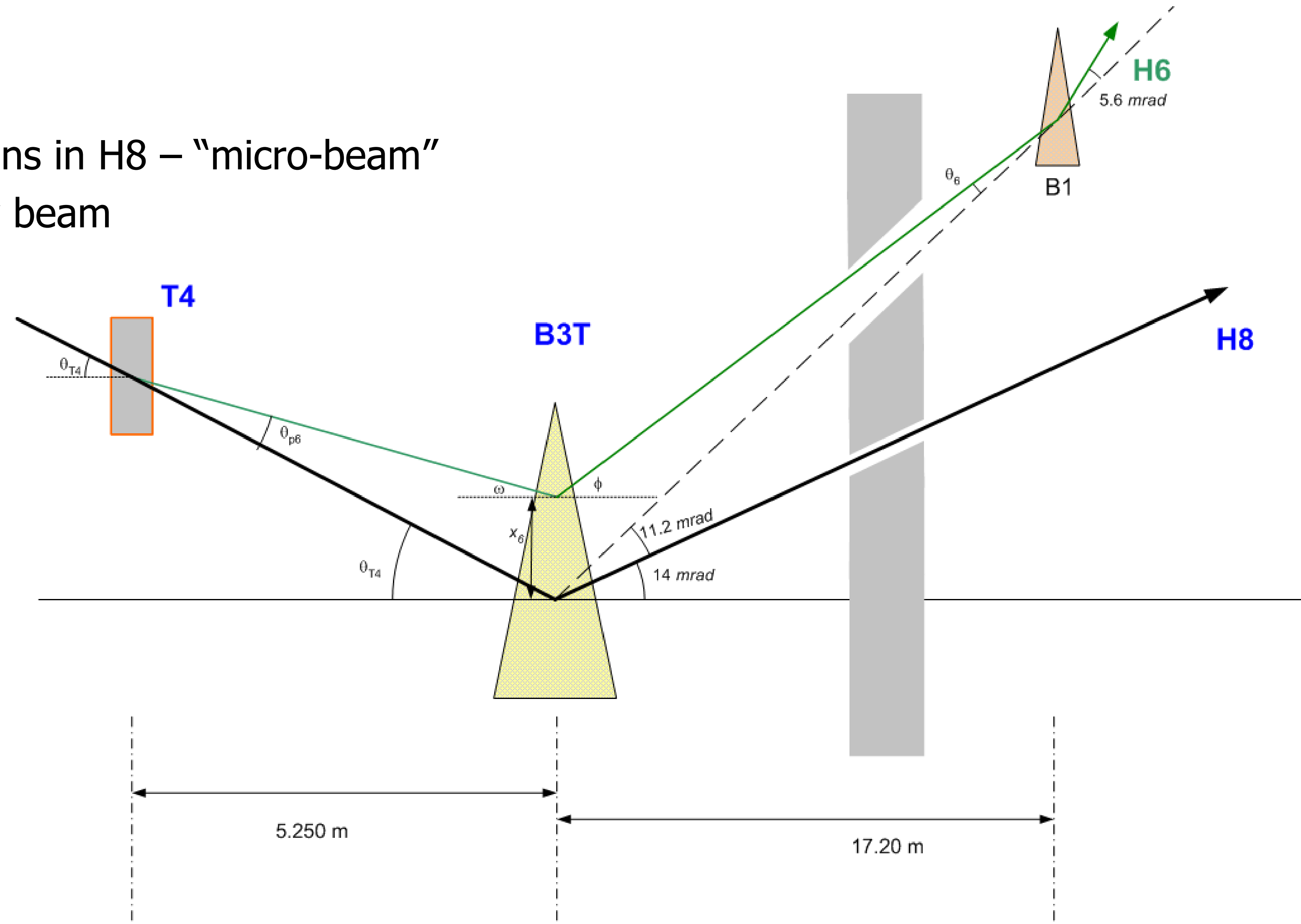
H8	H6	
Energy *(GeV/c)* @ 0 mrad prod. angle	Energy *(GeV/c)*	Prod. Angle *(mrad)*
+180	+120	0
	+100	-5.46
	+80	-13.36
+20	+10	-1.58
	+20	8.58
	+6	-15.13
-250	-100	-0.33
	-200	8.06
	-120	2.15
	-60	-10.23



… Wobbling - T4 target

Example 2:

- P0 beam OFF
- primary protons in H8 – "micro-beam"
- H6 secondary beam



Summary

The target station

- the **target box**:
  - the target itself: thin plate, ~2mm vertical, ~160mm wide, variable length
  - intensity monitors: TBIU (upstream) , TBID (downstream)
- wobbling magnets: B1, B2 upstream of target, B3 downstream
- beam TAXs : Target Attenuator

Safety - Survey

- survey (monitor) the current in the "wobbling" magnets and the position of the TBIU, TBID monitors
- for planned changes to the target station magnets (wobbling changes) a manual INHIBIT signal for the extraction has to be set

Wobbling changes

- initiated by the EA physicist upon the user requests
- presented and discussed in the EATC meeting, documented in the minutes
- performed by the operators, re-tuning of the the beam lines after the wobbling changes is often required

Particles and beams

Secondary beams

- transport particles particles directly produced in the primary targets
- three modes: HR, HT, FM
- energy and polarity depending on the wobbling setting

Target "wobbling":

- advantages:
  - several beams per target are available
  - flexibility of production angle and secondary beam energy
- drawback:
  - introduces coupling between beams: e.g. P0 + H8 + H6, H2 + H4
  - changes are difficult to agree and schedule

but the users (in particular the LHC detector calibration tests) demand a frequent change of beam energy and particle type

solution: **Tertiary beams**

Tertiary beams

- Transport particles produced from the decay or after interaction with matter of secondary particles

- Allow more flexibility (independence) of the users in different beam lines
  - keep longer periods with the same wobbling setting
  - use mainly the filter mode optics to avoid confusion

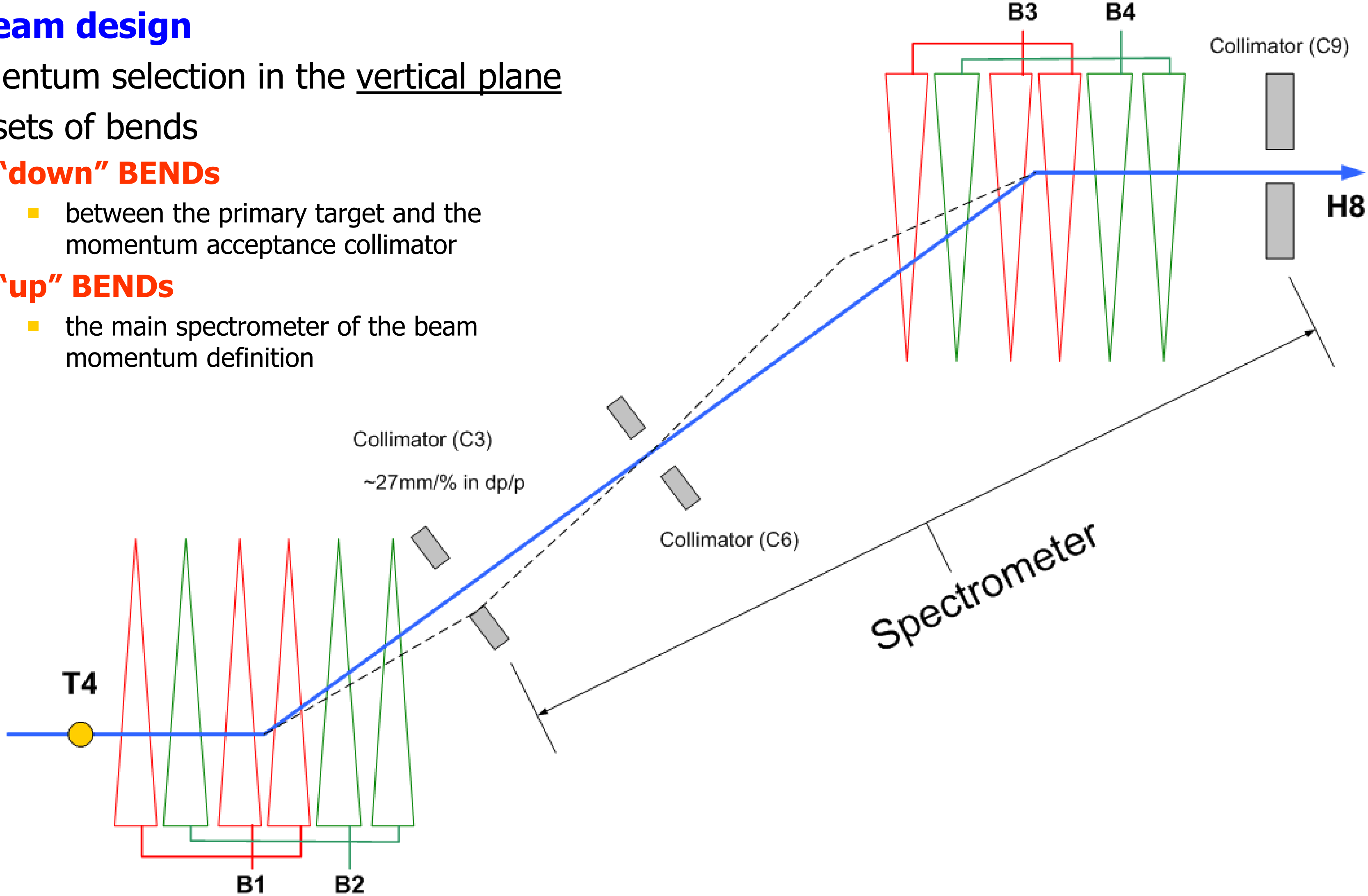
- Produced in two distinct ways:
  - **H6, H8:** use a **second target (filter)**
    - beam line tuned for two energies:
      - **E1 (high energy)** : from the primary target until the filter
        - → momentum selection by the "down" vertical BENDs
      - **E2 (< E1)** : from the filter until the experiment
        - → momentum selection by BEND-3 and BEND-4 (up vertical bends)
  - **H2, H4:** from the **conversion** or decay of secondary neutral particles

- **tertiary muon beams** of well defined momenta are produced by stopping pions in a closed collimator before the last bending magnets of the beam line

Secondary beams in EHN1 - reminder

Basic beam design

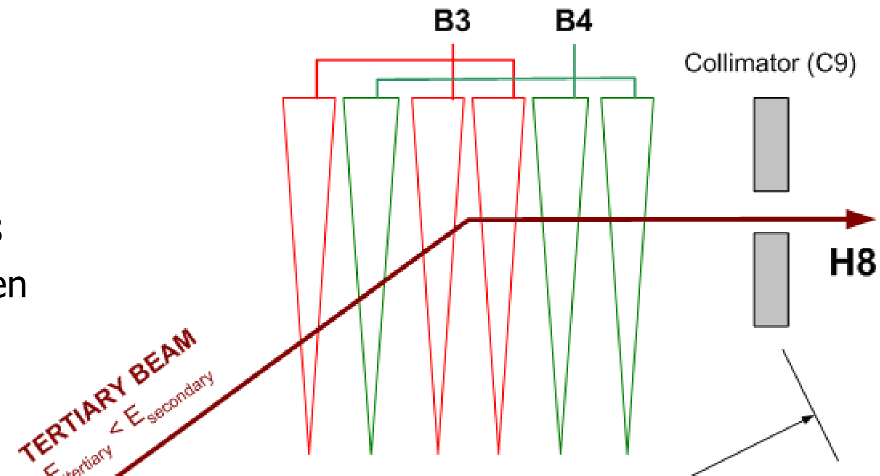
- momentum selection in the vertical plane
- two sets of bends
  - **"down" BENDs**
    - between the primary target and the momentum acceptance collimator
  - **"up" BENDs**
    - the main spectrometer of the beam momentum definition

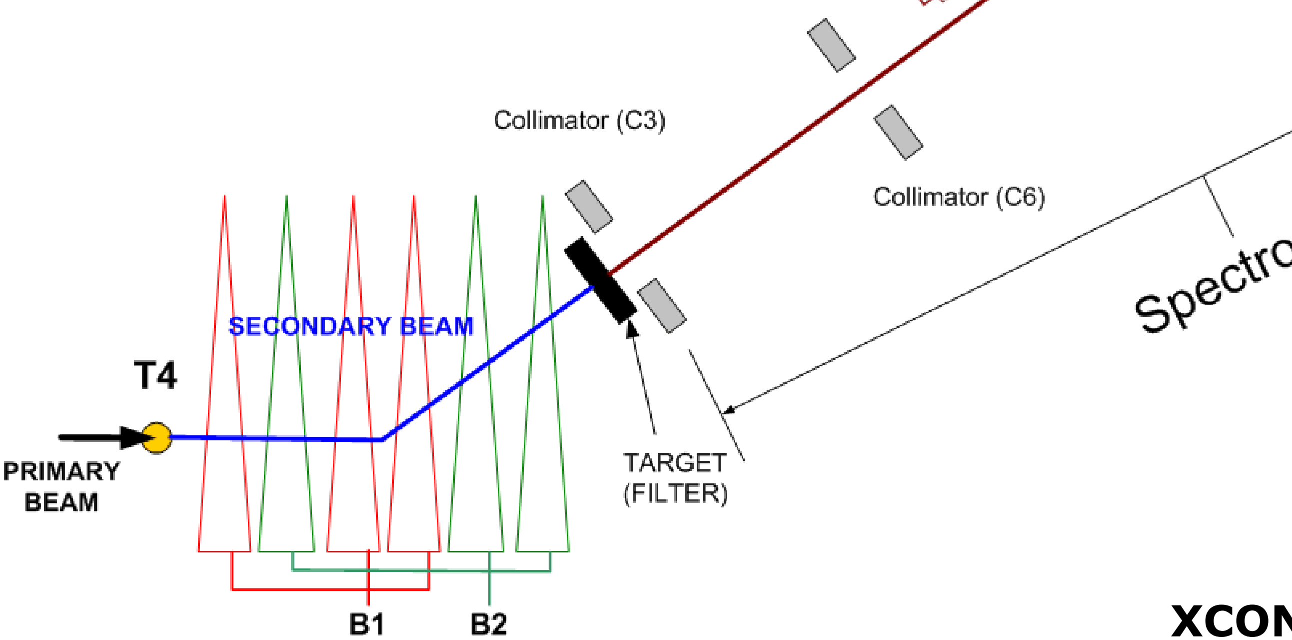


Particles and beams

Tertiary beams - H6, H8

- introduce a **target (filter)** after the "down" bends
- beam line tuned for two energies
- tertiary beams have typically lower rates
  - acceptance collimators can stay wide open
- choice of target material can enhance/select different particles





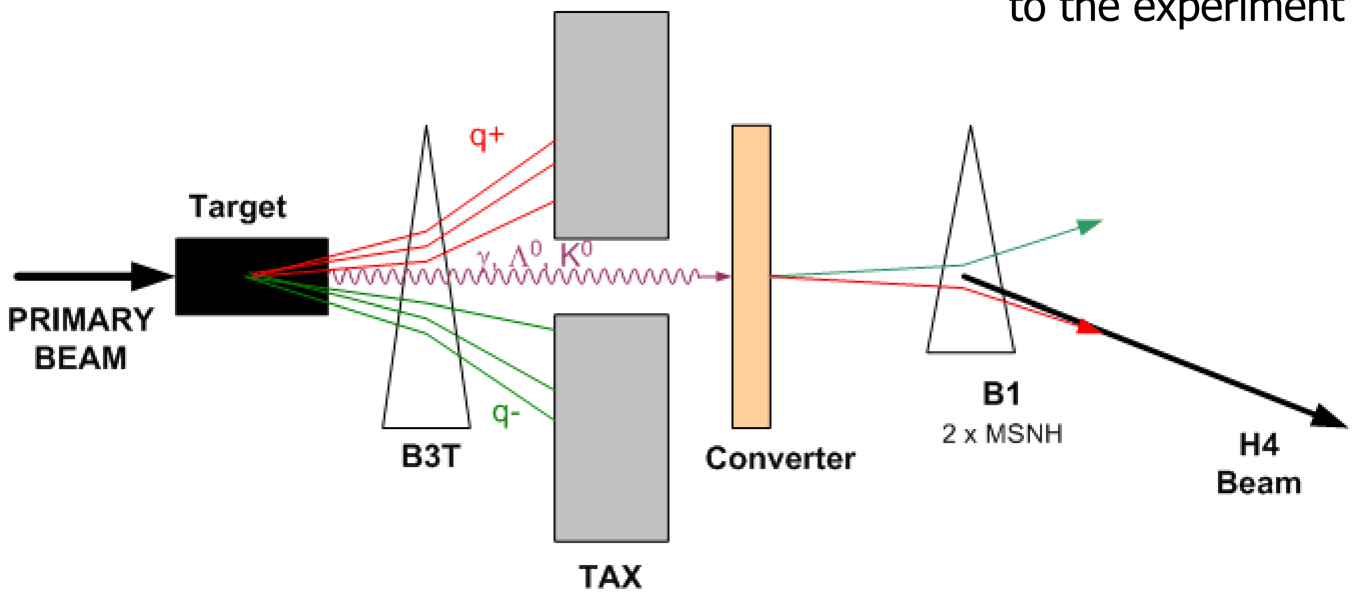
XCON fine positioning filter/converter

Tertiary beams - H2, H4

- use the B3 magnet of the wobbling as **sweeping magnet**
  - charged particles are absorbed in the TAX
  - neutral particles go through and hit the converter

  note:
  - neutral particles can have zero or non zero production angle

- use the **converter**
  - γ on Pb (CONVERTER=LEAD): to produce electrons (e^+, e^-)
  - COPNVERTER=AIR (no converter) to let K^0, Λ^0 , to decay
    - $K^0 \rightarrow \pi^+ + \pi^-$
    - $\Lambda^0 \rightarrow p + \pi^-$
- use **B1 of the beam line** to select the charge and particle for the tertiary beam to the experiment

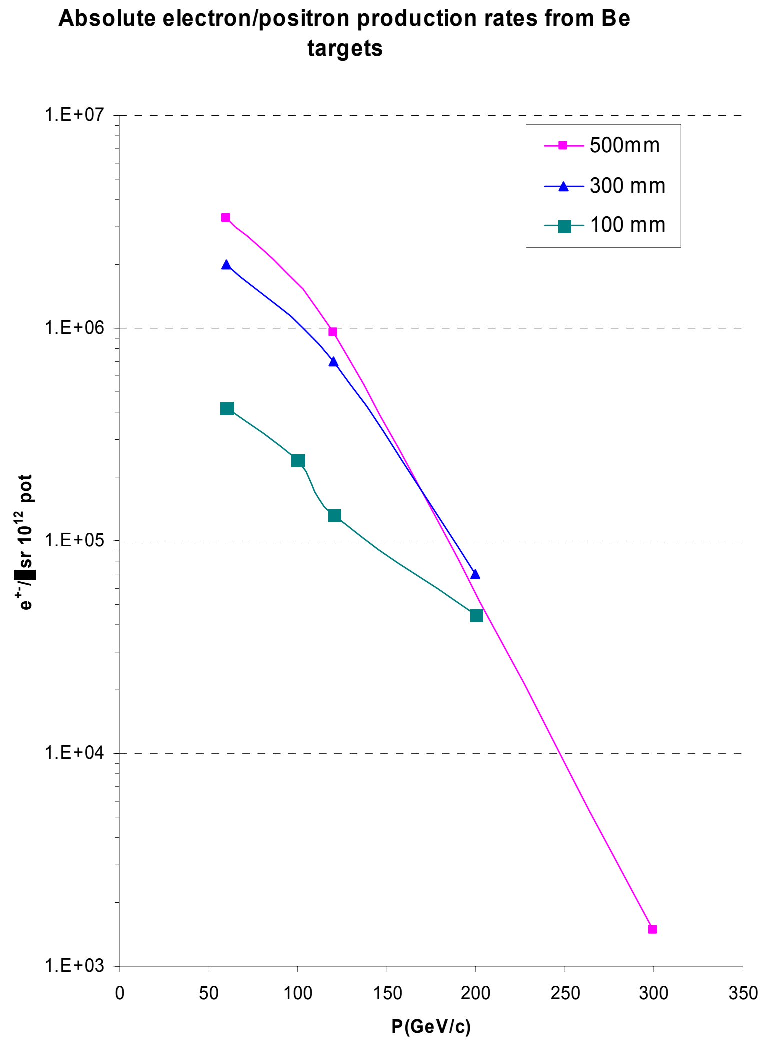


Particles and beams

Electron beams

Secondary beams

- electrons produced at the primary target
  - rate goes down with energy increase
- longer targets help electron production
  - rate ~proportional to target length
- at high energies (≥120 GeV/c) can be separated from hadrons by synchrotron radiation
- mixed beams pion (hadron) contamination for lower energies
  - user CEDAR or treshold Cherenkov counters for tagging



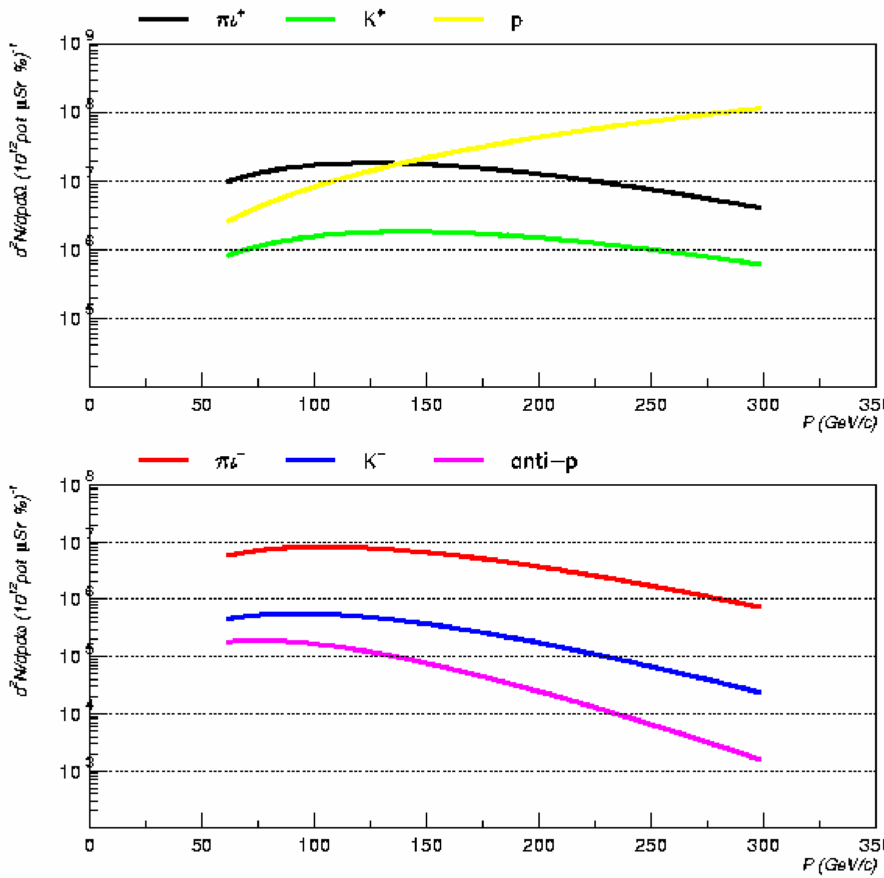
Tertiary beams

- **H6, H8**: use Pb as secondary target
  - few mm, or ~1-2 radiation lengths (X0)
  - radiation length: distance in matter where
    - electrons loose ~1/e of their energy
    - hadrons loose ~nothing
- **H2, H4**: electrons from photon conversion
  - high purity beams!

Hadron beams

Secondary beams

- hadrons produced at the primary target
- for positive sign beam a good fraction of the total hadron rate is protons
- using an absorber (~1-2 X_0 of Pb) in the beam we can eliminate any electron contamination



Particle production by 400 GeV/c protons on Be targets, H.W.Atherton et. al.

Tertiary beams

- **H6, H8**: use secondary target of Cu, $(CH)_n$
  - ~1 interaction length λ_I
  - <u>interaction length</u>: characterizes the average longitudinal distribution of hadronic showers
    - a high energy hadron has 1-1/e probability to interact within one lI
    - $\lambda_I >> X_0$ for most of materials
- **H2, H4**: hadrons produced in the decay of neutral mesons
  - $\Lambda^0 \rightarrow p + \pi^-$, $K^0 \rightarrow \pi^+ + \pi^-$

Muon beams

Secondary beams

- muons produced directly at the target area
- muons produced by the decay of (mainly) pions
  - muon momentum: 57-100% of the parent pion momentum
- to produce a pure muon beam for the experiment, is enough to close out of beam axis the last collimators of the beam line
- closing the collimator upstream of the last bend of the line we can obtain momentum selected muons
- rule of thump: muons in a $10\times10 cm^2$ trigger represent ~1% of the hadron/pion flux
  - there is another ~1% in a cone about $1 \times 1 m^2$ around the beam axis

Tertiary beams

- muons present only for tertiary beams in the energy range 57-100% of the secondary beam momentum

Beam tuning

Aim

- deliver good quality of beam to the experiment!
  - sufficient rate, spot size, particle purity,…
- is needed each time we change energy/wobbling/user

Assumption

- start from an already prepared beam file by the EA physicists
  - be sure it corresponds to the present wobbling setting
  - be sure it can fulfil the user requirements
    - typically the users know “their” files, but good to check it yourself too!!!

The first steps

- consult the logbook of the beam line
  - most of the files have been used already in the past
  - new files represent minor variations of existing files

- treat each plane independently
  - start with the vertical plane which is the most important to get the beam to EHN1
- select your observation point
  - a scintillator counter close to the end of the beam line
    - provided the beam can reaches it!!

… Beam tuning – EHN1 beams

Vertical plane

- close H-acceptance collimators to reduce the rate
- close the momentum defining collimators
  - “C3” and “C9”
- scan the current of the “down” BENDs to get the maximum rate
  - never touch the current in the “upper” BENDs otherwise the beam momentum changes
- check beam profile at various places between the “down” and “up” BENDs
  - use the available TRIMs to center the beam
- select a scintillator counter close to experiment to measure
  - use the TRIMs to steer and center the beam to the experiment

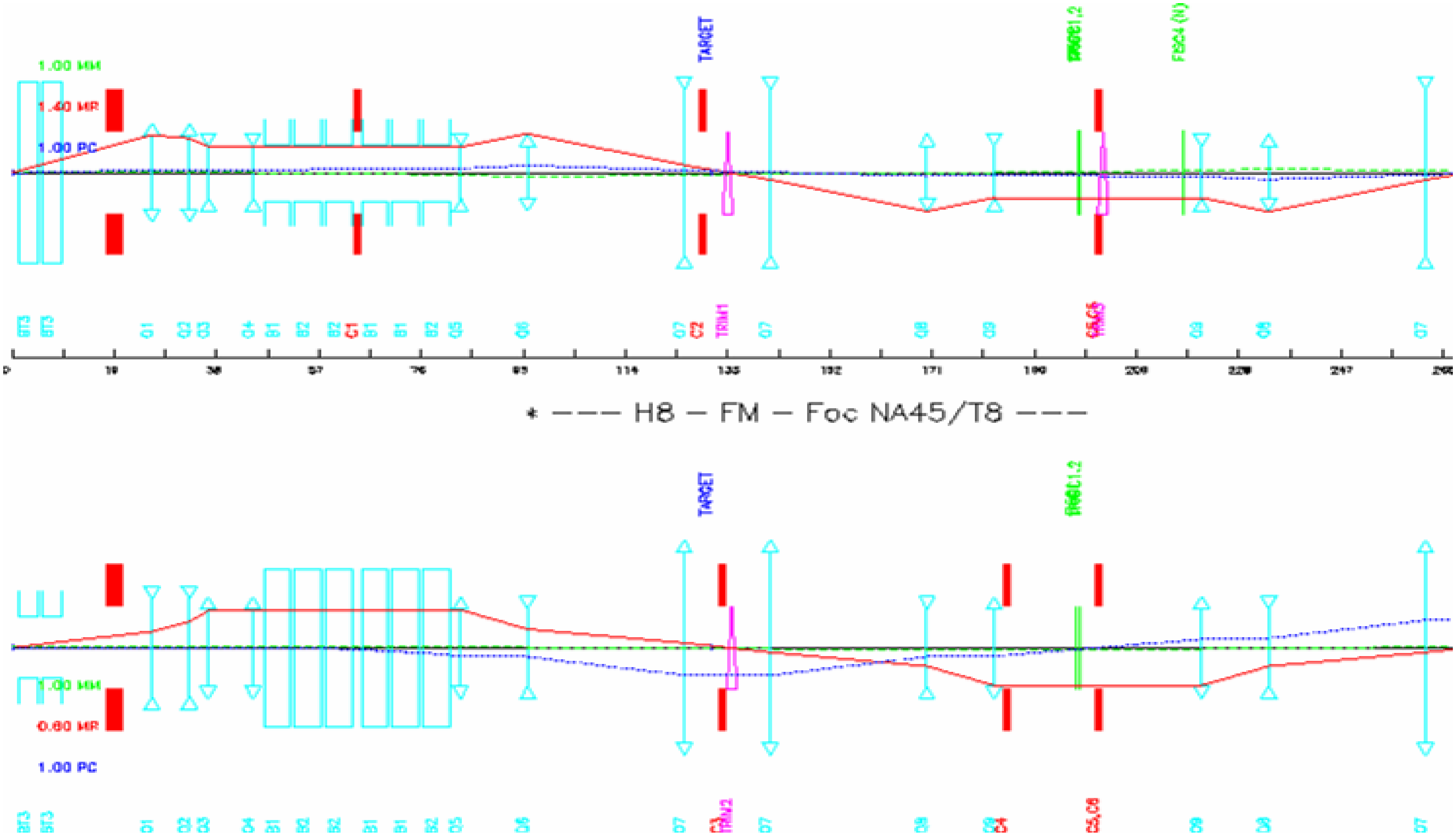
Horizontal plane

- close the V-acceptance collimators to reduce the rate
  - open the H-acceptance ones if previously closed!
- scan the current of the BEND-1 magnet if present (H2, H4, H6 beams) to get the maximum rate
  - close the collimator at the first focus point, typically “C2”
- check beam profile at various places in the tunnel
  - use available TRIMs to center the beam
- check beam profile at the experiment
  - use the last BENDs and the available TRIMs for steering

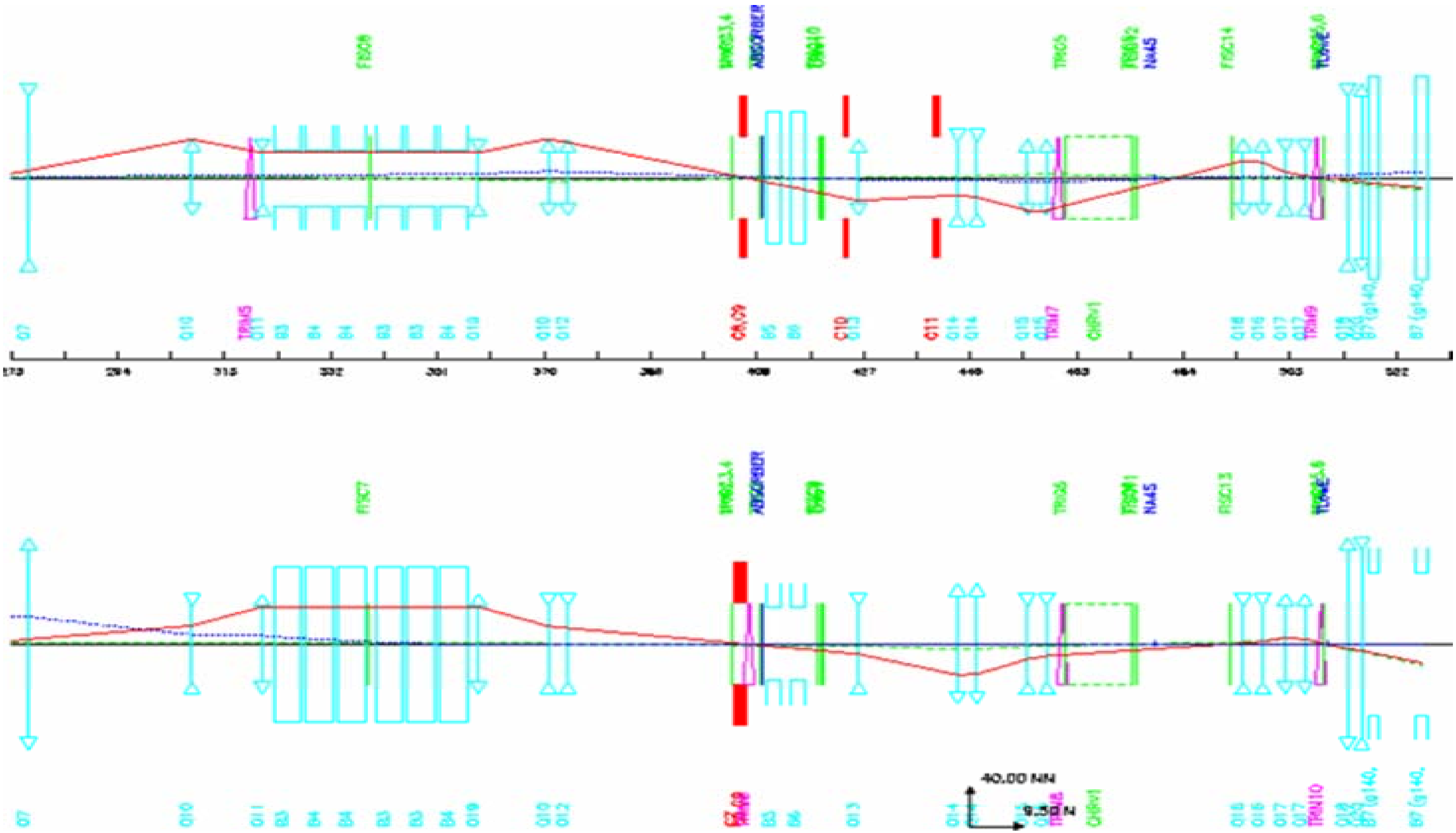
Note:

- you can use the Experimental scalers but be sure you know to what they are connected/measure
  - don’t always trust them, particular for ions!

… Beam tuning – H8



… Beam tuning – H8



Operational aspects

… Beam tuning – Watch out!

- electrons do not like material!
  - remove triggers or other detectors from the beam line, otherwise you may simply kill the whole beam
  - be careful when you try to measure/monitor things, since you may disturb the users

- referring to logbook is fine but
  - be sure you are comparing apples with apples
- follow the particles, consistent particle rates
  - use as much as possible normalized rates: rate/pot
  - monitor beam losses, be sure you are looking at the beam not at its halo
    - similar rates at different places along the beam line
      - scintillator counters are typically ∅ = 100mm but NOT ALL; Exp. Scalers can vary a lot!
- switching beam files:
  - secondary beams have high rates → acceptance collimators close
  - tertiary beams have low rates → acceptance collimators wide open

  therefore:

  switching from tertiary to secondary beam, load FIRST the collimators and then the magnets

… Beam tuning

Important

- Thing before acting

- To first order, all beam lines are quite similar
  - however there are some differences which need time to be familiar with

- Time is important for you and the users
  - there is always a limit to how good a beam can be; let the users decide

- Some users are quite experienced with their beam, and can do many things alone

- Good documentation is vital
  - <u>beam line snapshot</u>:
    - status of magnets/files/wobbling settings
    - status of collimators, target, absorber
    - rates in few counters (start, middle, end of beam line)

- Don’t be afraid to ask for help