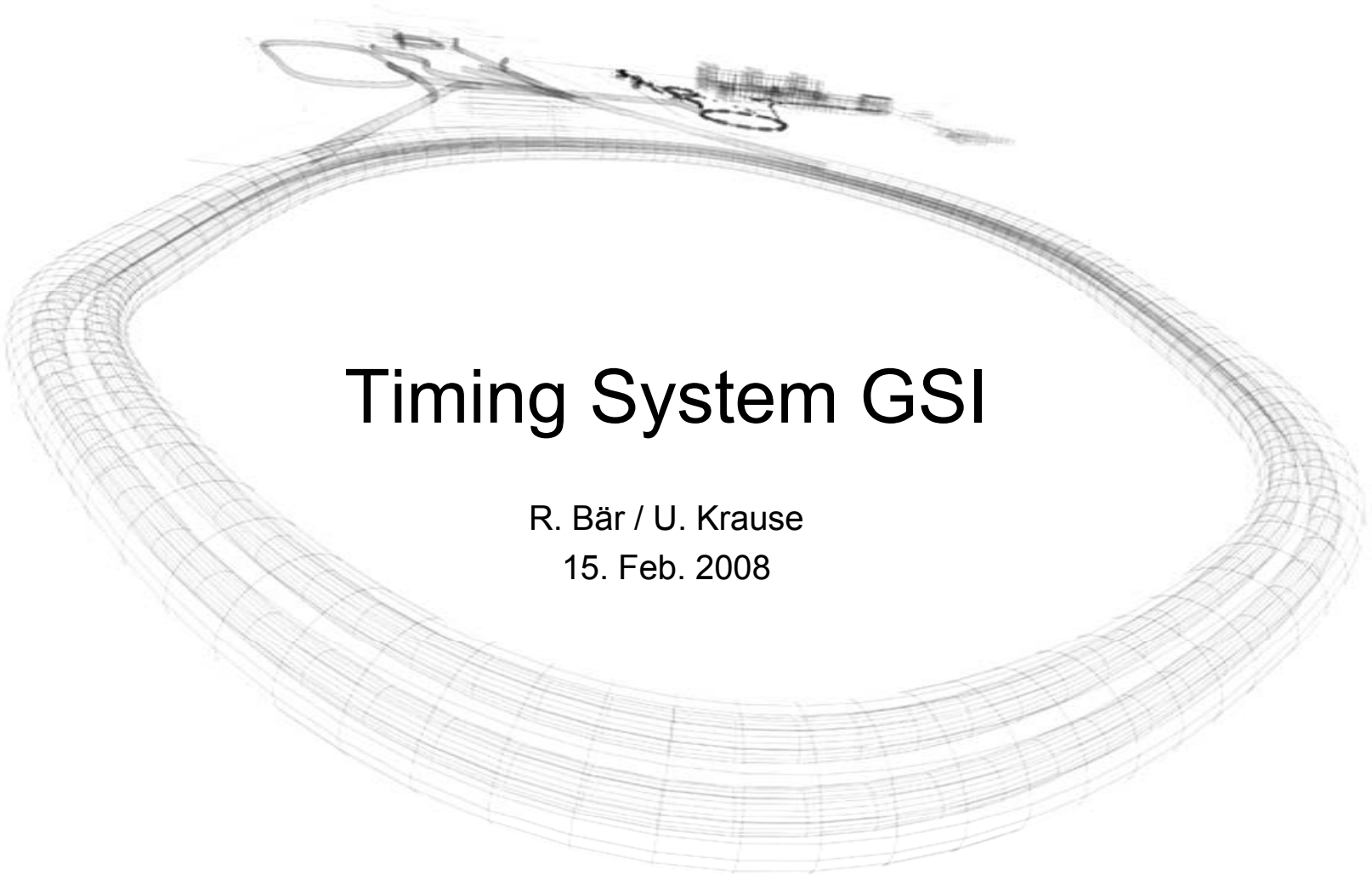


Timing System GSI

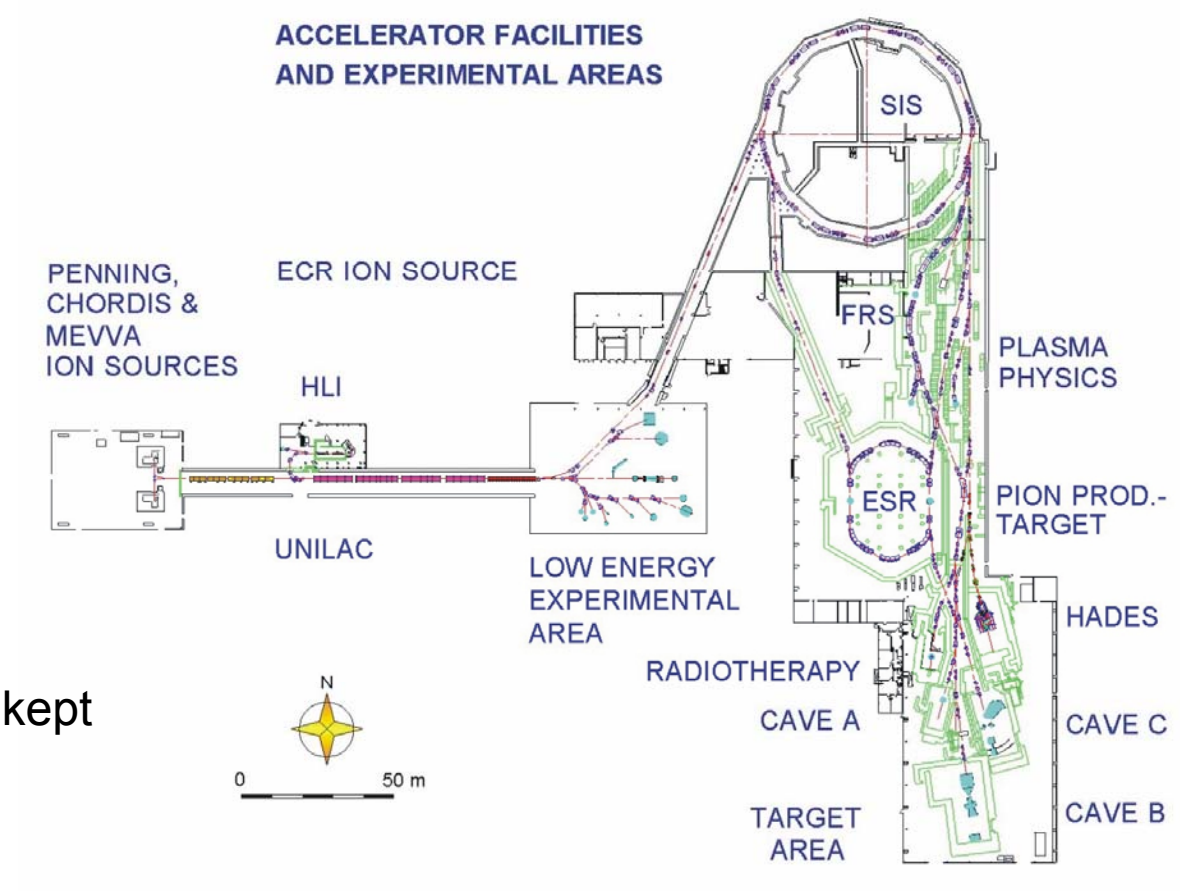
R. Bär / U. Krause

15. Feb. 2008

GSI: Today

(Heavy-) Ion reasearch

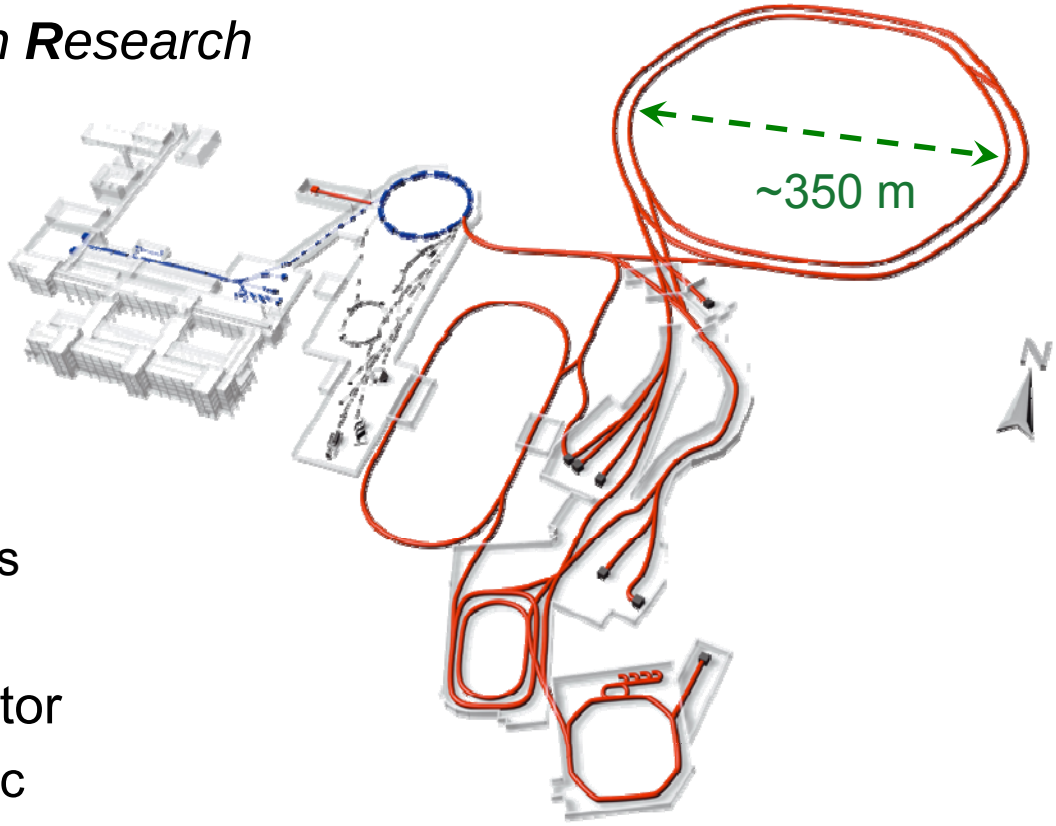
- H .. U
- Linac: Unilac
- Synchrotron: SIS
- Storage ring: ESR
  - Experimental setup
- Control system:
  - Established ~1985
  - Timing system:
    - Main characteristics kept



GSI Extension: FAIR

***F**acility for **A**ntproton and **I**on **R**esearch*

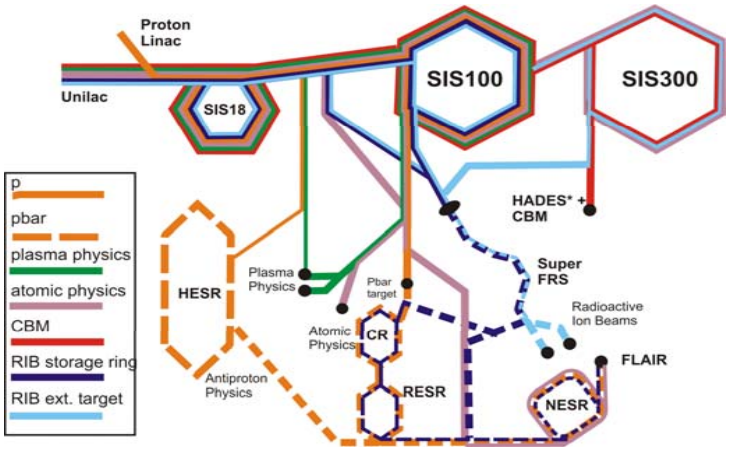
- 2 synchrotrons
- 4 major storage rings
  - plus some small
- Research area:
  - Present day (H .. U)
    - Including rare isotopes
    - Electron-ion interactions
  - Anti-Protons
- Current accelerators: Injector
  - Unilac, SIS, + new p-linac

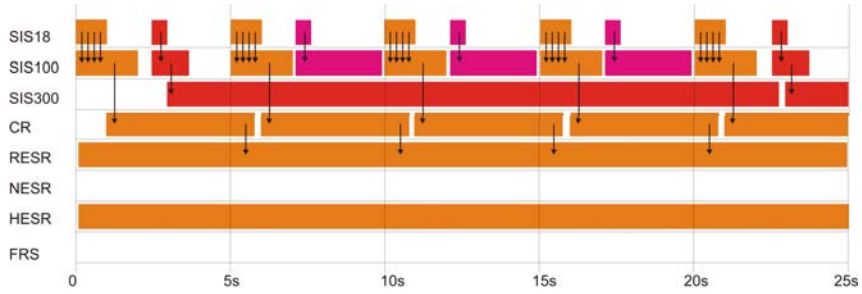


Timing system: Redesign needed

Use also for existing accelerators

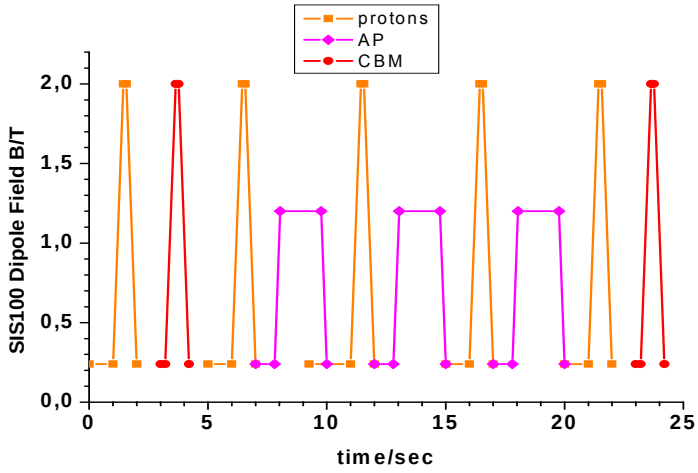
FAIR Operation: Time Multiplexing





Operation Mode #5: pbar in HESR, CBM in SIS300 and high energy Atomic Physics.

- Efficiently use facility
- Parallel operation of different areas
  - Different experimental programs
    - Different beams (ions, energy, ...)
  - Up to 4 experiments in parallel
- Operate areas interleaved
  - Minimize waiting times



Experiment Program at GSI

Block 4 / 2007	Oktober 2007	Schedule as of 01-Aug-2007

Week 40							Week 41							Week 42							Week 43							Week 44		
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
U228, Khuyagbaatar, Ar-40, PIG, 4.5 - 5.0, 2000 pnA, 5ms (UNILAC), Y7					U230, Antalic/Hessberger 40 Ar, 4.6 MeV/u, 2000 pnA, pulse 5.5 ms, Y7			b) U219, Ar, X8			U230, Antalic/ Hessberger, 40 Ar, around 4.6 MeV/u, 2000 pnA, 5.5 ms, Y7			U225, Heßberger, 40Ar (PIG), 4.5 - 5 MeV/u, 2000 pnA, 50 Hz, 5-5.5 ms, Y7							U000, machine experiments					c) U234, 112Sn, X7		d) U234, 116Sn, X7		e) 114 Sn, X7
a)	UBIO, Scholz/Schol z, 12 C, 11.4 MeV, X6		a)			b) U219, Ar, X8		g) U225, Ar, Y7		a)			f)	a)			f)	a)		f)										
											B, Bender C, 1.4MeV, max int., 5ms, 40Hz, UU																				
Therapy, Haberer, 12C (EZR), HTM																					S000, machine experiments									
S296, Lemmon/Aumann, 12C6+, 700 MeV/u, 1e5/spill, HTC							S333, Salabura/Stroth, Traxler, Pietraszko, 12C, 2.0GeV/u, 10E9, 2s extr., fast ramping, nights only, HAD							SiSt, Fehrenbacher, 12C, (EZR), 200 MeV, days only,HTA																	
						h) FRS000, 12C, FRS			S339, Herrmann/Y.Leifels, 12C (EZR), block mode, HTB					SBIO, Scholz, 12C, 100-400 MeV/u, therapy conditions, nights only, HTM																	
														S333, Salabura/Stroth, Traxler, Pietraszko, 12C, 2.0GeV/u, 10E9, 2s extr., fast ramping, nights only, HAD																			

Allocated blocks include the accelerator tuning time
a) B-Experiments, R. Mann, energy measurement for SHIP, 40Ar, copy of Y7, 1Hz, X4
b) U219, Schaedel, 40Ar (PIG), 4.5-5.5 MeV/u, 1 pmicroA (Pulse), 5 ms, X8
c) U234, Jungclaus/Wollersheim, 112Sn (ECR), about 4 MeV/u, 2 pnA, X7
d) U234, Jungclaus/Wollersheim, 116Sn (PIG), about 4 MeV/u, 2 pnA, X7
e) U234, Jungclaus/Wollersheim, 114Sn (ECR), about 4 MeV/u, 2 pnA, X7
f) U182, Kratz, J.V./Schaedel, 40Ar (PIG), 7-9 MeV/u, 1 pmicroA (Pulse), 5 ms, 5 Hz, X1and X8
g) U225, Heßberger, 40Ar (PIG), 4.5 - 5 MeV/u, 2000 pnA, 50 Hz, 5-5.5 ms, Y7
h) FRS000, Winkler, 12C6+, 300-800, variable , 1e8/spill, 3 sec spill , single shots (100 ns), FRS

Andreas Tauschwitz, Phone +49-6159-712723, E-mail beamtime@gsi.de

Wednesday, 17 October, 2007 13:25

- Experiments at GSI: Short, days to week
- Frequent beam set-up while other experiments continue

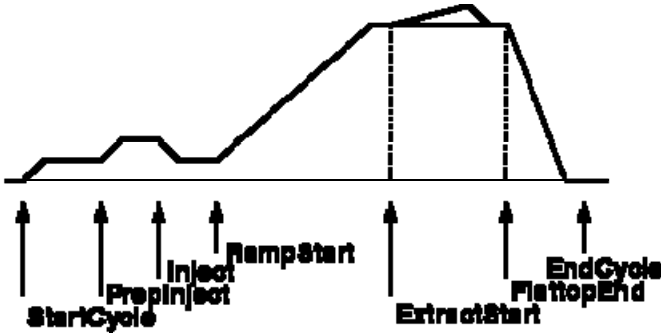
Provide Flexibility

- Frequent changes in beam pattern, beam settings
- Cycles not fully fixed
  - Storage rings *are the experiments*
    - Interactive beam manipulation, by experimentalists
      - Acceleration, deceleration, position shifting, cooling, ...
      - At least during set-up of experiment
  - Malfunctions: Interlocks
    - Alternative cycle continuation
- Broad time span:
  - Storage rings 'Cycle': minutes .. days
  - Synchrotrons (SIS18, SIS100) Cycle: ~1 s
  - Linacs (Unilac, p-linac) Cycle: 20 ms
    - Beam pulse 10 µs .. 5 ms

Timing: Equipment Synchronization

Event based

- Timing-event precision: ~50 ns
  - Simultaneous all over facility
  - Compensate propagation time
- Timing-event raster: 1 µs (as presently)
  - Event-separation: ≤ 10 µs (1 µs?)
- Cycle: Constructed from basic building blocks
  - Each triggered by *specific* timing-events
  - Many different events defined: ~100 (≥ 256)
- Provide local delays to adjust equipment



Timing Events

High precision timing?

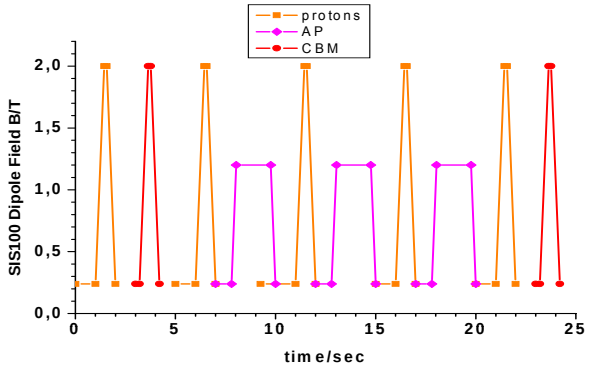
- **Bu**nch **Ti**ming **S**ystem BuTiS, dedicated system by RF group
  - High precision (sub-ns) clock pulses: 200 MHz + 100 kHz
  - Machine timing: Phase coupled to BuTiS

Timing: Accelerator Context

- Beam to handle next
  - And the one after next

  Number: 0..255
- Label each cycle
  - Label cycle subsection

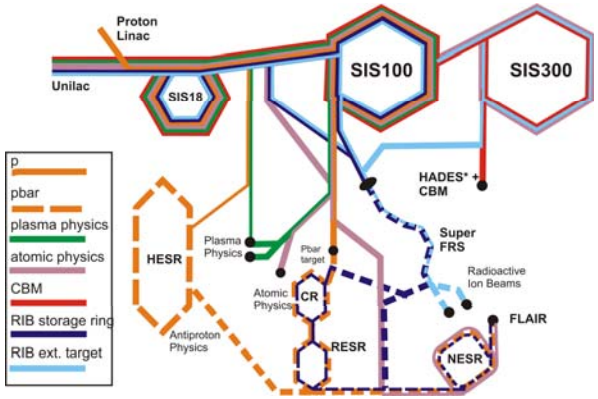
  Numbering of cycles / cycle sections
- Beam parameter
  - E.g. high, low intensity
    - Operate equipment adequately
- Time of day
- General interest data
  - Source, destination, ion type, ...

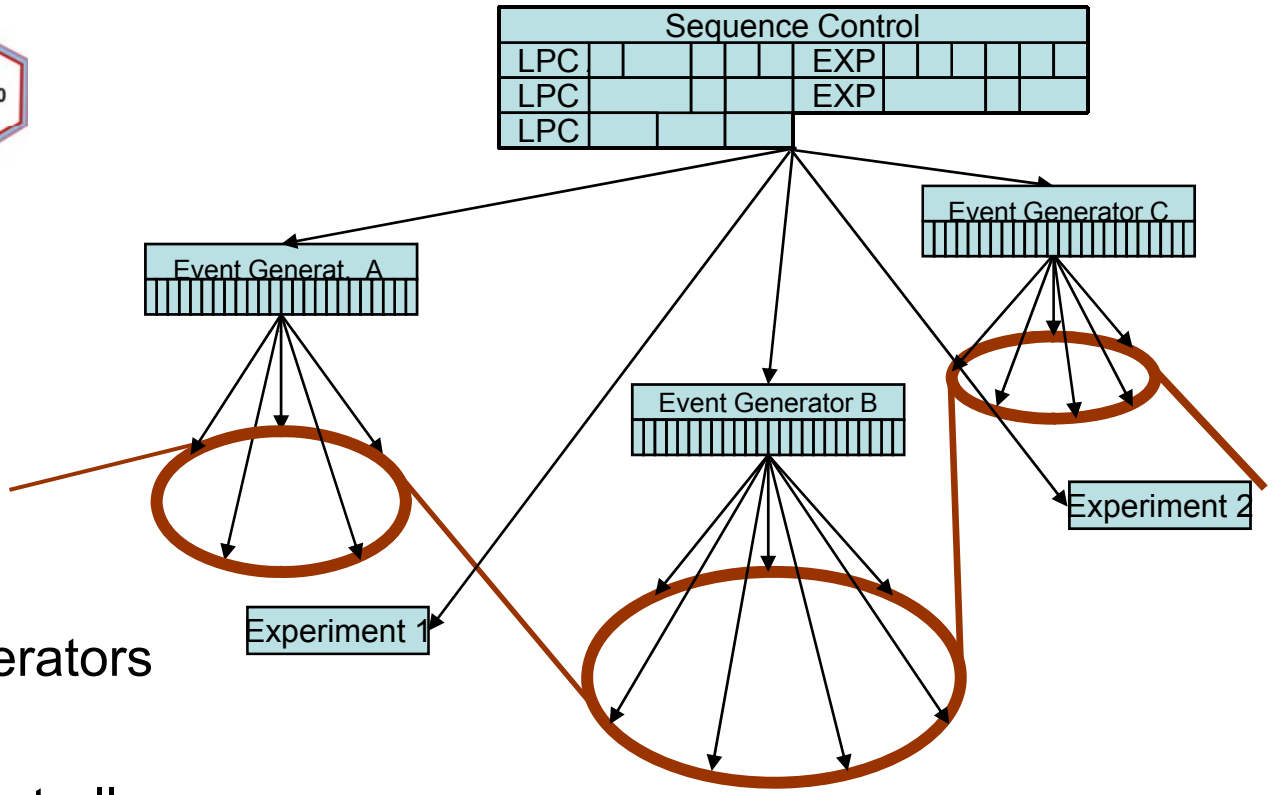


Needed for:

- Beam multiplexing
  - Which cycle to execute
- Labeling activities in facility
  - Read-back data
  - Interlocks
  - ...
- . . .

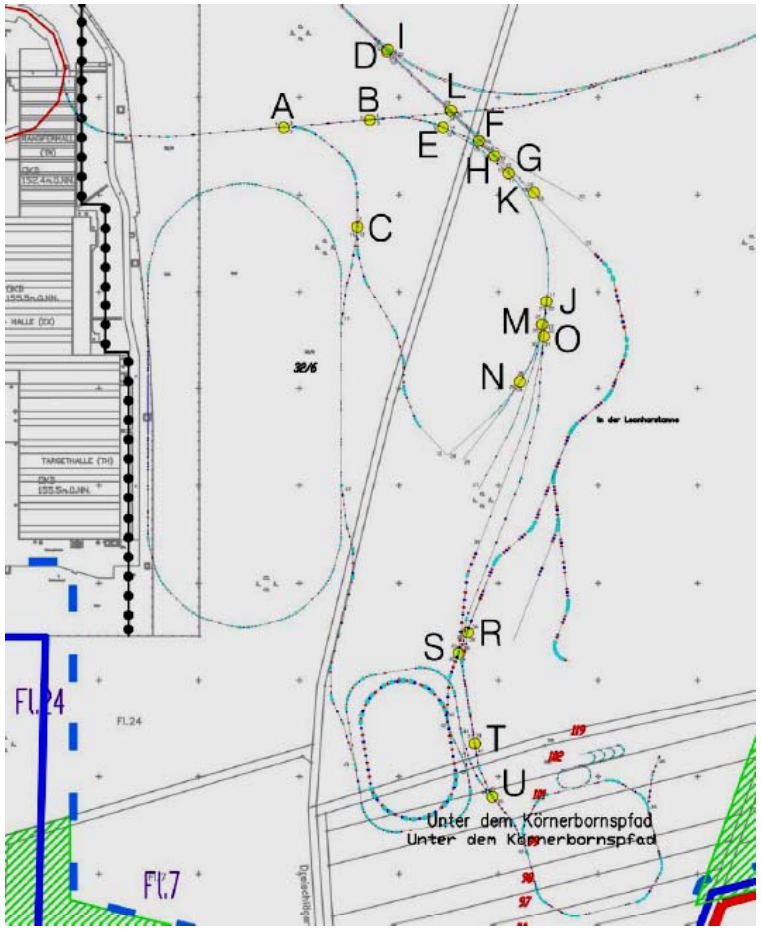
Timing System Outline

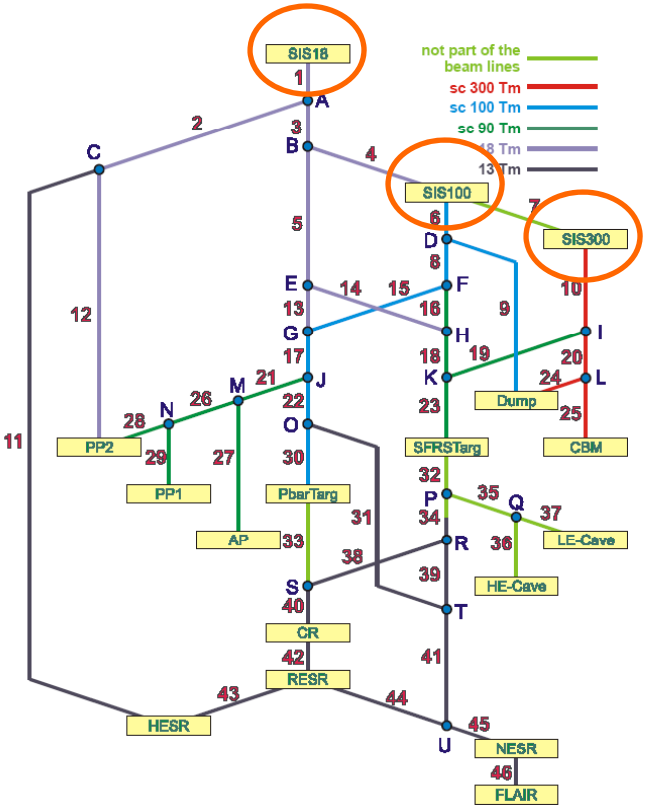


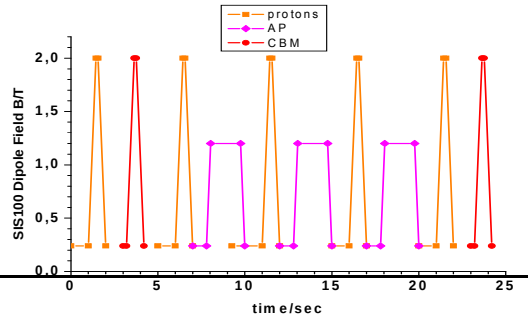


- Dedicated event generators
  - One per ring
- Master: Sequence controller
  - Coordination of cycles
  - Trigger cycles in event geneators

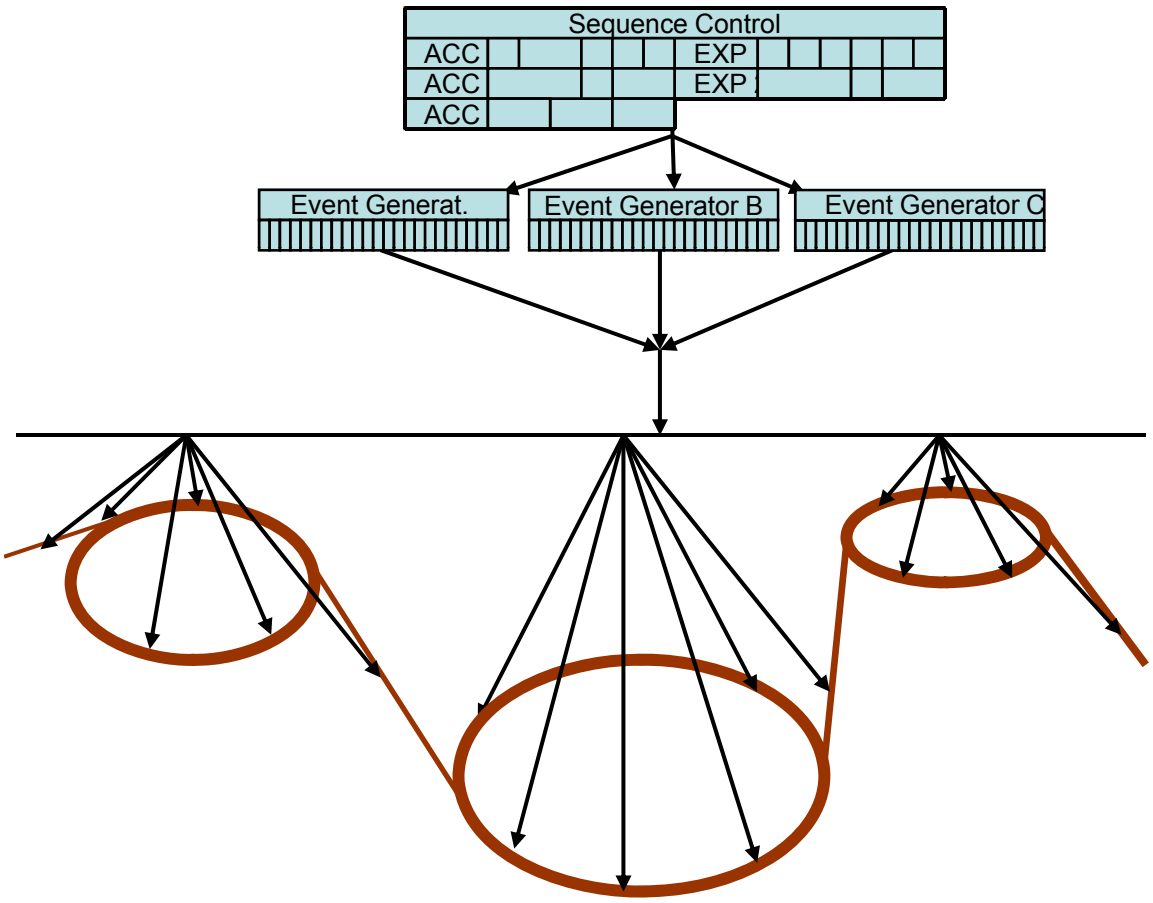
Beam Transfer: Switchyard







Common Timing Distribution



All event generators:

Same distribution line

Each timing receiver:

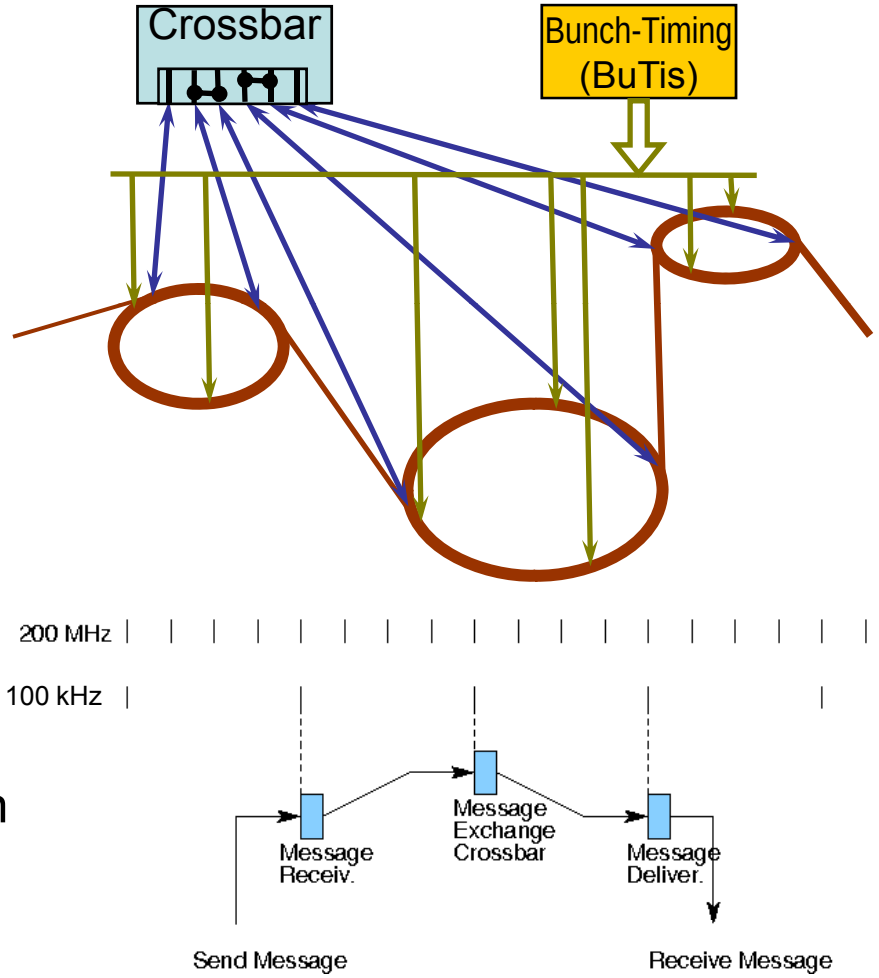
Access to all timing areas

Serial transmission:

- Timing events
  - Fixed time slots
    - One per event generator
  - One slot for time-of-day
- Other timing data
  - Short delays tolerabel
  - first come, first served

Synchron. Message Exchange: SMX

- Exchange of short telegrams
  - 128 .. 256 Bit
- Central crossbar
  - Dynamic connections
  - Cycle to cycle
- Fixed transmission time
  - 20 µs, independent from location
  - Related to BuTiS
    - High precision base clock
- Purpose:
  - Exchange of real-time information
    - Beam transfer: Bunch phase



Timing Distribution

Timing-Network

- High bandwidth
  - One line: ~10 Event generators
- GBit Ethernet?
  - Close to 1000 Bit / µs
  - Physical layer only
    - Fibre, cable
  - Back channel available
    - Interlock-signals?
    - Propagation time compensation?

Synchr. message exchange

- Same technology as timing network

Timing-Receivers

- More than 2000 receivers
  - Many devices:
    - Integrated front-end controller
      - ~1500 Power converters
    - Each requires its own receiver
- Support multiple platforms
  - VME, PCI, ...
  - Mezzanine
  - Specific: VHDL macro

Main Characteristics

Timing information

- Timing events
  - Timing precision 50 ns
    - Simultaneous in facility (1km)
  - Timing raster 1 µs
  - Event separation ≤ 10 µs
  - ~100 Events defined
- Accelerator context information
  - Beam number
  - Cycle / cycle section number
  - Beam parameters
  - Time of day
  - Beam related data

Timing components

- Event generators
  - Each ring: Separate event generator
    - Needed: 7, plus Linacs
  - Phase coupled to BuTiS clock
  - Coordination: Sequence controller
- Timing network
  - Common distribution lines
  - GBit bandwidth
    - Ethernet components?
- Synchr. message exchange
  - Same network technology as timing system