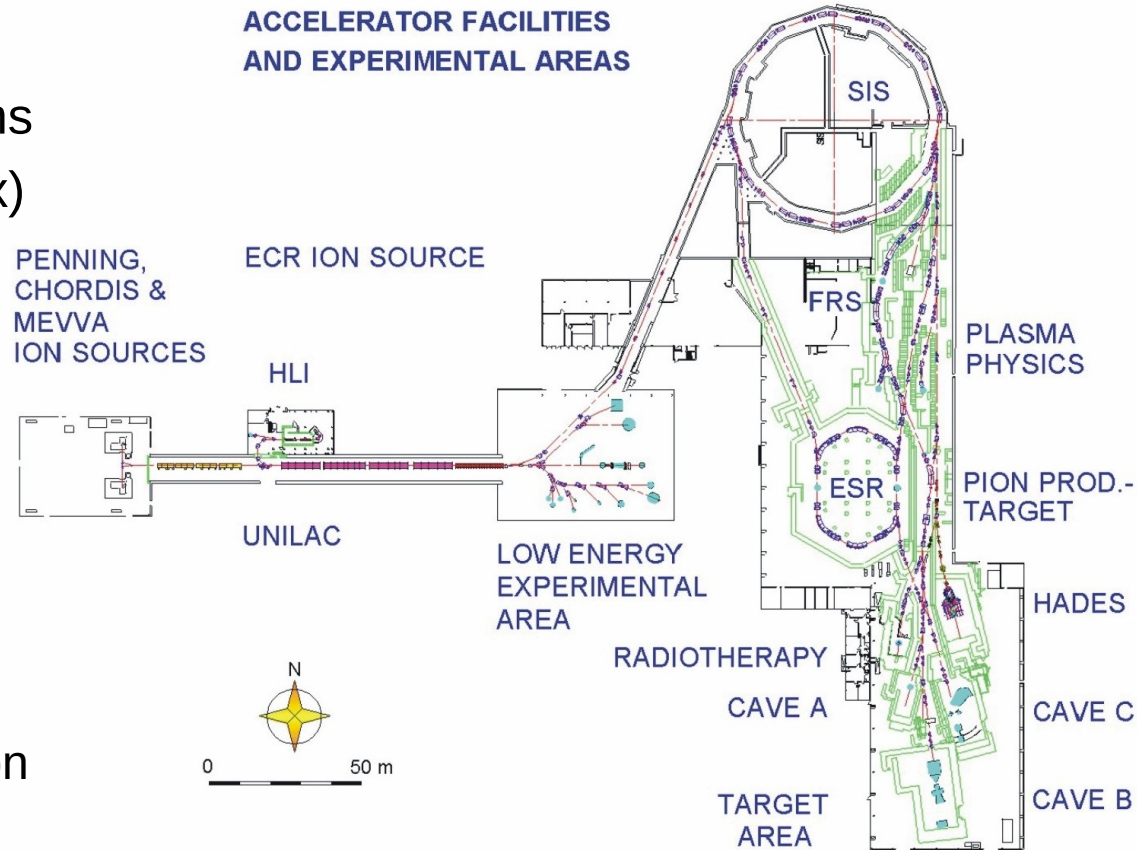


Timing System GSI

U. Krause
19. Jan. 2009

GSI: Present Day Facility

- Elements: H .. U
- Linac: Unilac
 - Beam-Puls: $\sim 100 \mu\text{s}$.. 5ms
 - Repetition time: 20 ms (fix)
- Synchrotron: SIS
 - Cycle length ~ 1 .. ~ 15 s
- Storage ring: ESR
 - Experimental setup
 - In-beam experiments
 - Fixed-target beams too
 - Bunch modification, acceleration, deceleration



Accelerator Operation

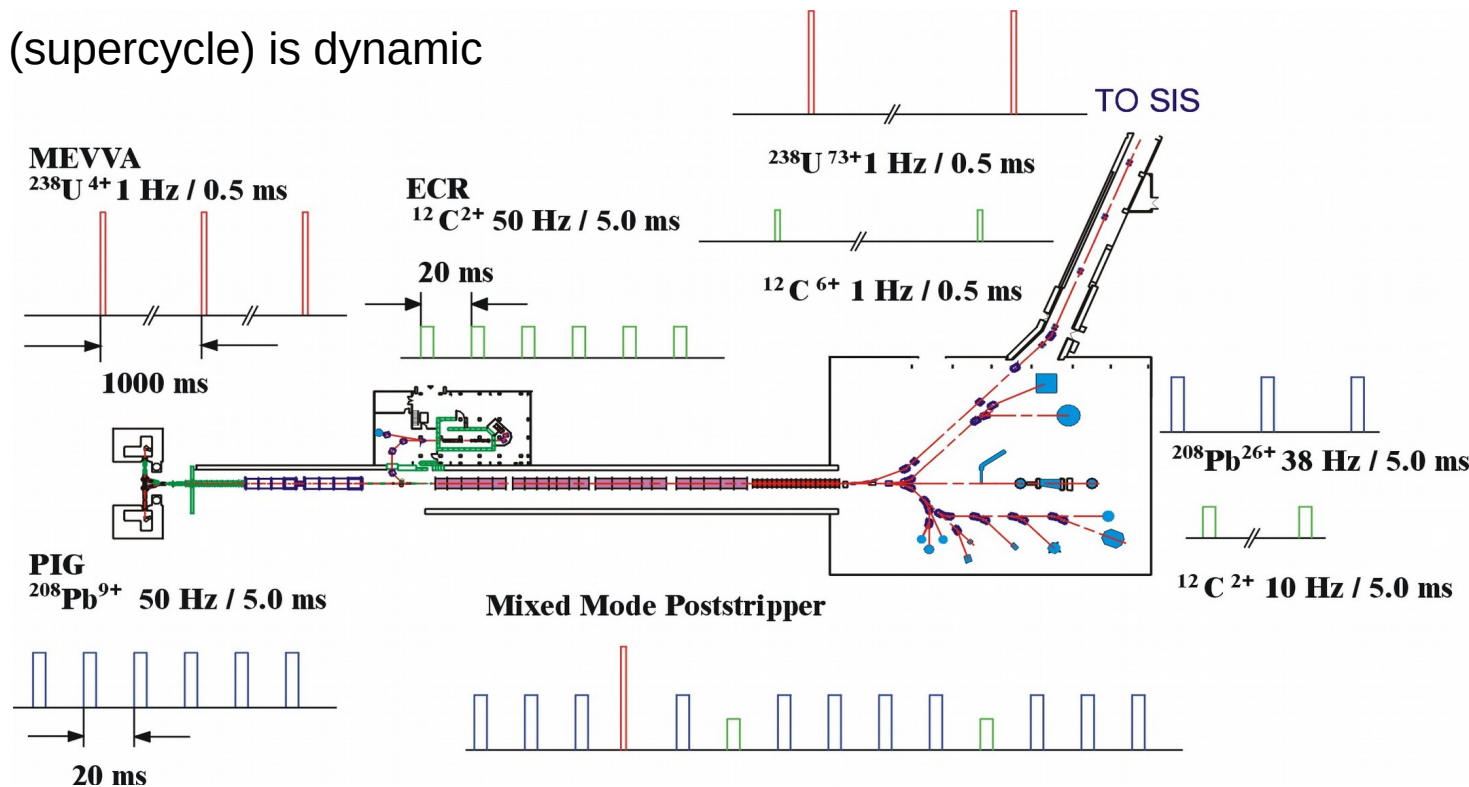
Unilac / SIS: Puls switching

ESR: Setup for one beam only

~ 5 experiments in parallel

Beams flexibly interleaved

Cycle sequence (supercycle) is dynamic



Experiment Program at GSI

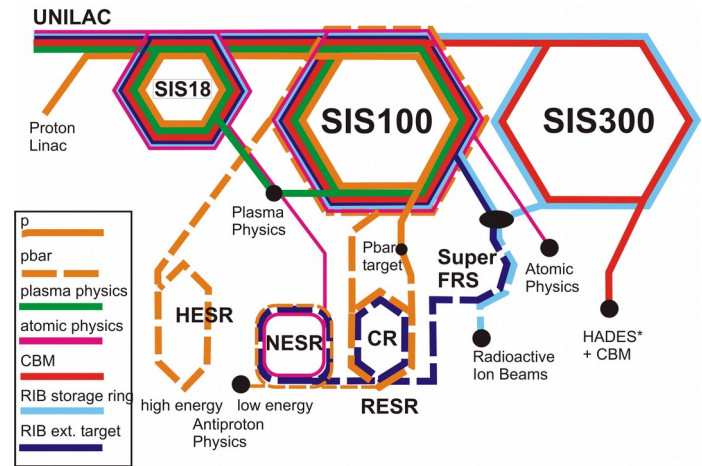
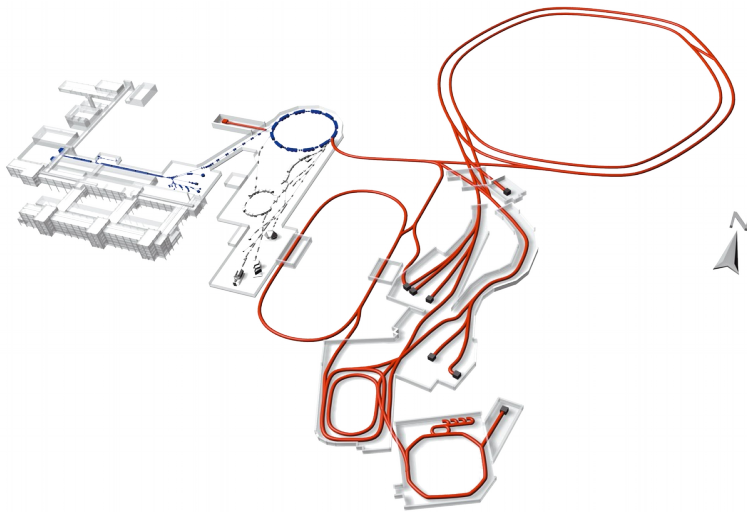
- Experiments at GSI: Short, days to weeks
- Frequent beam set-up while other experiments continue

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 pA, 5ms (UNILAC), Y7					U230, Antalic/Hessberger 40 Ar, 4.6 MeV/u, 2000 pA, pulse 5.5 ms, Y7						b) U219, Ar, X8			U230, Antalic/Hessberger, 40 Ar, around 4.6 MeV/u, 2000 pA, 5.5 ms, Y7					U225, Heßberger, 40Ar (PIG), 4.5 - 5 MeV/u, 2000 pA, 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/Scholz, 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, Hermann/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																						

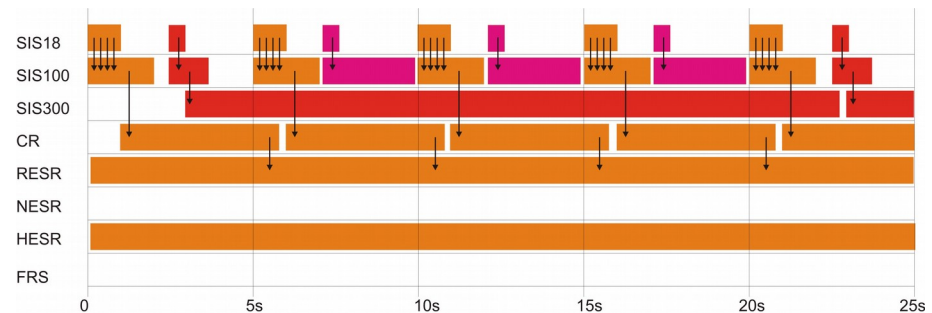
Allocated blocks include the accelerator tuning time
a) B-Experiments, R. Mann, energy measurement for SHIP, 40Ar, copy of Y7, 1Hz, X4
b) U219, Schaedel, 40Ar (PIG), 4.5-5.5 MeV/u, 1 pA (Pulse), 5 ms, X8
c) U234, Jungclaus/Wollersheim, 112Sn (ECR), about 4 MeV/u, 2 pA, X7
d) U234, Jungclaus/Wollersheim, 116Sn (PIG), about 4 MeV/u, 2 pA, X7
e) U234, Jungclaus/Wollersheim, 114Sn (ECR), about 4 MeV/u, 2 pA, X7
f) U182, Kratz, J.V./Schaedel, 40Ar (PIG), 7-9 MeV/u, 1 pA (Pulse), 5 ms, 5 Hz, X1 and X8
g) U225, Heßberger, 40Ar (PIG), 4.5 - 5 MeV/u, 2000 pA, 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

Present Day GSI -> FAIR



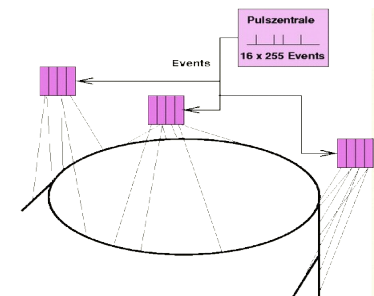
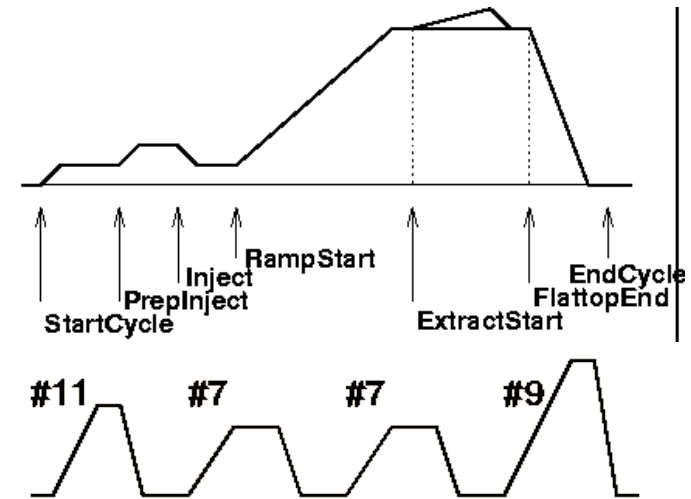
- Extended facility
 - More rings, larger area
- Several experiments in parallel
 - Different beams interleaved
 - Frequent changes in beam pattern
 - Not as frequently as today
 - However: Still often...



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

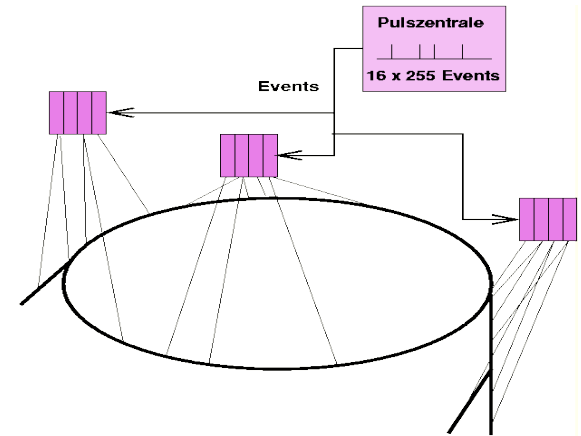
General Timing System: Tasks

- timing-events
 - cycle synchronization
 - e.g. start magnet ramp / RF ramp
 - identifier for beam (virtual accel.)
 - pulse to pulse beam switching
 - cycle ident
 - cycle number / time
 - online cycle status
 - cycle intentionally empty (no beam), high intensity, ...
 - time of day
- distribution: timing generators
one per accelerator



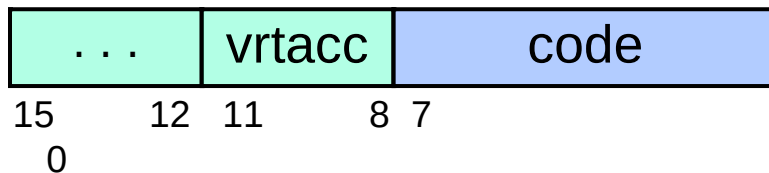
GSI Timing Network

- 16-Bit Messages
 - Timing-Events ("event")
- Network: MIL STD 1553B
 - 1 MHz, $\sim 20\mu\text{s}$ per timing event
 - Star-topology
 - Propagation time adjustment foreseen
 - but not implemented, facility is small
- Different timing areas
 - Unilac, SIS, ESR
 - Separate networks
 - Independent timing generators
 - Synchronized for (during) beam exchange



Outline of Timing-Message

- 16 bit messages
- Event code
 - Bit 0 .. 7
 - Activity (what to do)
- Event data
 - Bit 8 .. 15
 - Parameter (how to do)



- Code:
 - Actions (in cycle)
 - 32: Start_Cycle
 - 43: Ramp_Start
 - 44: Prep_Injection
 - ...
- Data:
 - Bit 12 .. 15:
 - Originally not used
 - Bit 8 .. 11:
 - Virtual accelerator
 - Which beam is affected

Virtual Accelerator

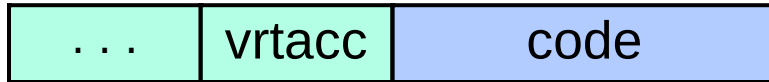
- Different beams in machine
 - Max. at a time: 16
 - Labeled by a number (0..15)
 - “Virtual accelerator”-number
- Assignment of number:
 - Dynamically, on set-up of beam
 - Any virtual accelerator number may identify any beam
 - Table on operation level:
 - Virt.acc. 7 *now* is a Ne beam with 0.9 GeV/u to Experiment Cave B
 - Virt.acc. 8 *now* is a U beam with 0.5 GeV/u to ESR
 - ...
 - Hold (and logged) in database
- Virtual accelerator is local for machine
 - Unilac virt. acc. 9 may serve SIS virt. acc. 7 and 11



Virtual Accelerator II

- Some numbers fixed, however:
 - Rigidly, Unilac virt. acc. 15: “Empty cycle”, inserted automatically
 - By habit, SIS virt. acc. 14: “Beam to ESR”
 - Virtual accelerator describes a full cycle
 - Injection to extraction (including clean-up for next cycle)
 - Virtual accelerators are independent from each other
 - Can be executed in any sequence
 - To certain level, remanences *cause* small interactions
 - But: ESR:
 - Virtual accelerator means a cycle-phase
 - Injection, acceleration, storage for measurements, ...
 - Virtual accelerator has to start where predecessor had ended
- Future: Introduce explicit cycle phases
Use virtual accelerators for different beams only

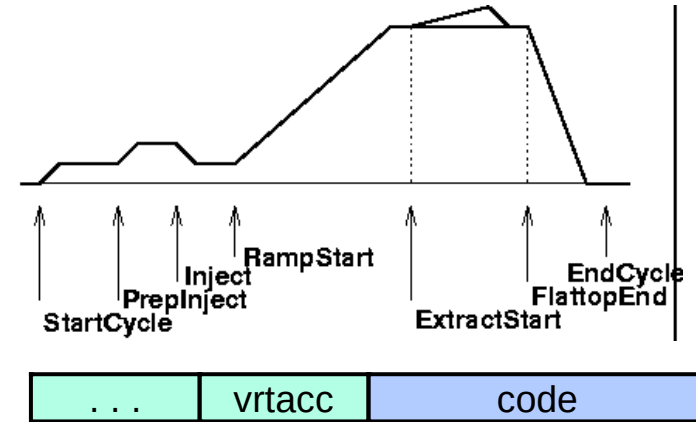
Virtual Accelerator: Announce



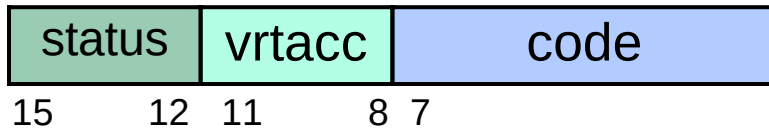
- Every event-message contains virtual accelerator
 - Event message directly indicates which data-set to be used
- Event message for next cycle *could* be sent in running cycle
 - Not done, events are always sent in running cycles
 - Eases modifying cycle sequence
 - Next cycle determined after end of cycle
- No forewarning implemented
- Therapy operation:
 - Parametrization of virtual accelerator
 - Announce next beam *once* before cycle
 - Allows for broad range of beams (255 energy x 15 intensity x 7 focus)

Timing-Event: Receiver

- Trigger action on front-end controller
 - Provide event-message
 - Front-end controller analyses content
- Provide HW trigger-signals
 - Filter for event-code, virt. acc., ...
- *No delay-units* in timing-receiver
 - Delayed reaction used no so often
 - Instead timing-event is shifted
 - Timing-event granularity: 1 μs
Follow up: 30 μs (20 μs)
 - Delayed reaction is in responsibility of user of timing-triggers
 - Flexible delay units provided as separate device
 - RPG ("Rahmen-Puls Generator")
set up via control system



Timing-Message: Beam Status

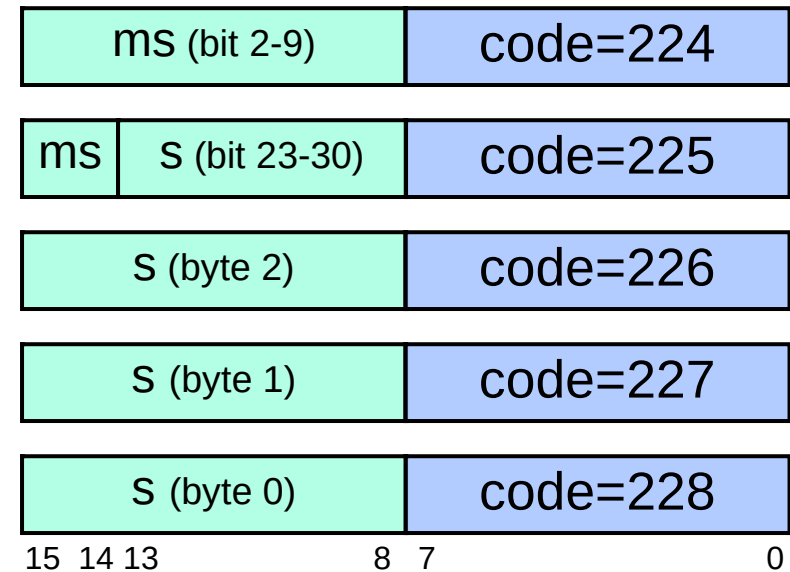


Bit⁰ 12 .. 15: Online-information of current beam

- Bit 15: High-current
Beam loading => correct in RF generators
- Bit 14: No-beam
Cycle without beam => disable beam diagnostics
(cycle as usual, but beam disabled)
- Bit 13: Rigid-beam
Low charge state => set power supplies for high magnet current
(give maximum switch time, avoid overheating)
- Bit 12: - - -
not yet used

Timing-Message: Time-of-Day

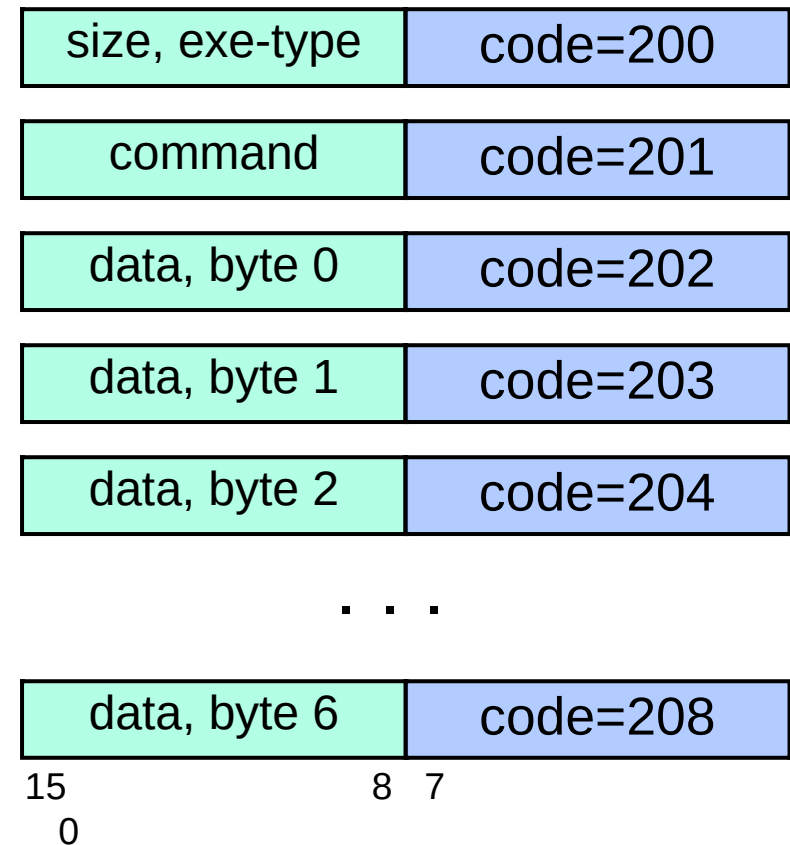
- Time-of-Day:
 - Seconds since 1. Jan. 2008
 - Current milli-seconds
 - 5 Byte total
 - 30 bit s, 10 bit ms
- Data in sequence of messages
- Once per cycle
 - Unilac: After start
 - SIS/ESR: Before start
- Usage
 - Clock synchronization
 - Front-end controller
 - Cycle ident
 - Stamps of equipment data etc
 - Cycle start time



Timing-Message: Commands

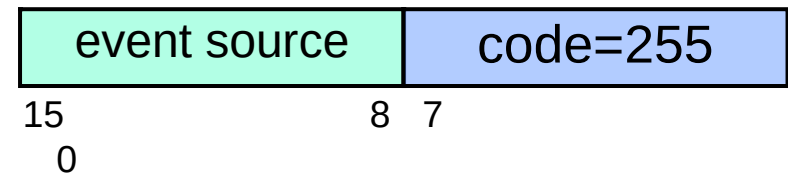
- Extended actions: Command
 - with 0 .. 7 byte of data
- 255 command codes possible
- Execution-type:
 - Immediate
 - Queued
- Send a sequence
 - Variable length

- Usage:
 - Command-broadcast to all front-ends
 - Introduced for medical operation



Timing-Message: Event-Generator ID

- Command-Event
 - Non real-time activities now possible
 - GSI front-end: Execute "user action"
- Bit 8 .. 15: Code of event generator
- Event generators:
 - SIS
 - 7 timing sub-areas
 - ESR
 - Unilac
 - 7 timing sub-areas
 - Local event generator
 - For test purpose
 - Event receiver
 - Generates command events automatically
 - To keep front-end controller alive

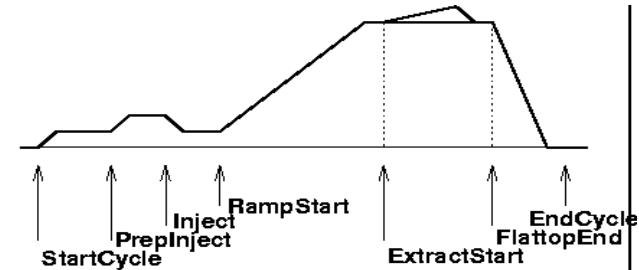


GSI Timing-Messages: Extensibility

- Started with simple outline
 - Event code + virtual accelerator number
- Extended in various directions
 - Timing system now covers all (most?) basic needs
- Event-messages model for future?
 - Present implementation clumsy
 - All had to be squeezed into 16-bit messages
 - Analyse kind of provided information
 - Surely all will be requested in future too
 - Probably even more
- Take care of, and keep, solid and clean structure
 - Then extensions in various ways will be possible
 - Also where nobody now even thinks of

Event Generator SIS/ESR: Cycle

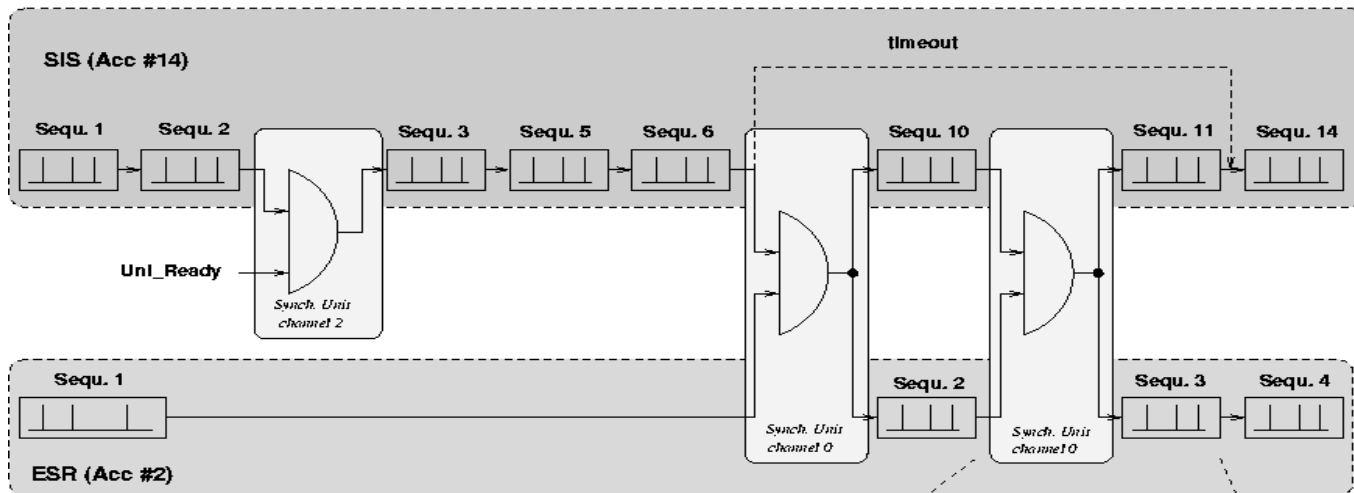
- Timing-events arranged in event channels
 - Event message
 - Time relative to channel start
- Cycle: Sequence of channels
 - 1 – 2 – 3 – 2 – 3 – 2 – 3 – 6 – 7 – 9 – 8
 - Channel-start:
 - Sequenced, start at end of previous channel
 - Triggered, start by externally HW input
- Event channels are loaded from operating level
 - Part of accelerator set data
 - Channel content
 - as well as channel sequence
- Separate sets of event channels for each virt. acc.



event	Time [μ s]		
32	1		
75	70		
70	140	[μ s]	
...	...	25	
0	136175	0000	e [μ s]
	0	70030	1
	0	0	8145
	0	0	4645
	107		9845
	0		31945

SIS/ESR, Event Channels

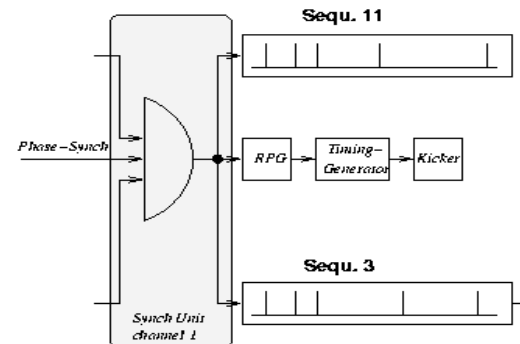
Channelsynchronisation SIS/ESR (H=1 Extraktion)



channels in Synchronisation Unit:

- channel 0: Trans_Start_1/2 (61/62)
Async_Trans (79)
- channel 1: Kick_Start_1/2 (49/69)
- channel 2: Uni_Ready (38)

Extraktion with RF-Synchronisation



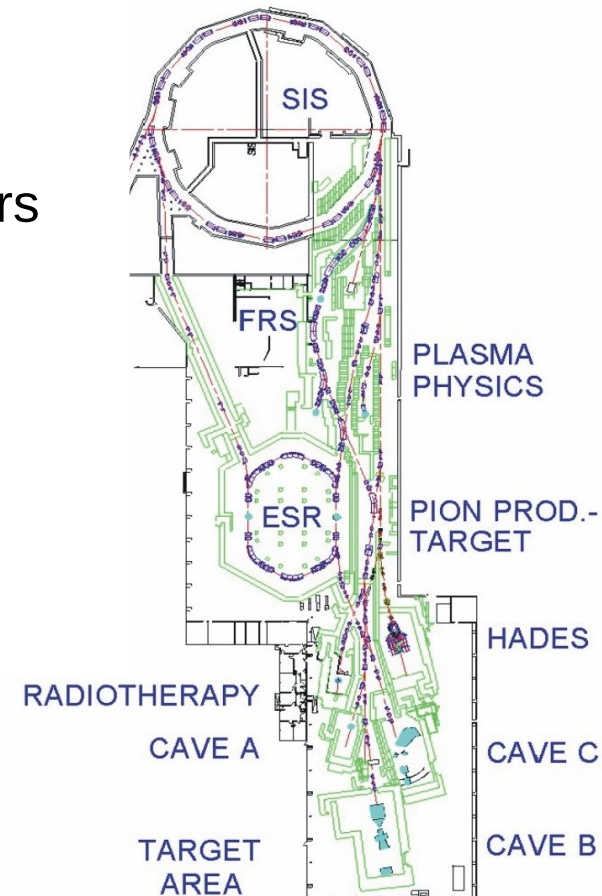
Supercycle SIS (and ESR)



Supercycle:

$$11 - 2 \times 7 - 9$$

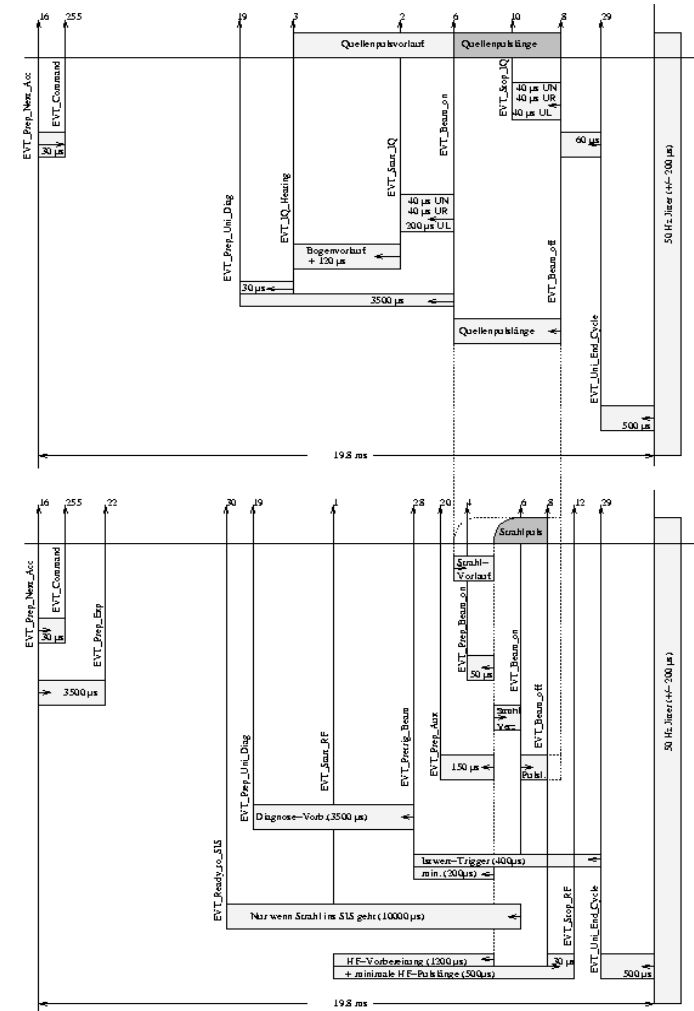
- Operators: Set up sequence of virtual accelerators
 - Number has to be assigned
 - Beam has to be defined before
 - Beam path geometry is set up automatically
- Sequence is executed as was set-up
 - Execution of virtual accelerator is skipped:
 - When beam-path to experiment not OK
 - Input from interlock-system
 - Execution is not requested from experiment
 - Execution has to be requested via request line
- Asynchronously inserted cycles are possible
 - Usage: Beam request from ESR



Event Generator, Unilac

Higher level of automatism

- Fixed 20 ms cycle length
 - 50 Hz pulse repetition
- Execution rates for virtual accelerators
 - No explicit sequences
 - Automatic best approach
 - At least "empty-cycle"
 - Virt. acc. 15
- Beamdiagnostics inserted:
 - Pulse rate reduced
 - Length of beampulse reduced
- Beam-puls length, position
 - No explicit event tables
 - Event sequence is fixed
 - Event positions calculated automatically



Event Generator: Interlocks

Close interaction of timing system with interlock system

Unilac: One big combined unit

Sub-modules: event sequencer, cycle coordinator, interlock, ...

- Failure in one location?
 - At least one device in interlock-state?
 - No beam through this location
 - SIS: Skip cycle
 - Unilac: Execute cycle, but block beam
No-Beam flag is set
- Beams not affected will continue
 - SIS: More often, disturbed virt. acc. will not take time