The CERN Accelerator School

Closing remarks

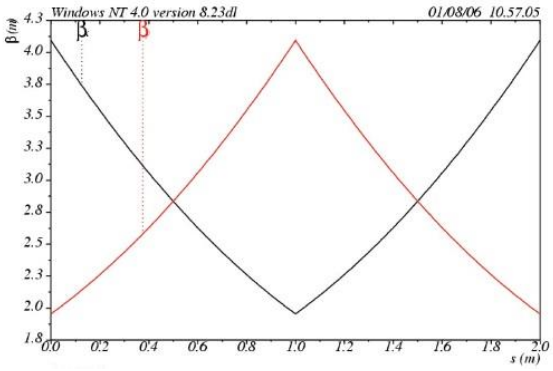
Hermann Schmickler

The “minimum takeaway”

- **Transverse and longitudinal beam dynamics**
  - trajectory, closed orbit, synchronous particle
  - horizontal and vertical phase/trace-space, preserved action
  - Twiss-parameters: Beta-function, Phase advance, tunes (H+V+synchrotron)
  - Dispersion-function, momentum compaction, slip factor
  - transverse and longitudinal focusing
  - chromaticity: origin and correction
  - transport matrix, tracking, dynamic aperture, bucket-area
- **Emittance**
  - emittance = average action of all particles
  - Liouville Theorem
  - RMS emittance, geometrical emittance
  - adiabatic damping, radiation damping
- **Imperfections**
  - dipole displacement: OK, dipole tilt: vertical deflection
  - quadrupole offset: extra deflection; quadrupole tilt: coupling
  - sextupole offset: extra quadrupole, sextupole tilt: coupling
- **Beam instrumentation**
  - Basic BPM functionality
  - How to measure losses, profiles
  - time and frequency domain signals, tune measurement
- **Collective effects**: Head-Tail, Wakefields, Direct Space Charge, Instabilities
- **Types of accelerators:** Linacs, Cyclotrons, Synchrotrons, Colliders, Lightsources

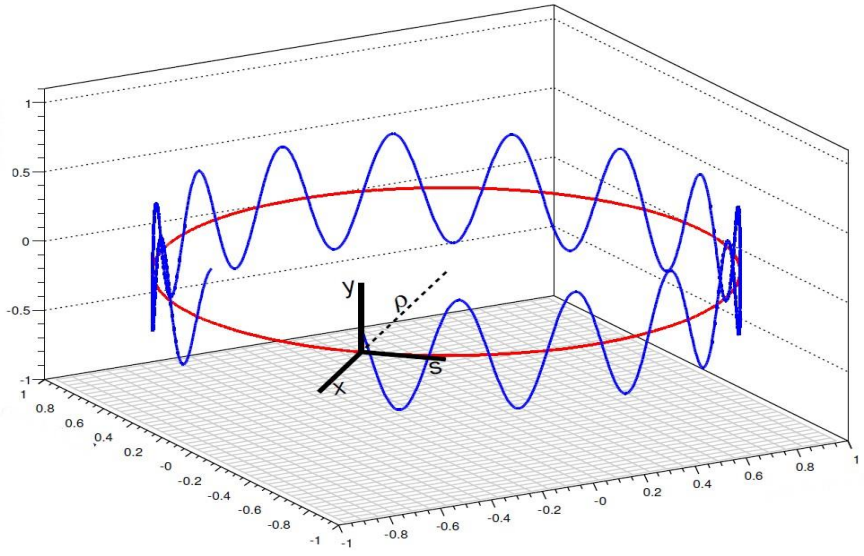
5 slides to retain

1) Horizontal and vertical beta function $\beta_{H,V}\ (s)$:

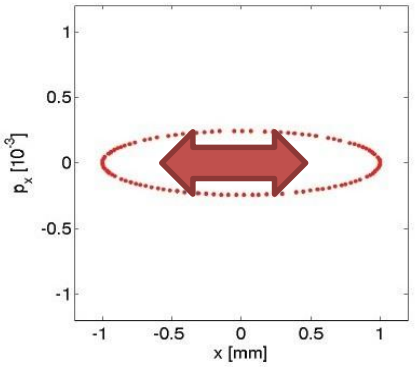


- Proportional to the square of the projection of the phase space ellipse onto the space coordinate
- Focusing quadrupole → low beta values

Although the shape of phase space changes along s, the rotation of the particle on the phase space ellipse projected onto the space co-ordinate looks like an harmonic oscillation with variable amplitude: called **BETATRON-Oscillation**



$$x(s) = const \cdot \sqrt{\beta(s)} \cdot cos\{\mu(s) + \varphi\}$$



Interpretation of the Twiss parameters (2/2)

2.) $\alpha = -\frac{1}{2}\frac{d\beta}{ds}$

α indicates the rate of change of β along s
α zero at the extremes of beta (waist)

3.) $\mu = \int_{s1}^{s2} \frac{1}{\beta}\,\mathrm{ds}$

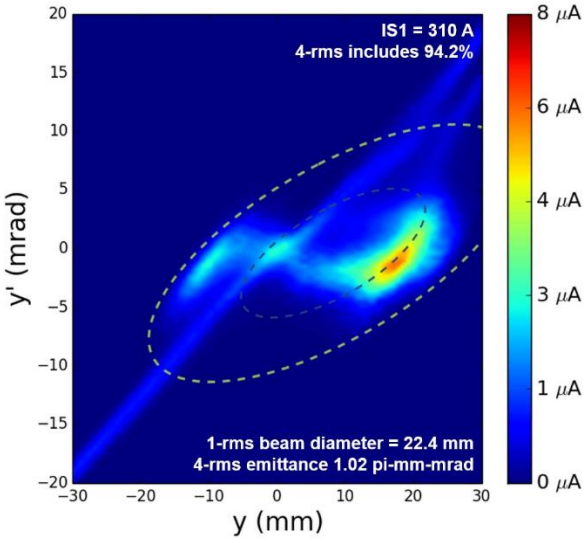
Phase Advance: Indication how much a particle rotates in phase space when advancing in s

Of particular importance: Phase advance around a complete turn of a circular accelerator, called the betatron tune Q (H,V) of this accelerator

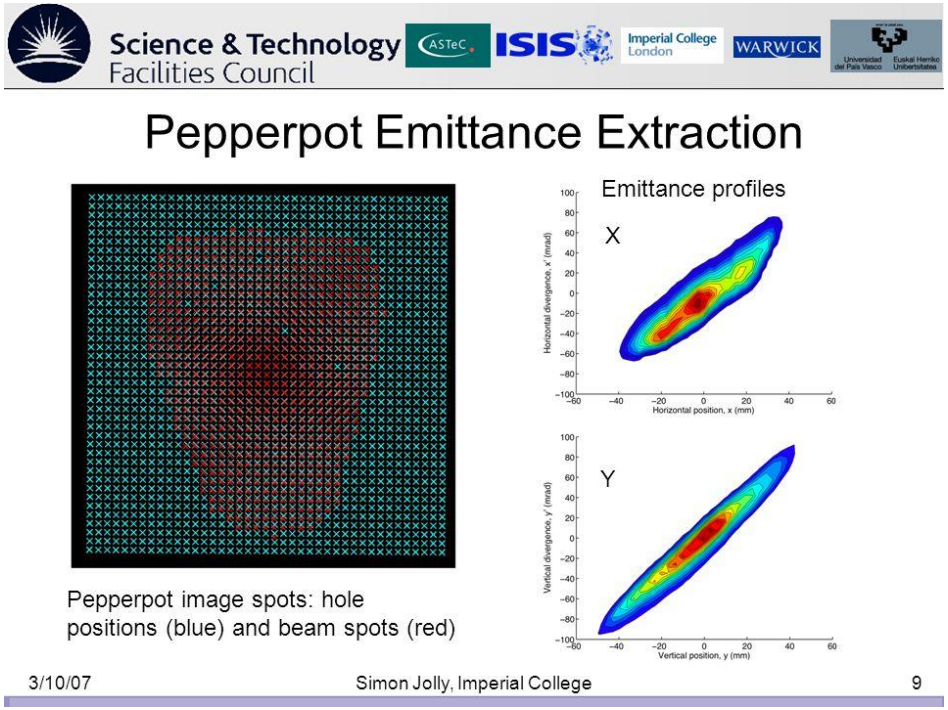
$$Q_{H,V} = \frac{1}{2\pi}\int_0^C \frac{1}{\beta_{H,V}}\,ds$$

Finally: a beam

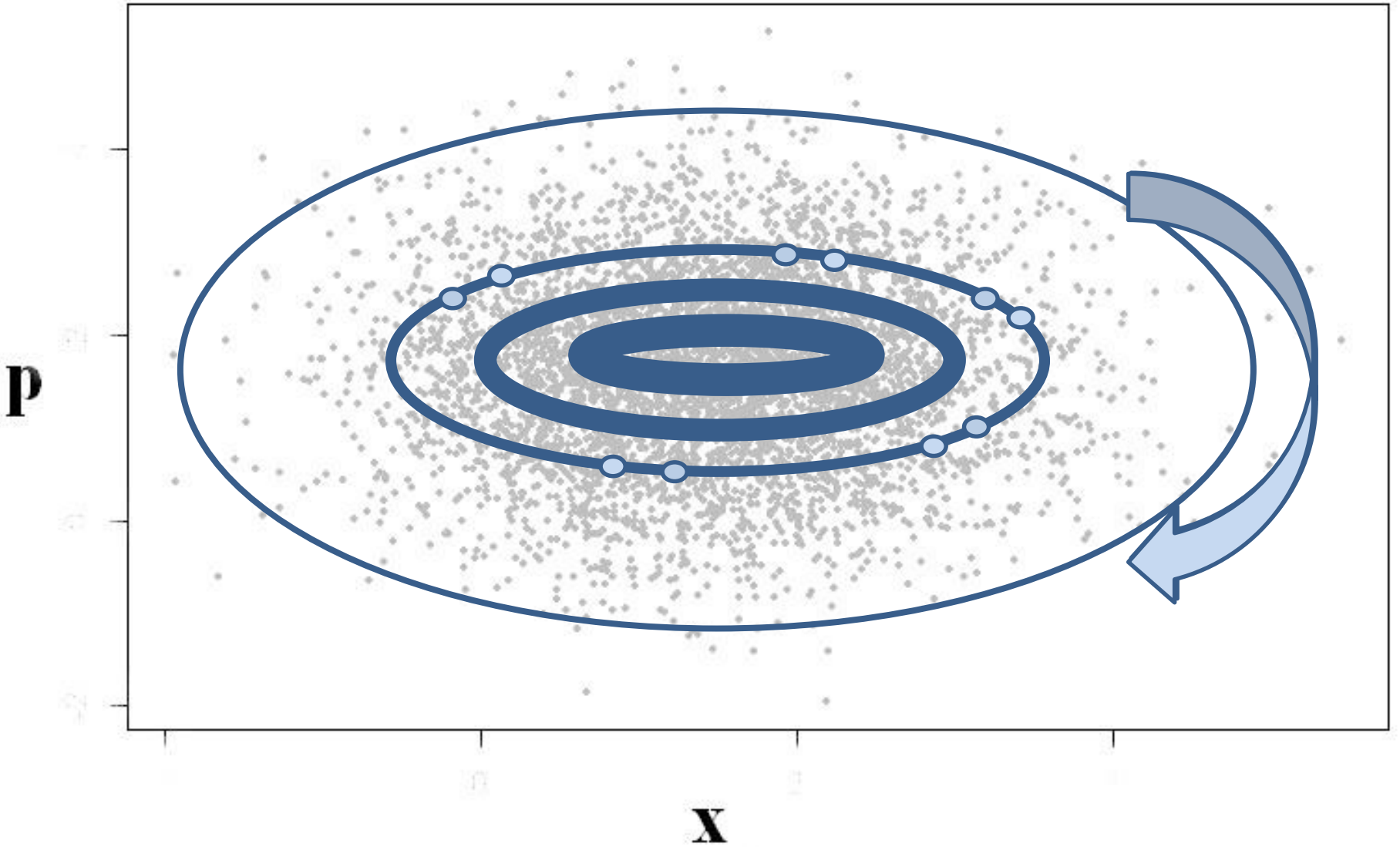
We focus on “bunched” beams, i.e. many (10 ^{11}) particles bunched together longitudinally
From the generation of the beams the particles have transversally a spread in their original position and momentum.



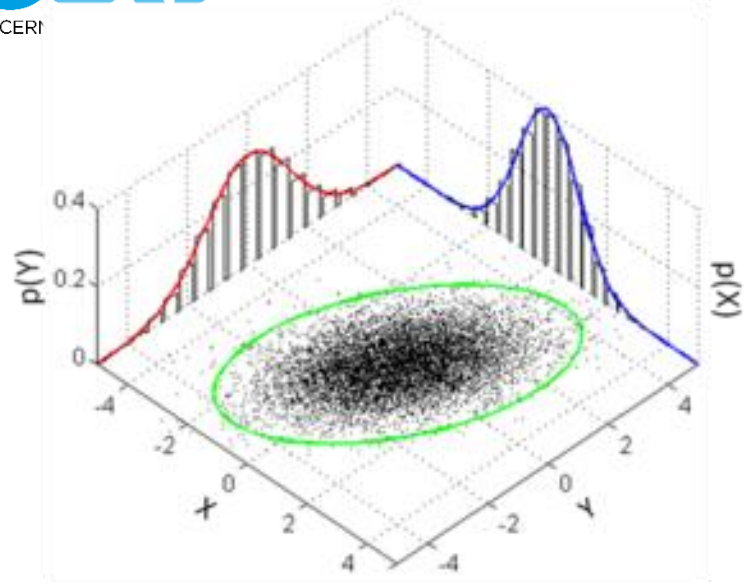
Source: ISODAR (Isotope at rest experiment)



Gaussian beam profile in x and p

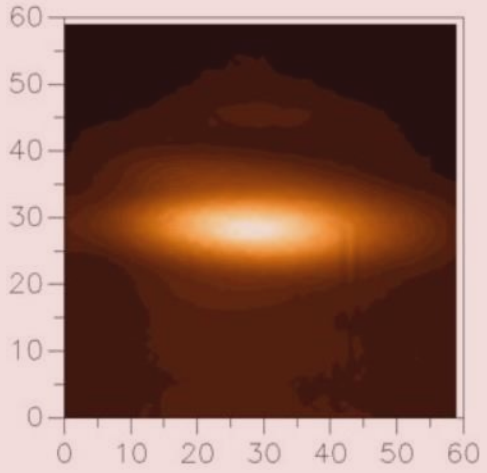


What do we normally measure from the phase-space ellipse?

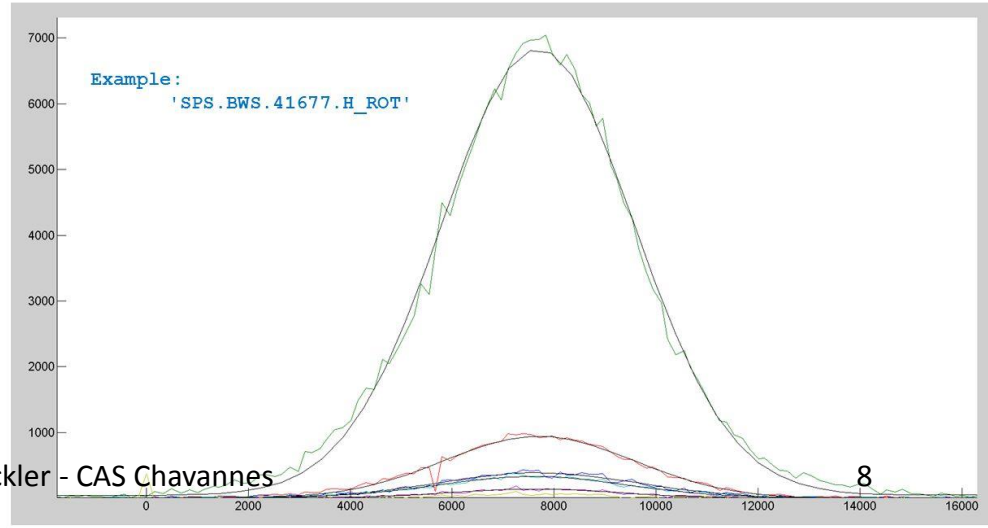


- At a given location in the accelerator we can measure the position of the particles, normally it is difficult to measure the angle…so we measure the projection of the phase space ellipse onto the space dimension:
→called a profile monitor

Attention! The standard 2 D image of a synchrotron light based beam image is NOT a phase space measurement



FITTING



Some background info

- Last course 2 years ago (High Tatras, Slovakia)
- Next course in September 2022 probably in Kaunas (Lithuania)
- Visit and choice of hotel in autumn based on Covid considerations
- Same program as two years ago, nevertheless 9 iterations of program to accommodate speaker availabilities.
- Incomplete proceedings available on the web
- Expect complete and printed copies in February/March 2022 Every participant will be asked by email for his postal address and will get (if wanted) a printed copy.

Statistics

- 68 participants
- 23 different nationalities
- Age span: 20 … 48
- 45 males / 23 females

Feedback Discussion

- Comments to the program
- Balance of topics
- Balance between accelerator types
- Hands-ON Courses

- Level of the lectures

Project “CAS videos”

Presently two major attempts to produce MOOC’s in the field of accelerator physics:

- Nordic Accelerator School
- ARIES

CAS proposes to film its lectures and to put them onto our website including an electronic index baptized “CASopedia”

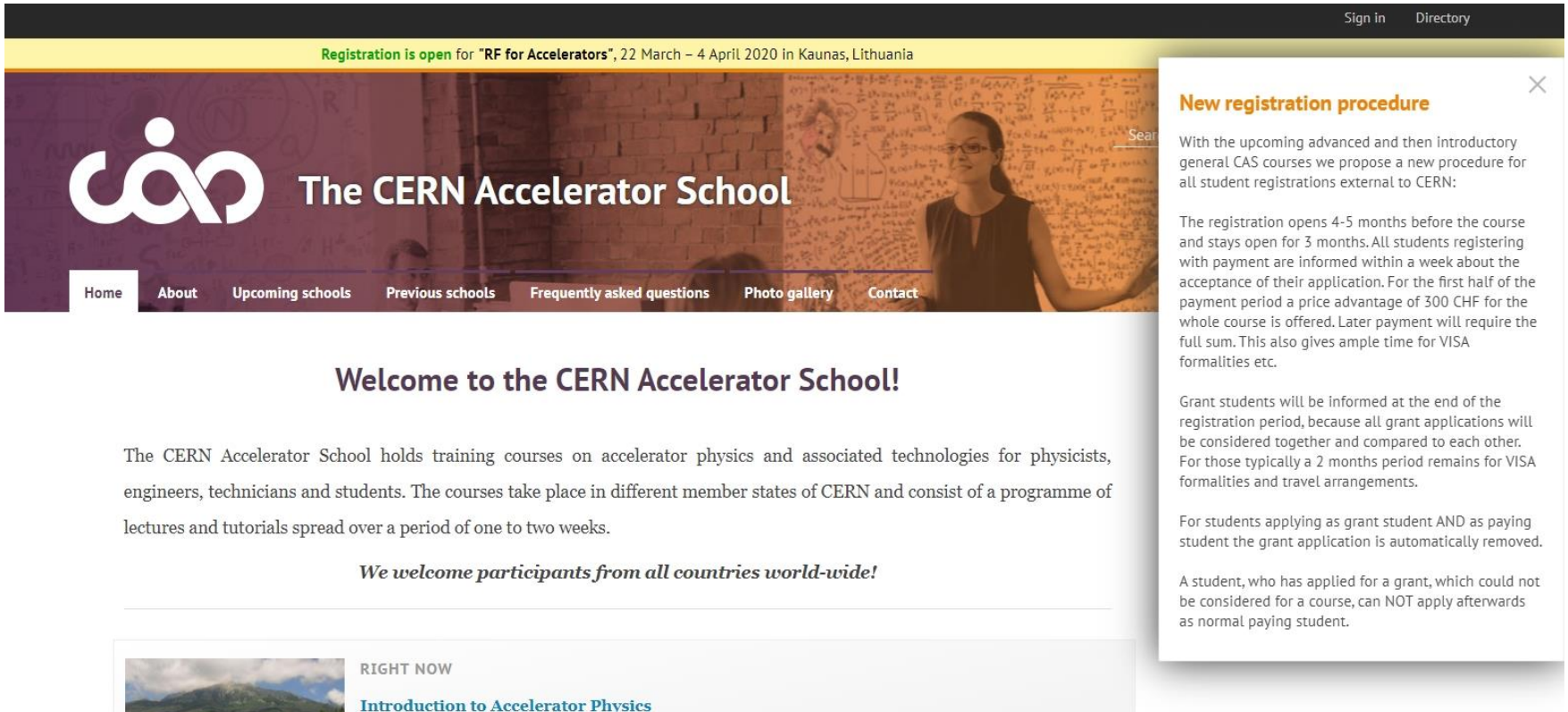
- first attempt: introductory in Budapest; no index
- now: this introductory course;
  (provided we get the necessary resources)

MOOC: Massive Open Online Course

Our website: http://cas.web.cern.ch/

Author: Anastasiya

Our major depository of information…large effort to keep the site up to date



Our CAS video on the website

https://cas.web.cern.ch/

Feedback

- Please help us
- Very important
  - F
  - F
- Abou
  - The lectures
  - The tutorials
  - The place
  - Anything else

VACUUM FOR PARTICLE ACCELERATORS
6-16 June, 2017
Glumslov, Sweden

YOUR IMPRESSIONS OF THE PROGRAMME

Please mark each lecture with a number 1 to 5 in each of the three columns labelled "Level, Content and Presentation". The meaning of the numbers is as shown below. Please return this sheet to Barbara Strasser or Roger Bailey as soon as possible when completed. Your answers are confidential.

LEVEL	CONTENT	PRESENTATION
1 – Much too low	1 – Completely uninteresting	1 – Very poor
2 – Low	2 – Uninteresting	2 – Poor
3 – Just right	3 – Of some interest	3 – Fair
4 – Too high	4 – Interesting	4 – Good
5 – Much too high	5 – Very interesting	5 – Very good

TITLE	LEVEL	CONTENT	PRESENTATION
Introduction to Cryogenics			
Cryopumping			
Industrial Vacuum Applications			
Beam Induced Desorption			
Beam-Gas Interaction			
Surface Characterisation			
Interactions between Beams and Vacuum System Walls			
Surface Cleaning & Finishing			
Thin-Film Coating			
Controlling Particles/Dust in Vacuum Systems			
Beam Induced Radioactivity & Radiation Hardness			
Radiation Damage and its Consequence			
Control & Diagnostic			
Vacuum Design Aspects			
Manufacturing & Assembly for Vacuum Technology			
The Real Life of Operation			
Challenges for Vacuum Technology of Future Accelerators			

If you have any general comments about the course, please write them on the reverse side of this page.

We keep the feedback open until Sunday this week…last chance!

“Testimonials” on the CAS website

- All it needs:
  - a photo
  - name + affiliation + CAS course
  - “a sentence”

Social life during course:

- Next to the course teaching the most important aspect of the school
  " digital training cannot replace CAS courses"
- What happened:
  - people socialising (and even working) up to late in the evenings
  - lots of interactions students <-> teachers
  - cinema evening
  - excursion

Last not least:

This course would not have happened without:

- lecturers: they do all the work for “love”

- the Hands-ON courses teachers:
  - Guido, Andrea, Volker, Axel, Heiko, Alexandre, Simon

- The “souls” of the event:
  - Delphine
  - Maria
  - Michela
  - Anastasiya

- YOU