HELMHOLTZ GEMEINSCHAFT

Die SD-Geräte bei FAIR HEBT

auf einem sicheren Weg zu den Experimenten

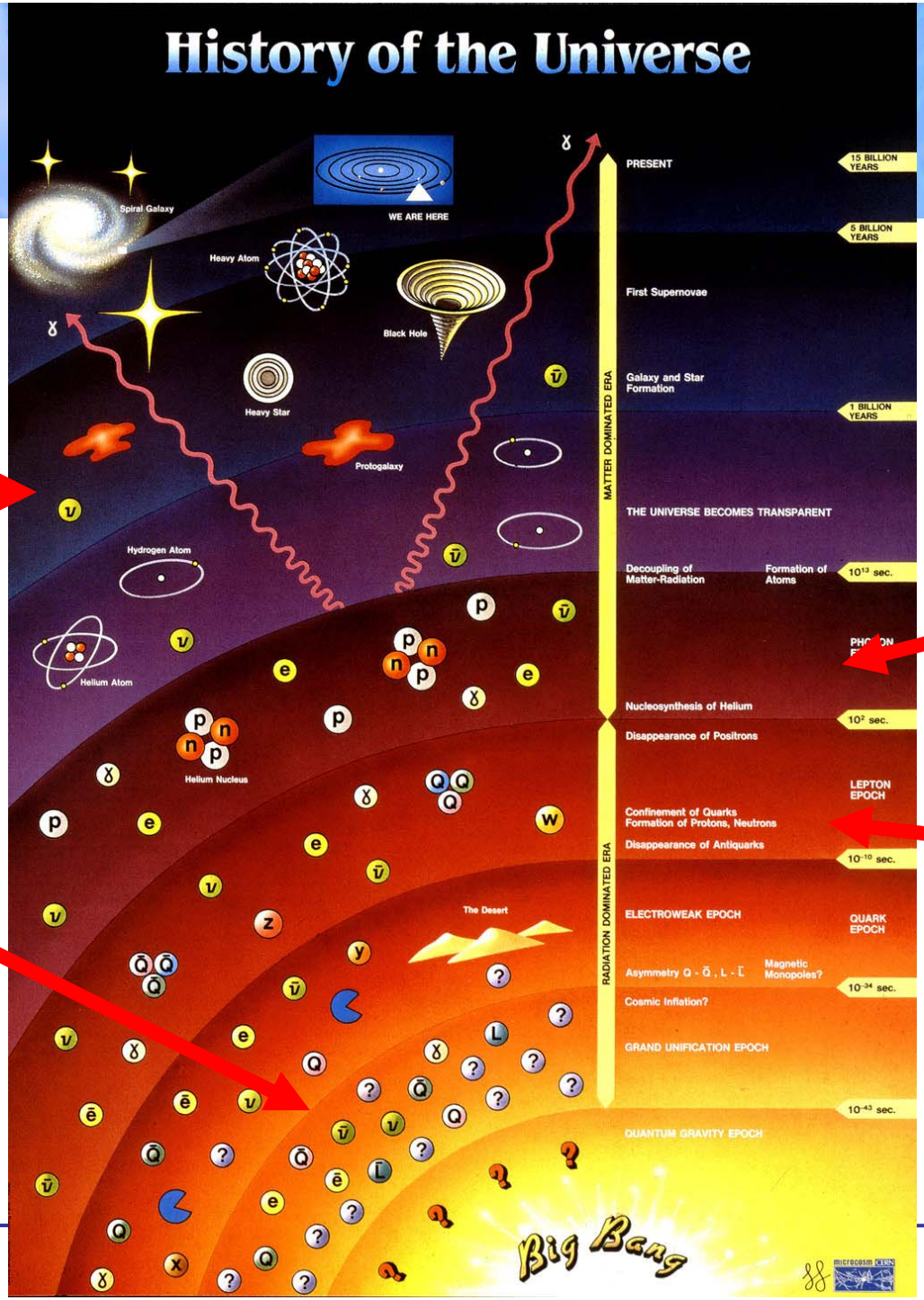
Georg Schepers
GSI - SD/HAD1
SD Abteiliungsseminar
27.04.2009

GSI

FAIR
Wofür?

NUSTAR
„Element-synthese“

PANDA
„CP“
„CPT“
FLAIR



PHELIX
„Nucleo-synthese“

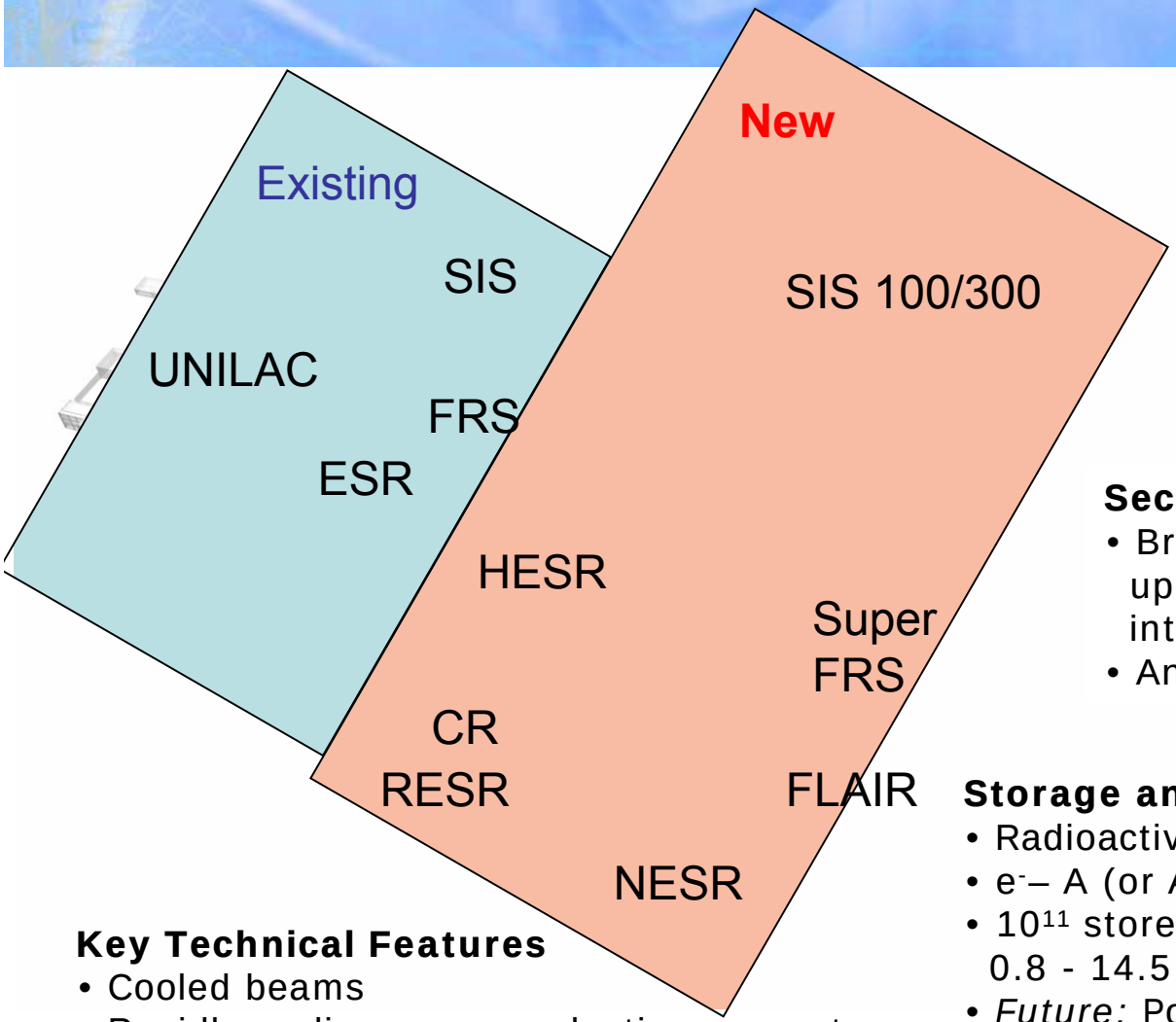
CBM
„QGP“

$E = m c^2$

Überblick

- **FAIR HEBT**
  - der Weg für Schleicher und Raser
- **Diagnosekomponenten**
  - offene Augen
- **Strahldiagnose @ HEBT**
  - das Projekt

FAIR



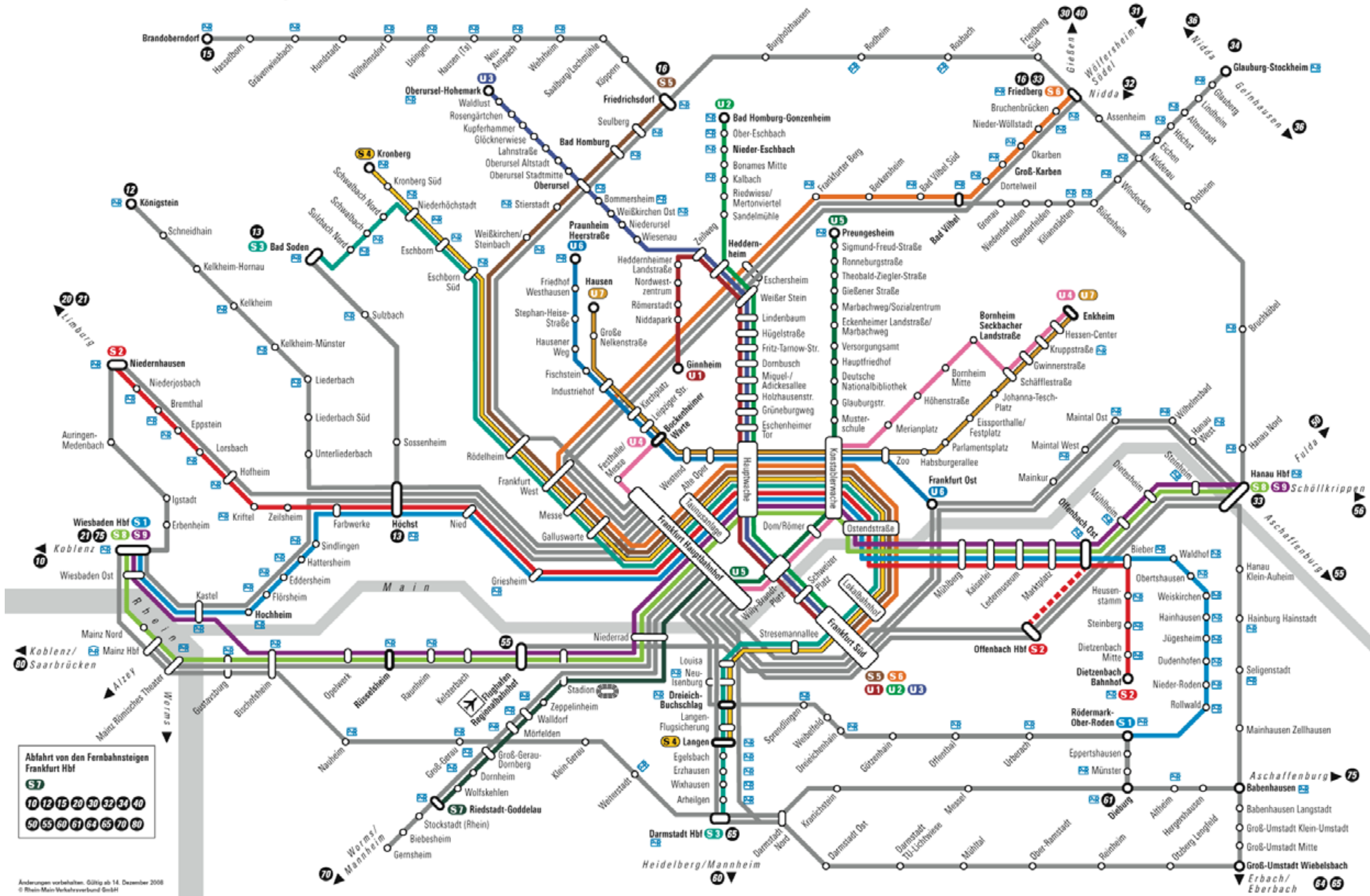
Primary Beams
- **$^{238}U^{28+}$** : 10^{12}/s @ 1.5-2 AGeV;
- **$^{238}U^{92+}$**: 10^{10}/s @ up to 35 AGeV
- **Protons** : 2 x10^{13}/s @ 30 GeV; up to 90 GeV
- 100-1000 times present intensity

Secondary Beams
- Broad range of radioactive beams up to 1.5 - 2 AGeV intensity up to 10 000x over present
- Antiprotons 0 - 15 GeV

Storage and Cooler Rings
- Radioactive beams
- e^-– A (or Antiproton-A) collider
- 10^{11} stored and cooled antiprotons 0.8 - 14.5 GeV/c
- *Future:* Polarized antiprotons (?)

Key Technical Features
- Cooled beams
- Rapidly cycling superconducting magnets
- Parallel Operation

„Linienplan“



Brandoberndorf
Königstein
Bad Soden
Kronberg
Oberursel-Hohemark
Friedrichsdorf
Bad Homburg
Bad Homburg-Gonzenheim
Ober-Eschbach
Nieder-Eschbach
Friedberg
Glauburg-Stockheim
Preungesheim
Praunheim Heerstraße
Hausen
Heddernheim
Ginnheim
Enkheim
Niedernhausen
Wiesbaden Hbf
Wiesbaden Ost
Mainz Nord
Mainz Hbf
Höchst
Hochheim
Frankfurt Hauptbahnhof
Hauptwache
Konstablerwache
Frankfurt Ost
Frankfurt Süd
Offenbach Ost
Offenbach Hbf
Hanau Hbf
Rödermark-Ober-Roden
Dietzenbach Bahnhof
Dieburg
Babenhausen
Groß-Umstadt Wiebelsbach
Darmstadt Hbf
Langen
Dreieich-Buchschlag
Riedstadt-Goddelau
Flughafen Regionalbahnhof
Rüsselsheim
Main
Rhein
Abfahrt von den Fernbahnsteigen Frankfurt Hbf
Änderungen vorbehalten. Gültig ab 14. Dezember 2008
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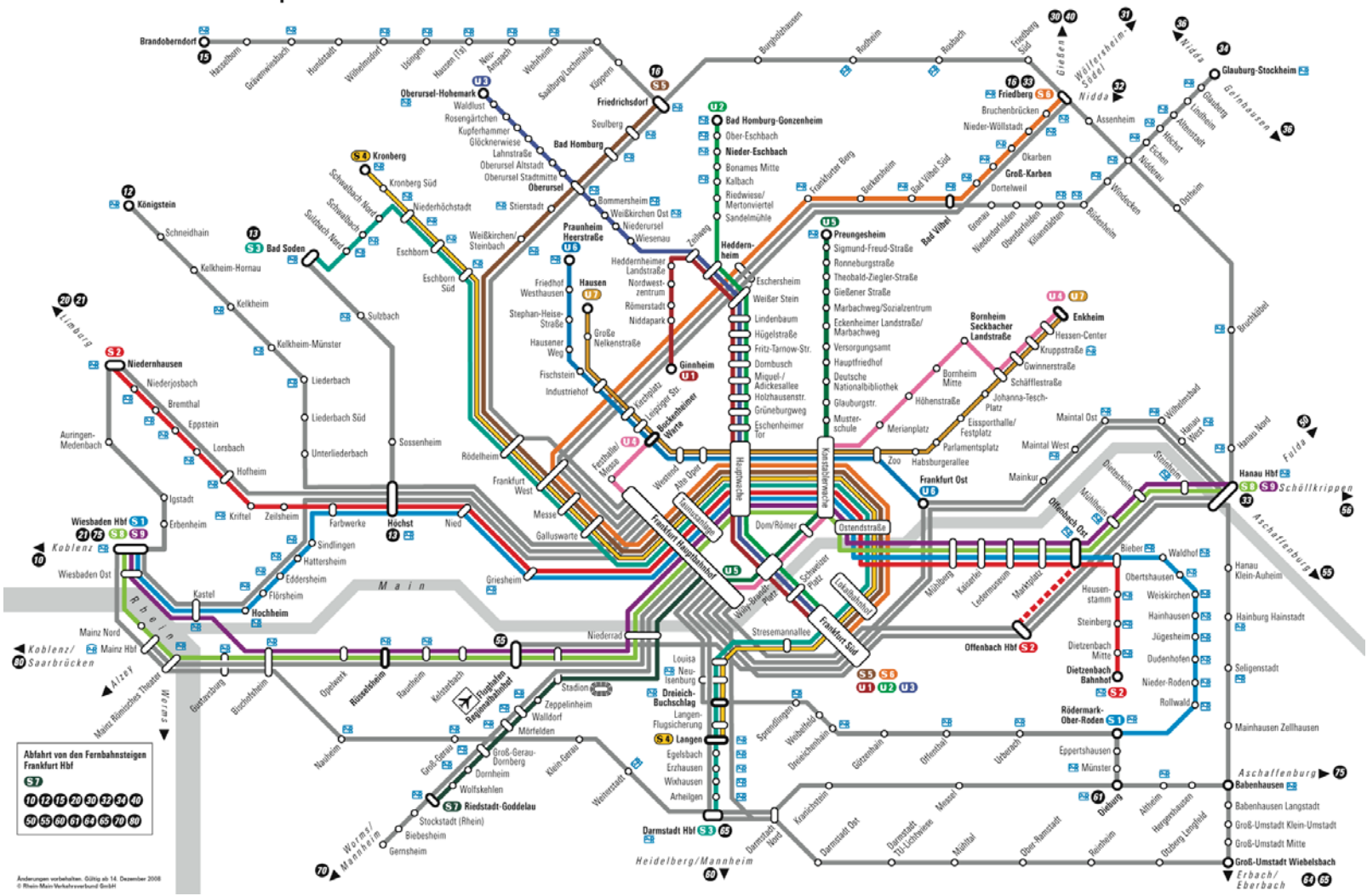
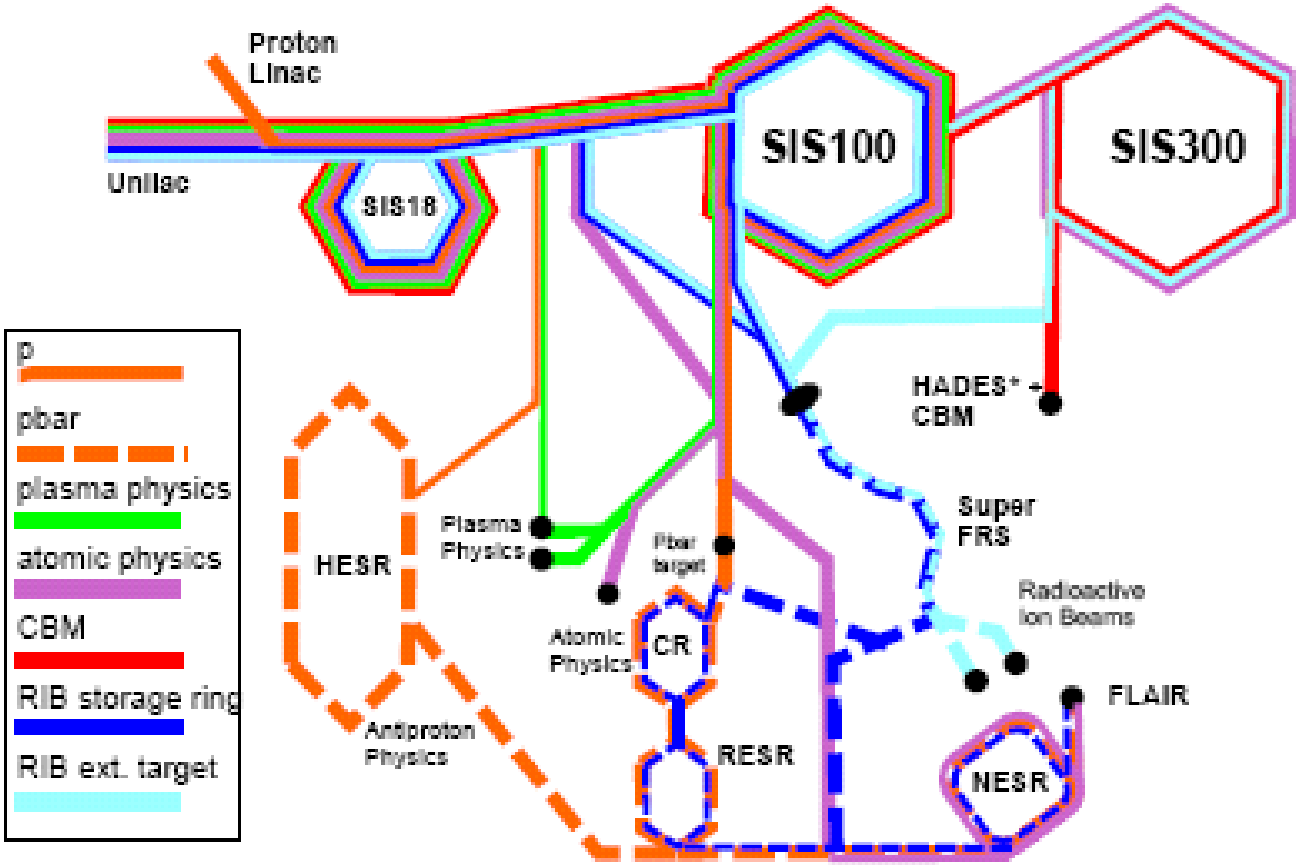
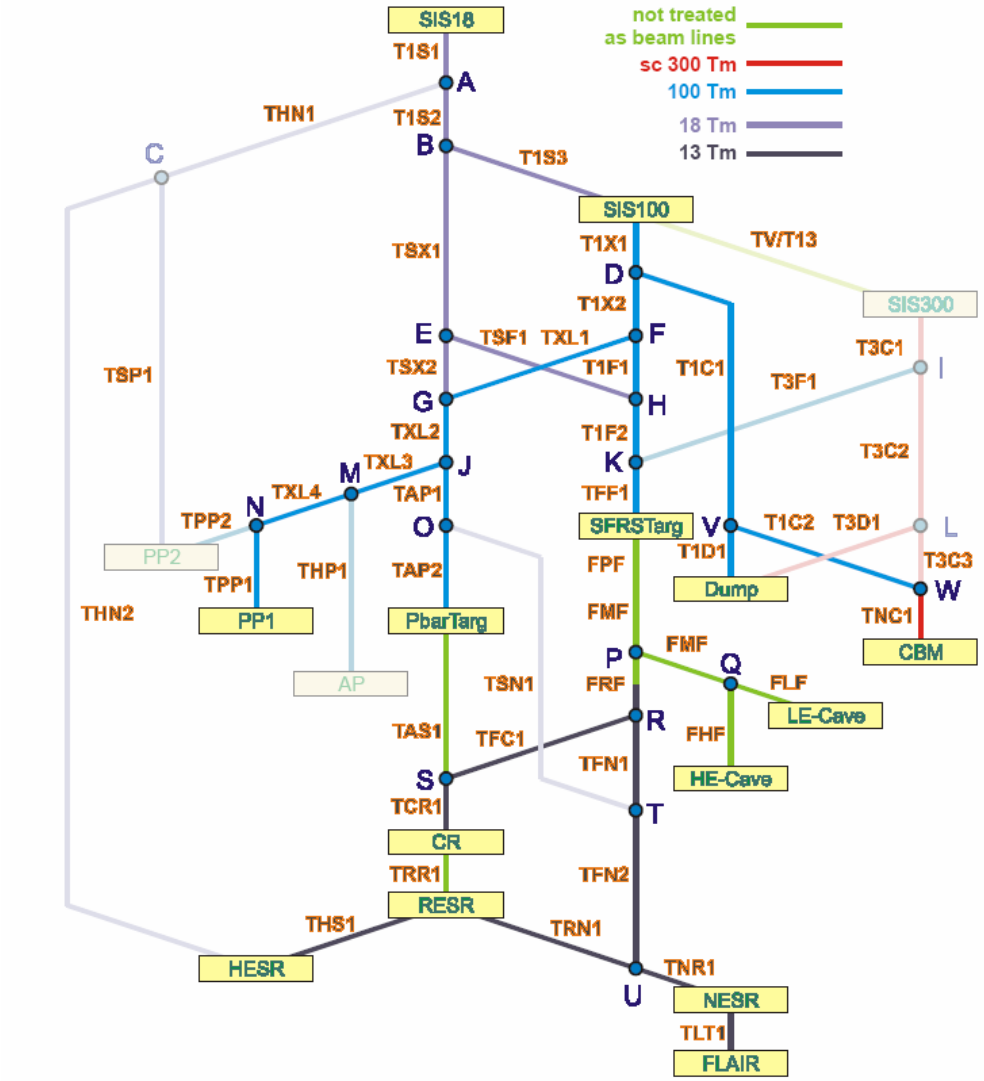
„Linienplan“ Metro Frankfurt



Paralleler Strahlbetrieb FAIR



Strahllinienplan HEBT



HEBT Strahlführung

#	from	to	particles species	rigidity range [Tm]	max. hor. emittance [mm*mrad]	max. vert. emittance [mm*mrad]	max. momentum width [±%]
c1	SIS18	SIS100	ions, protons	9-18	50	20	0.1
c2	SIS18	SFRSTarget	ions	18	25	10	0.3
c3	SIS18	AP-Cave	ions	18	25	10	0.1
c4	SIS18	NESR	ions	13	25	10	0.1
c5	SIS18	PP2 perp.	ions, protons	9-18	25	10	0.3
c6	SIS18	HESR	protons	13	25	10	0.1
c7	SIS300	Dump	ions, protons	27-300	10	4	0.01
c8	SIS300	CBM-Cave	ions, protons	27-300	10	4	0.01
c9	SIS300	SFRSTarget	ions	27-100	10	4	0.01
c10	SIS100	Dump	ions, protons	27-100	25	10	0.1
c11	SIS100	CBM-Cave	ions, protons	27-100	25	10	0.1
c12	SIS100	SFRSTarget	ions	27-100	25	10	1
c13	SIS100	pbarTarget	protons	100	6.5	2.5	1
c14	SIS100	PP1-Cave	ions, protons	27-100	25	10	1
c15	SIS100	PP2-Cave	ions, protons	27-100	25	10	1
c16	SIS100	AP-Cave	ions	27-100	25	10	0.1
c17	SFRS	CR	r-ions	13	200	200	1.5
c18	SFRS	NESR	r-ions	13	50	20	0.5
c19	pbarSep	CR	antiprotons	13	240	240	3
c20	CR	RESR	r-ions, antiprotons	13	5	5	0.01
c21	RESR	NESR	r-ions, antiprotons	13	5	5	0.01
c22	RESR	HESR	antiprotons	13	5	5	0.01
c23	NESR	FLAIR	ions, r-ions, antiprotons	0.3-4.5	20	20	0.2

Der Strahl

Dipole: Ablenkung

- **Lorentz Kraft** $F_L = qE \pm q\,[v \times B]$

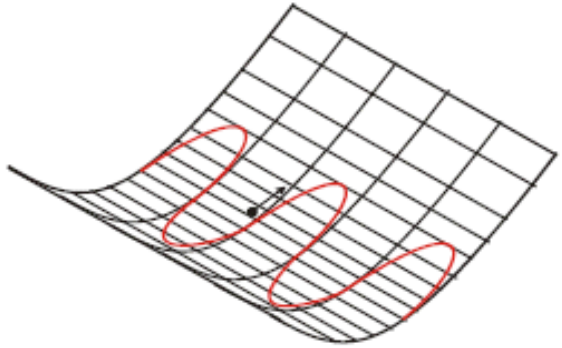
- **magn. Steifigkeit** $B \cdot \rho = \frac{m \cdot v}{q}$

B Magnetfeld in T (Tesla)
ρ Krümmungsradius der Teilchenbahn in m (Meter)
v Geschwindigkeit in m/s (Meter pro Sekunde)
m Masse des Teilchens in kg (Kilogramm)
q Ladung in e (Elementarladung)

Der Strahl

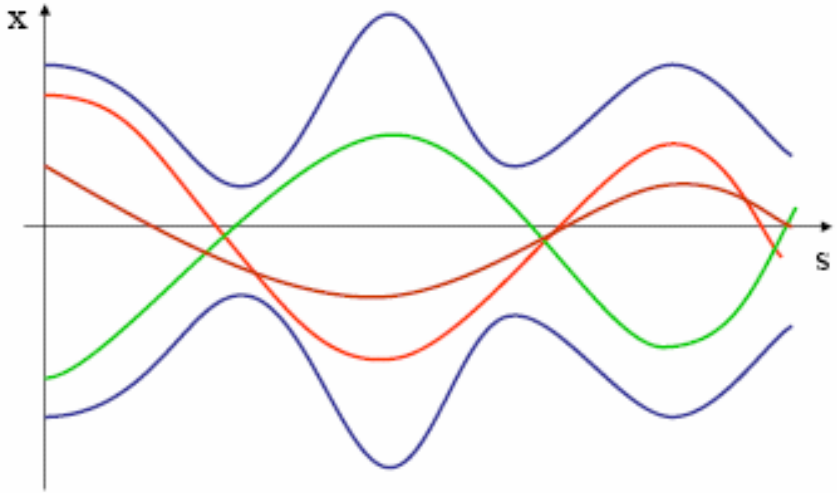
Quadrupole: Fokussierung, Ausdehnung des Strahls

Teilchen:
- Schwingungen um den Sollorbit
- beta-Funktion



Emittanz
- Phasenraum-Ellipse x, x‘
- Maschieneneigenschaft
- konstant

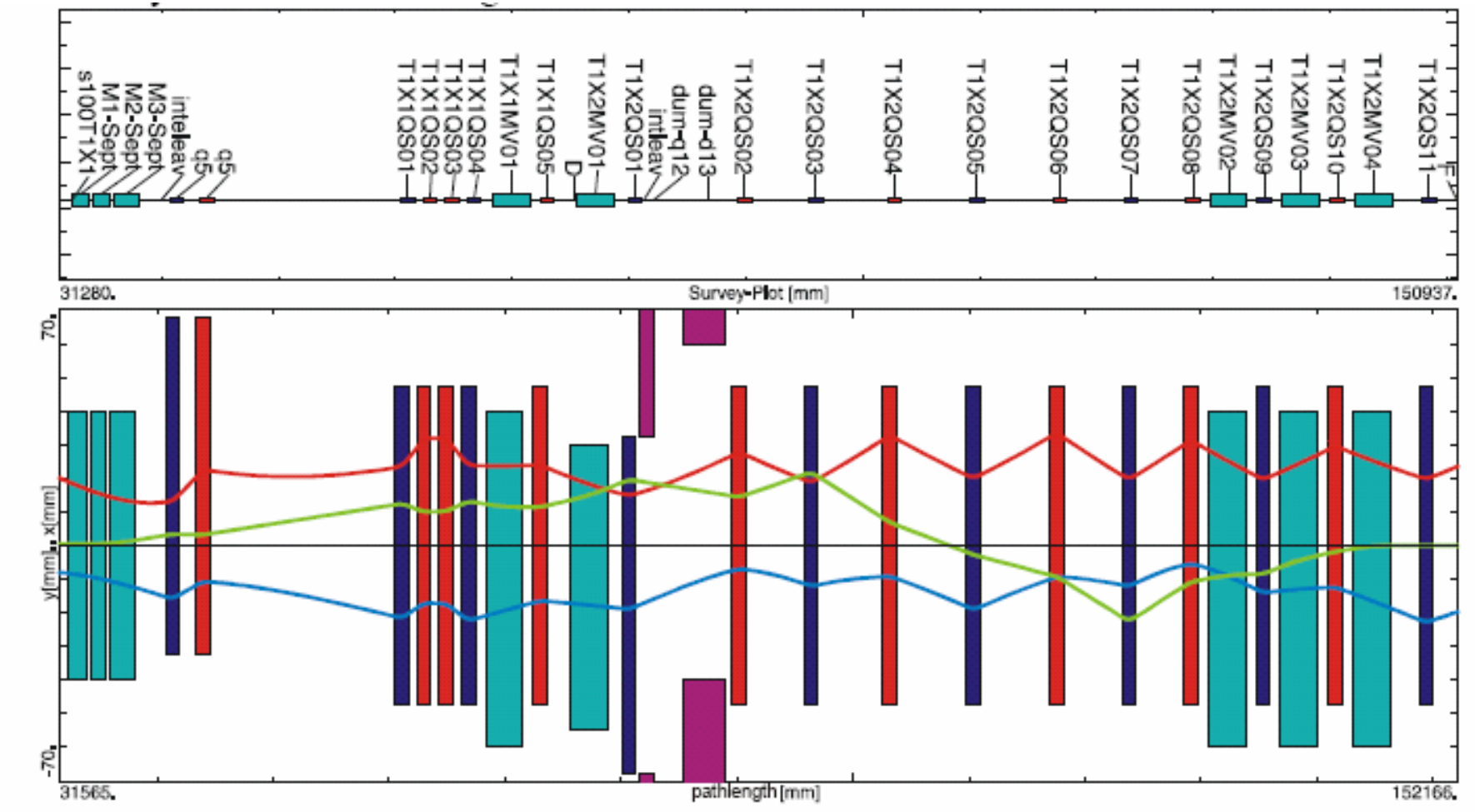
Dispersion
- Ablage durch Impulsabweichung

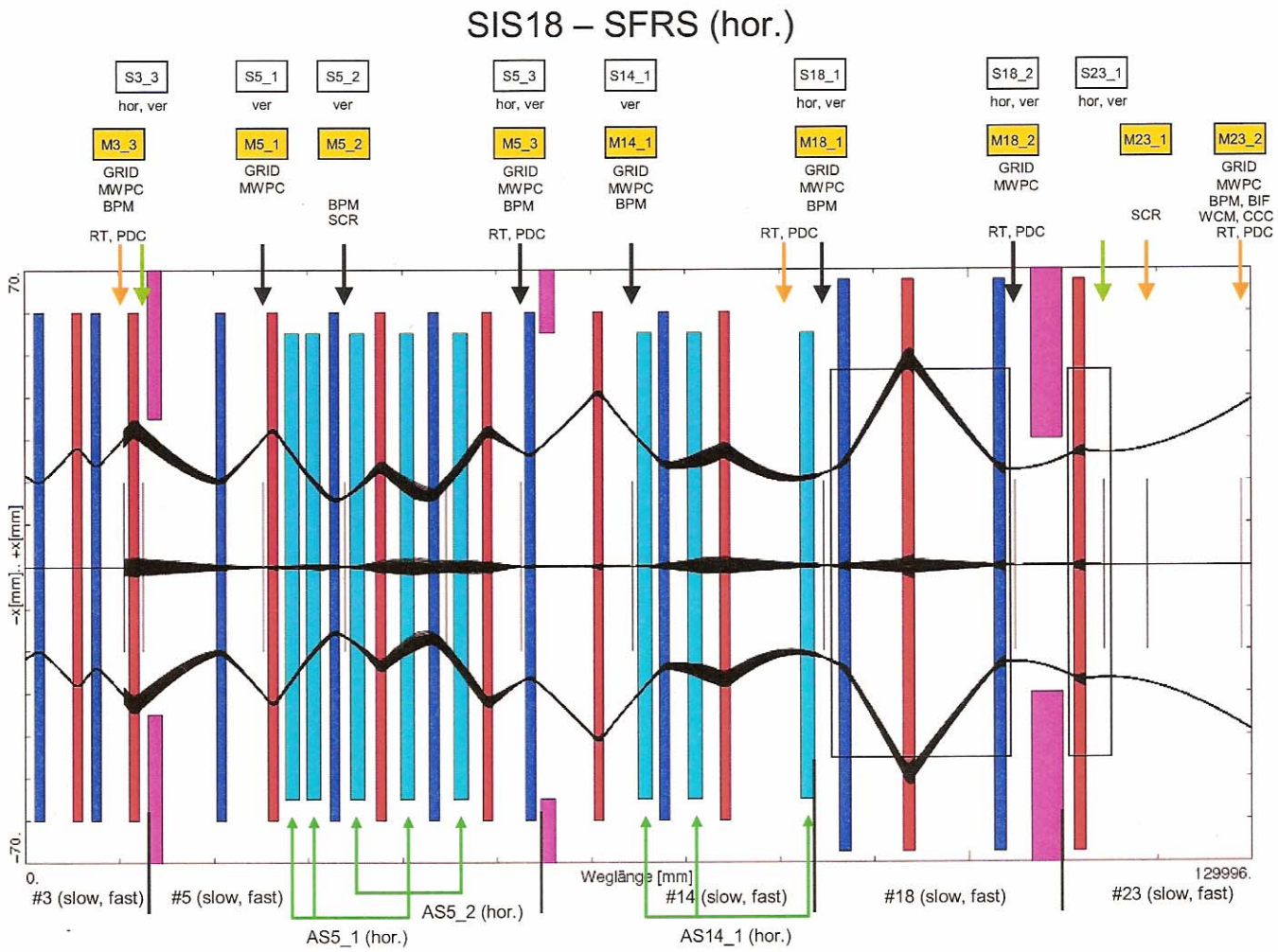


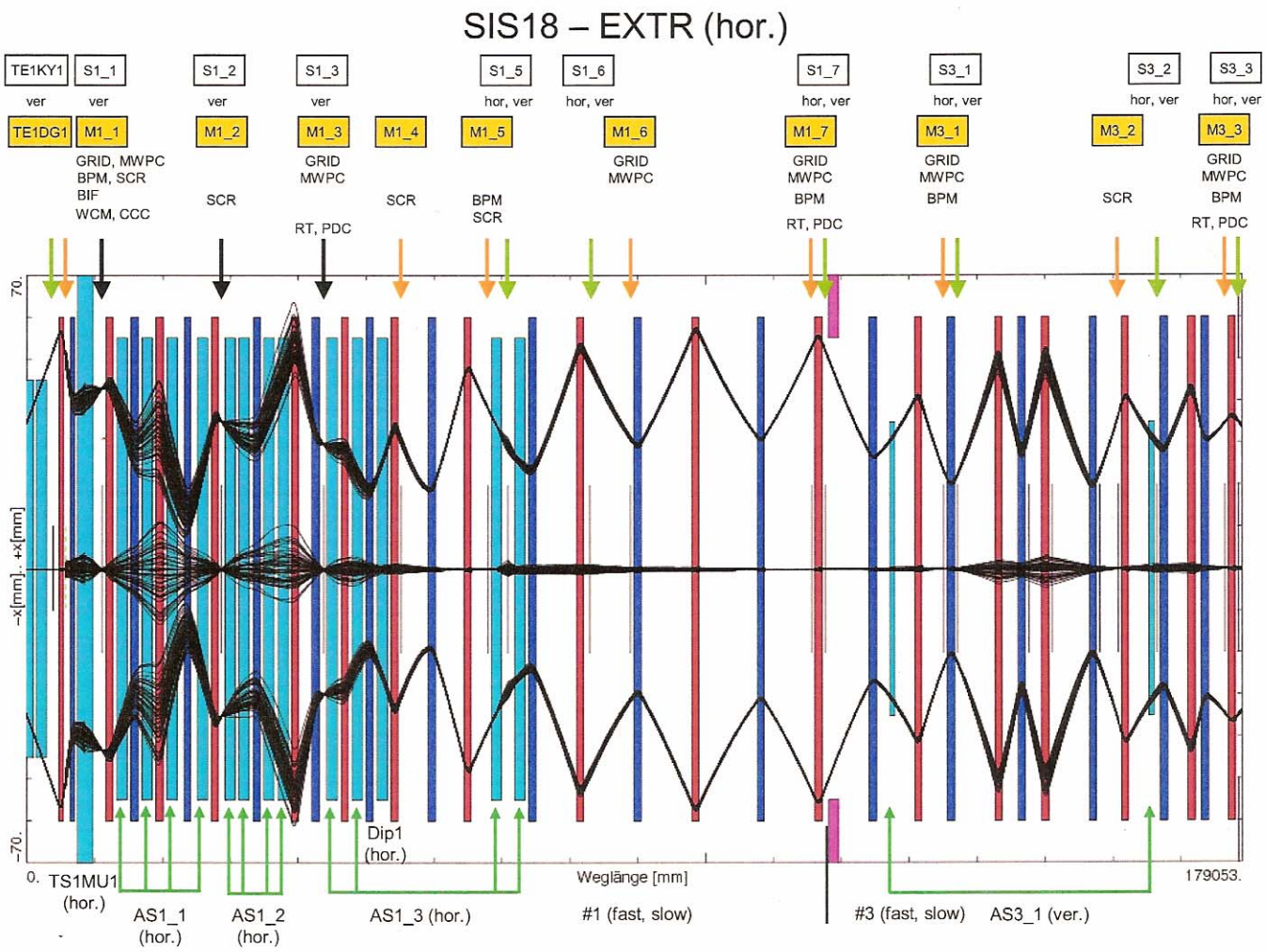
Strahl-Envelope:

$$X = 2E(s) = 2\sqrt{\varepsilon\beta x(s) + Dx^2(s)(\Delta p/p)^2}$$

SIS100 zu SFRS




SIS18 – SFRS (hor.)
S3_3
hor, ver
S5_1
ver
S5_2
ver
S5_3
hor, ver
S14_1
ver
S18_1
hor, ver
S18_2
hor, ver
S23_1
hor, ver
M3_3
GRID
MWPC
BPM
M5_1
GRID
MWPC
M5_2
BPM
SCR
M5_3
GRID
MWPC
BPM
M14_1
GRID
MWPC
BPM
M18_1
GRID
MWPC
BPM
M18_2
GRID
MWPC
M23_1
SCR
M23_2
GRID
MWPC
BPM, BIF
WCM, CCC
RT, PDC
RT, PDC
RT, PDC
RT, PDC
RT, PDC
RT, PDC
70.
−x[mm], +x[mm]
−70.
0.
Weglänge [mm]
129996.
#3 (slow, fast)
#5 (slow, fast)
AS5_2 (hor.)
AS5_1 (hor.)
#14 (slow, fast)
AS14_1 (hor.)
#18 (slow, fast)
#23 (slow, fast)


SIS18 – EXTR (hor.)
TE1KY1
S1_1
S1_2
S1_3
S1_5
S1_6
S1_7
S3_1
S3_2
S3_3
ver
hor, ver
TE1DG1
M1_1
M1_2
M1_3
M1_4
M1_5
M1_6
M1_7
M3_1
M3_2
M3_3
GRID, MWPC
BPM, SCR
BIF
WCM, CCC
SCR
GRID
MWPC
RT, PDC
BPM
70.
-70.
-x[mm] ... +x[mm]
0.
179053.
Weglänge [mm]
TS1MU1
(hor.)
AS1_1
(hor.)
AS1_2
(hor.)
Dip1
(hor.)
AS1_3 (hor.)
#1 (fast, slow)
#3 (fast, slow)
AS3_1 (ver.)

Herausforderung für Strahldiagnose Komponenten

- alle Ionenarten, Protonen und Antiprotonen

- Höchste Strahlströme gepaart mit niedrigen Strömen
  - destruktive Messmethoden für niedrige Ströme
  - nicht destruktive für hohe Ströme

- Präzise Strahlführung nötig

- die komplexe quasi-parallelen Operationen machen ein höchst verläsliches und flexibeles Datenaufnahmesystem nötig

Zu messende Strahleigenschaften in der HEBT

- **Strahlstrom**
- **Bunch Ladung/ Zeitstruktur**
- **Strahlschwerpunkt**
- **Transversales Profil**
- **Strahlverlust**

Zu messende Strahleigenschaften in der HEBT

- **Strahlstrom**
  RT, FCT, CCC, PDC
- **Bunch Ladung/ Zeitstruktur**
  FCT
- **Strahlschwerpunkt**
  BPM
- **Transversales Profil**
  PG, MWPC (el.), Screens, BIF(optc.)
- **Strahlverlust**
  IC, Szintillatoren, Cherenkovzähler

SD-Komponeneten in der HEBT

Device	Measured Parameter	Intercept./non-intercept.	Extraction	Remark			N
Resonant Transformer (RT)	beam current	non-intercept	fast				33
Fast Current Transformer (FCT)	bunch charge/ time structure	non-intercept.	fast				18
Particle Detector Combination (PDC)	current	intercepting	slow	low intensities			22
Cryogenic Current Comparator (CCC)	current	non-intercept.	slow	high intensities			6
Beam Position Monitor (BPM)	centre-of-mass		fast				54
SEM-Grid (PG)	transverse profile	intercepting	fast	profile & position	PRM (Profile Monitor)	CMM (Centre-of-Mass Monitor)	65
Scintillation Screen (SCR)	transverse profile	intercepting	fast & slow	profile & position			39
Multi-Wire Proportional Chamber (MWPC)	transverse profile	intercepting	slow	profile & position			47
Beam Induced Fluorescence (BIF)/ Ionization Profile Monitor (IPM)	transverse profile	non-intercept.	fast & slow	profile & position, high intensities			18
Beam Loss Monitor (BLM)	beam loss	non-intercept.	fast & slow	shared with storage rings, in total 32			8

Strahl Strom

Transformatoren
- Messung des Strahlmagnetfeldes
- nicht strahlzerstörend
- gepulster und kontinuierlicher Strahl
- niedriege Nachweisschwelle

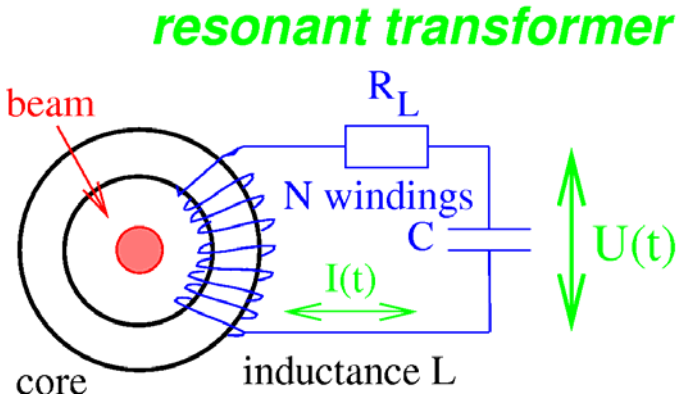
Teilchendetektoren
- Messung von Energieverlust in Materie
- strahlzerstörend
- für niedriege Ströme bei hoher Energie
  (z.B. langsame Extraktion)

Strahl Strom

Nicht destructive Messung des Strahlmagnetfeldes

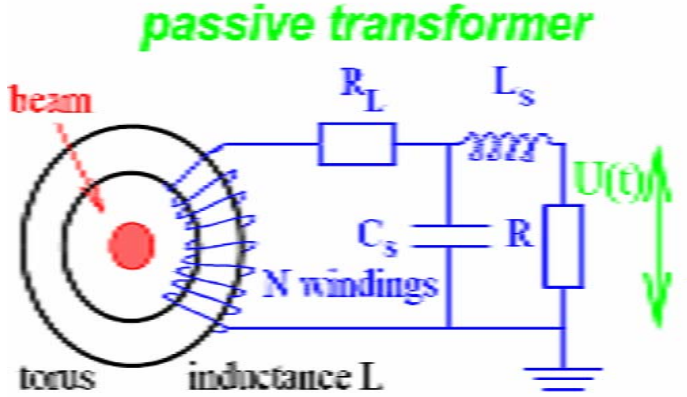
Resonant Transformer

- **Höhe der ersten Schwingungsamplitude proportional zu Strahlstrom**



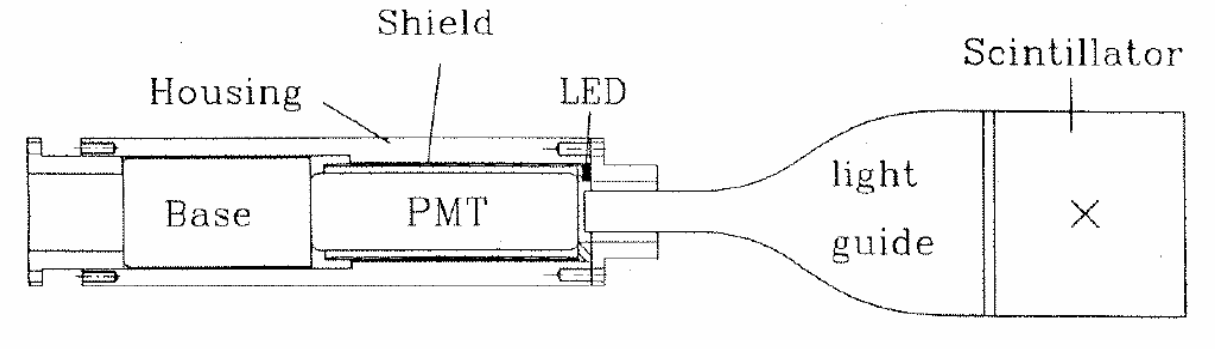
Fast Current Transformer

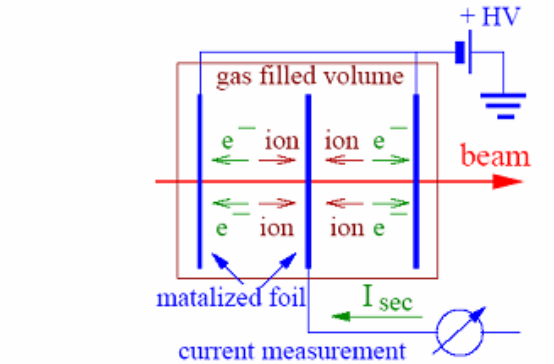
- **mißt die Bunch-Struktur**
- **durch Einsatz eines schnellen ADCs kann aus der Integration des digitalen Signals der Strahlstrom bestimmt werden**

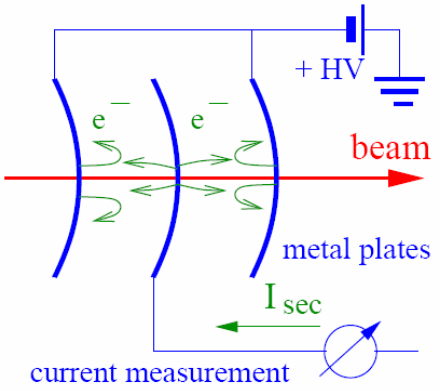


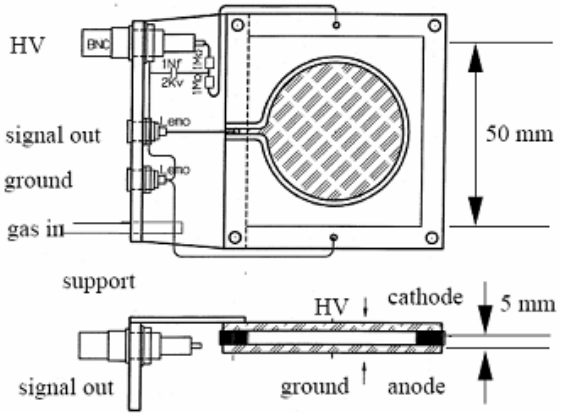
RT unnötig, wenn digitales Rauschen < analoges Rauschen

Strahlstrom
Particle Detector Combination
Scintillator, Ionization Chamber, Secondary Electron Monitor







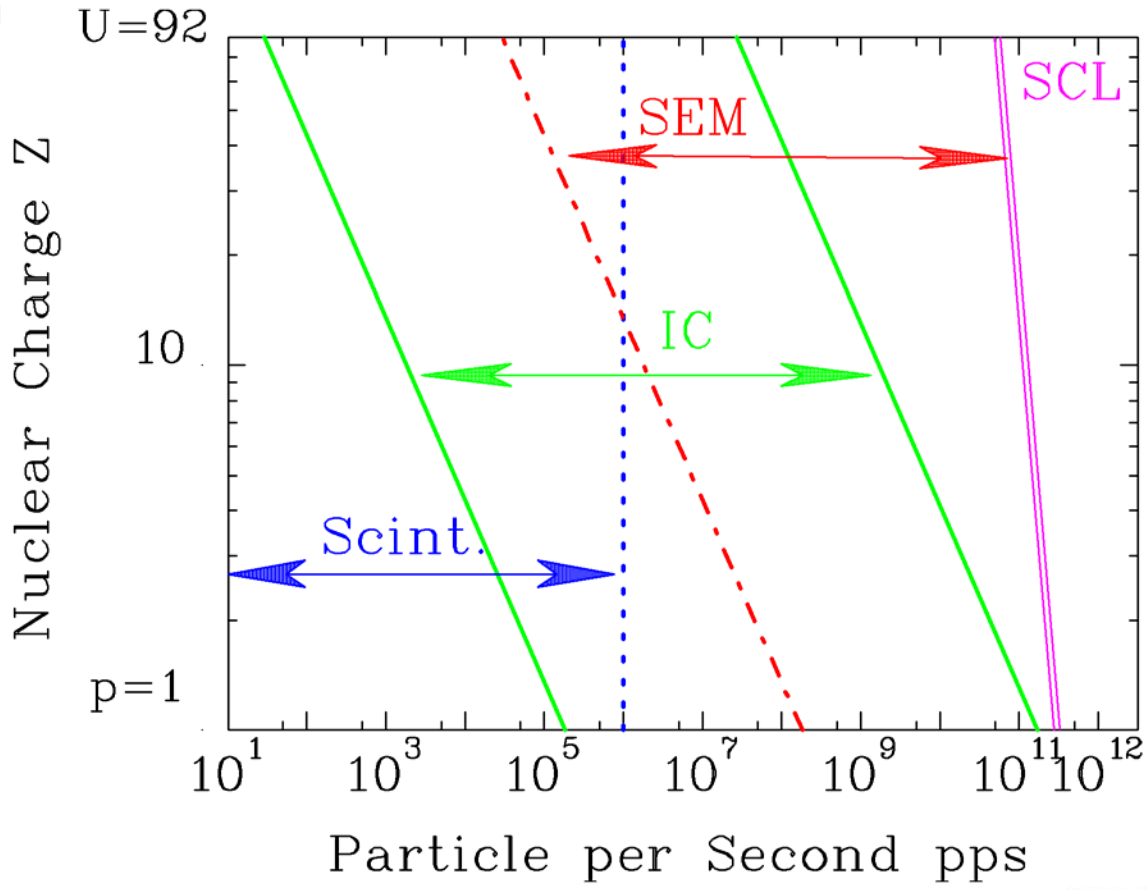


SEM

IC

Strahlstrom
Particle Detector Combination
Scintillator, Ionization Chamber, Secondary Electron Monitor

Überdeckung des gesamten Bereichs der Strahlströme



SD – FAIR team

Georg Schepers
Beata Walasek-Hoehne
Marcus Schwickert
Peter Forck
Tobias Hoffmann
Carsten Mueller

Aufgaben:
- Überblick
- Kommunikation, intern + extern
- Information sammeln und verbreiten
- Planung: Kosten und Flächenbedarf
- Bearbeitung möglicher EoIs
- Erstellen von Spezifikationen

Kostenschätzung FCT für die HEBT

	A	B	C	D	E
1	**Component: Fast Current Transformer**				
2					
3		**component**	**cost**	**occupancy**	cost per unit
4		Rack	4200	0.25	1050
5		Crate (VME)	5500	0.50	2750
6		Controller (VME)	2500	0.50	1250
7		Local SW (FESA-developm.)			0
8		Timing	1500	0.50	750
9		fast ADC	10000	0.50	5000
10		Connector Box	2000	0.42	840
11		LWL Converter	2000	1.00	2000
12		small parts	1000	1.00	1000
13	**Cost per unit €:**				14640
14					
15					
16					
17					
18	**Number of components:**	14			
19	**Cost per unit €:**	14640			
20					
21	**Total Costs €:**	204960			
22					
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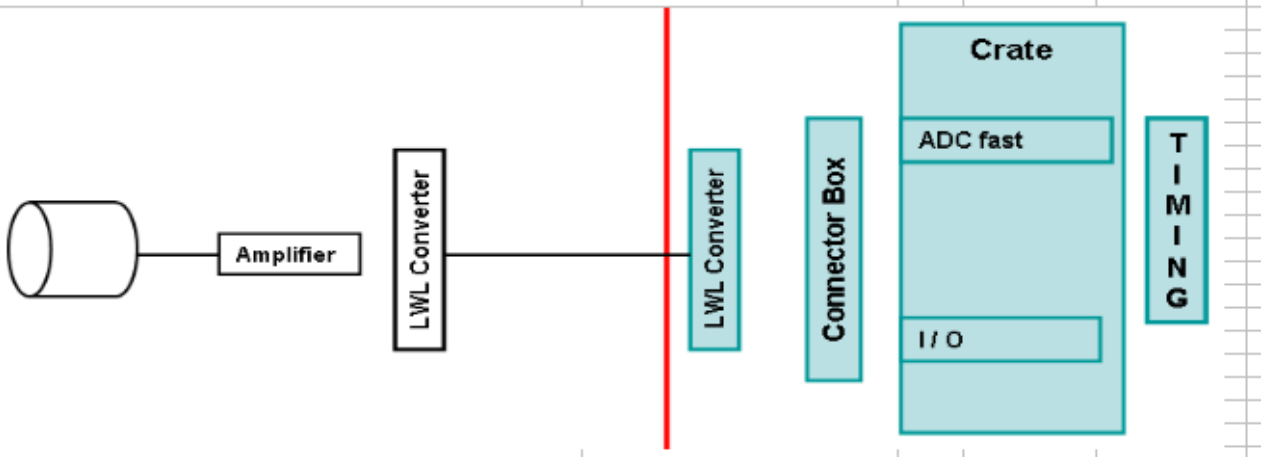


Strahldiagnose für HEBT:

Ohne Strahldianose ist FAIR blind
und der Strahl auf unsicherem Weg

Noch viel Arbeit zu tun:

Standardisierung

Evaluation der anvisierten Detektoren

kann der RT durch einen FCT ersetzt werden?

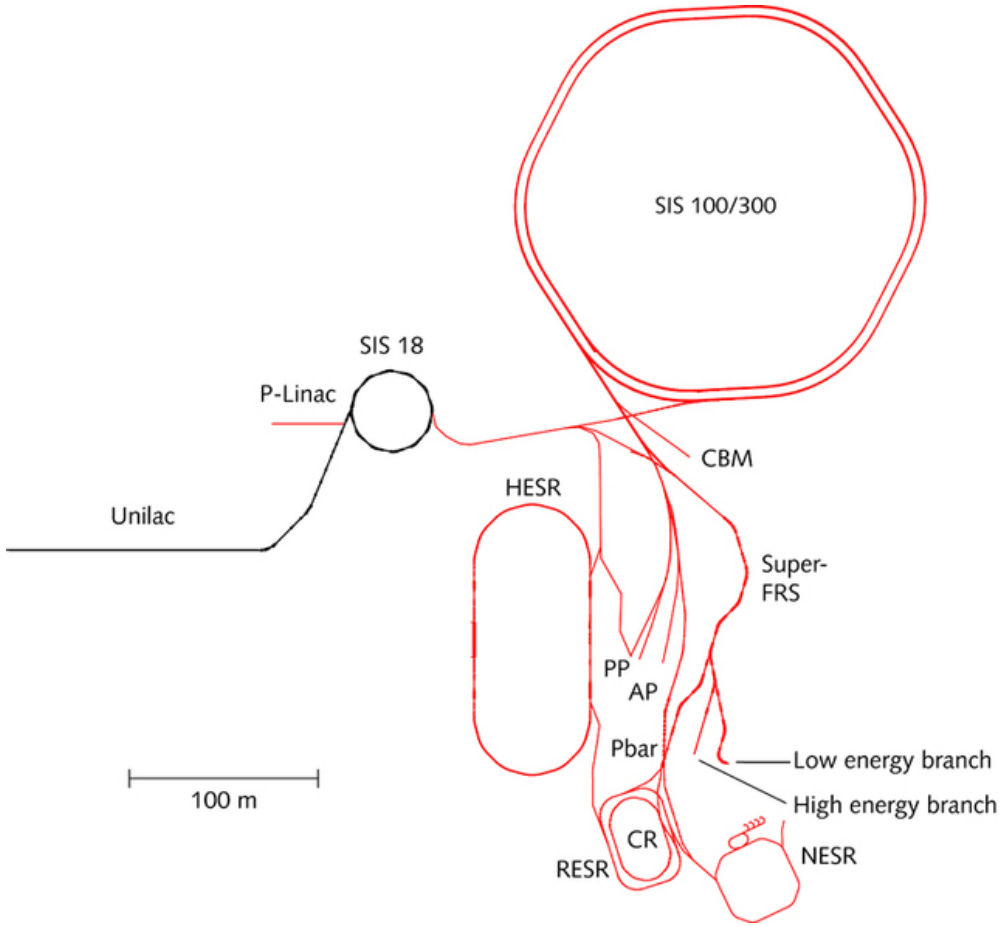
R&D CCC, BIF . . .

aber...es ist eine große Herausforderung!


Vielen Dank!
FAIR

BACK UP

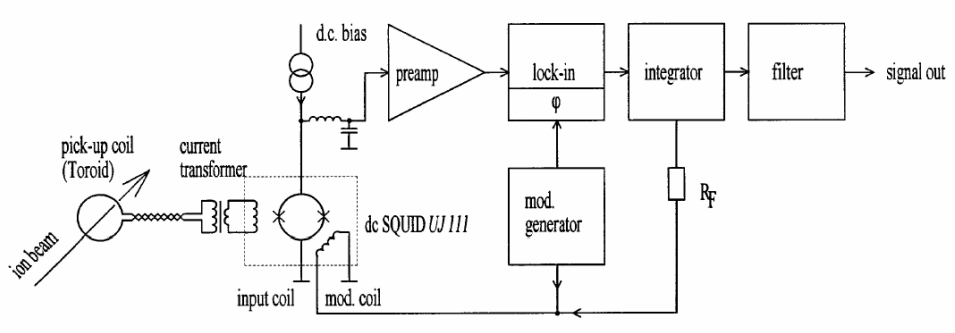
Experimente @ FAIR



The fast cycling, superconducting
synchrotrons are build for high current operation with theaim of secondary ion and
antiproton production. A large variety of low current secondary beams as well as the antiprotons
are stored and cooled in the four storage rings. A complex operation scheme with multiple use of
transport lines is foreseen. This demands an exceptional high dynamic range for the beam
instrumentation. Due to the enormous beam power, non-destructive methods are mandatory for
high currents as well as for the low current secondary beams due to the low repetition rate.
Precise measurements of all beam parameters and automatic steering or feedback capabilities are
required due to the necessary exploitation of the full ring acceptances. Moreover, online beamcorrections
with short response times are mandatory for the fast ramping super-conducting magnets. An overview of the challenges and projected innovative solutions for varioudiagnostic

FAIR: Experimente und Einrichtungen:

- **NUSTAR:** **N**uclear **ST**ructure **A**strophysics and **R**eactions
  Super – FRS , rare isotop beams
- **PHELIX: P**etawatt **H**igh-**E**nergy **L**aser for **H**eavy **I**on **E**xperiments
  Nukleosynthese
- **PANDA:** anti**P**roton **AN**ihilations at **DA**rmstadt
  hadron spectroscopy
- **CBM: C**ompressed **B**arionic **M**atter
  States and phases of strongly interacting matter
- **FLAIR: F**acility for **L**ow-energy **A**ntiproton and heavy-**I**on **R**esearch
  Antihydrogen, CPT


d.c. bias
preamp
lock-in
φ
integrator
filter
signal out
pick-up coil
(Toroid)
current
transformer
ion beam
dc SQUID UJ 111
mod.
generator
R_F
input coil
mod. coil