How to operate Spectrometer and Dump safely ?

TTF2 Review Meeting in Salzau, 20-23. Jan. 2003, M. Schmitz -MIN-

A. Overview, General Information

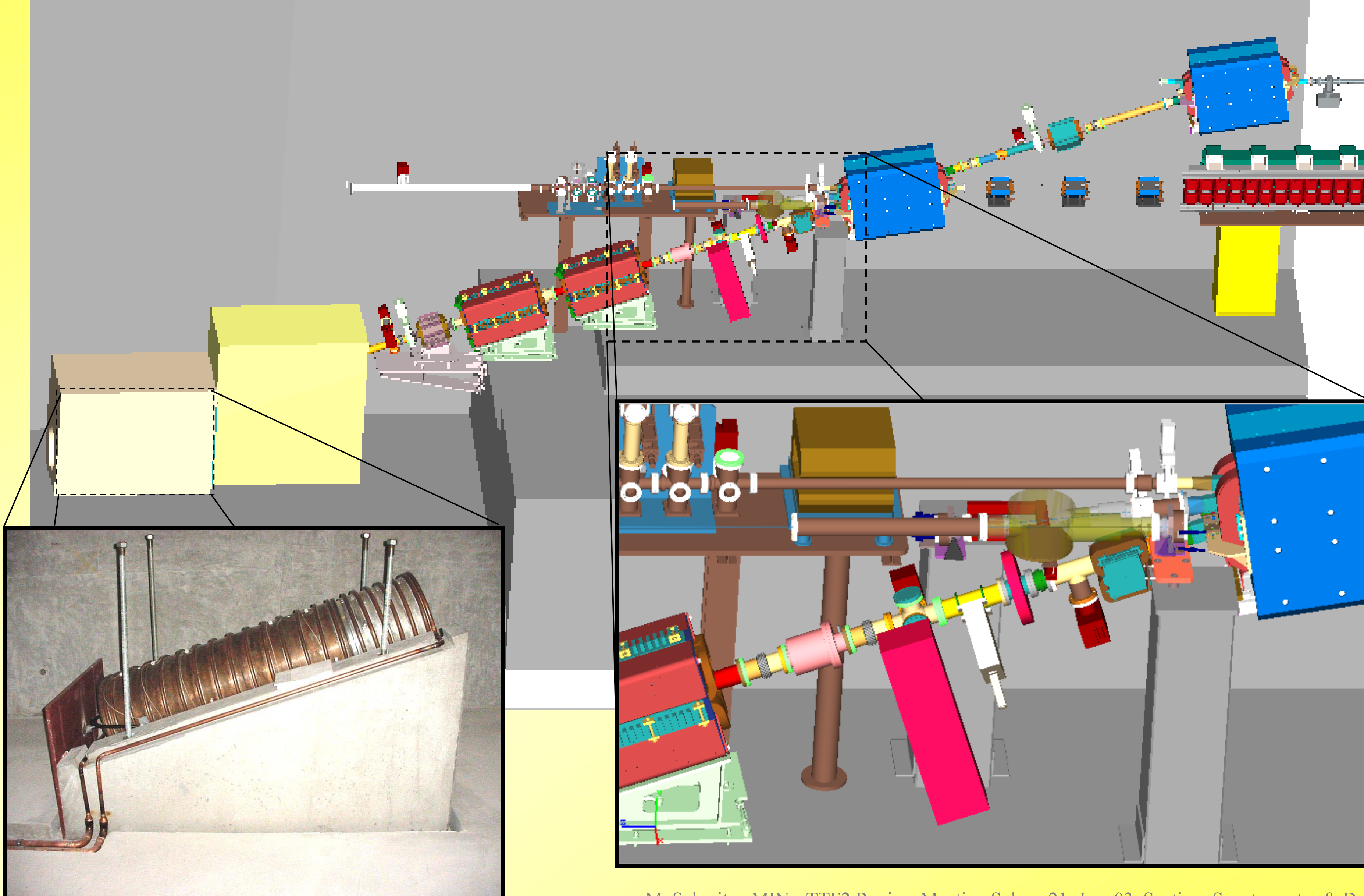
B. Information on special Components

C. Philosophy of Optics & Layout

D. Status, Time Schedule

E. Questions, Next Steps

A: Overview



A: General Information

Tasks of this Section

1.) Spectrometer,

- measure energy with accuracy of:

  relative energy spread $(\Delta p/p)_{rel} \leq 1 \cdot 10^{-4}$

  absolute energy measurement $(\Delta p/p)_{abs} \approx 1 \cdot 10^{-3}$

- momentum acceptance $(\Delta p/p)_{max} \geq \pm 3\%$

2.) Beam Dump, i.e. absorb beam with:

- beam energy $E_0 \leq 1.6$ GeV
- bunch train population $N_t \leq 4 \cdot 10^{13}$ e-
- bunch train repetition $\nu_t \leq 10$ Hz

  ⇒ average beam current $I_{ave} \leq 64$ µA

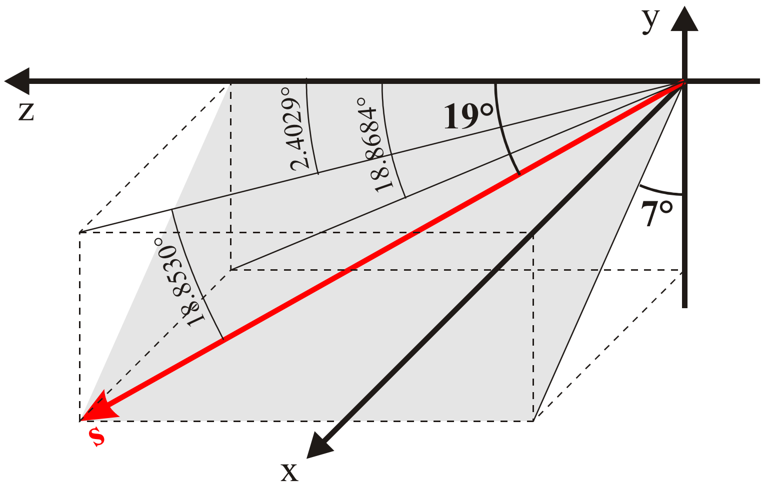
  average beam power $P_{ave} \leq 102$ kW

  energy per bunch train $W_t \leq 10.2$ kJ

Geometry of this Section

- 7° tilt of deflection plane wrt. vertical plane
- 19° = 331.6 mrad deflection angle of dipole

  ⇒ D(s) ≈ s/3 (s: drift space behind dipole)



- main axes of components in beam line

  || and ⊥ wrt. deflection plane

- quite „crowded“ region,

  3 beam lines close together

B: Absorber

- **re-use old TTF1 dump and modify by:**

  40cm front part extension

  ⇒ average heating in Al reduced

  slow beam sweeping r_{slow} = 2cm

  ⇒ average heating in C and Al reduced

- **beam spot at dump entrance $\sigma_x \cdot \sigma_y \geq 1mm^2$**

  ⇒ instantaneous heating in C max. ≈ 250K

- **max. temperatures just after bunch train**

  in graphite ≤ 400°C (+200K w/o sweep)

  in aluminum ≤ 250°C

- **dump operates at normal atmosphere**

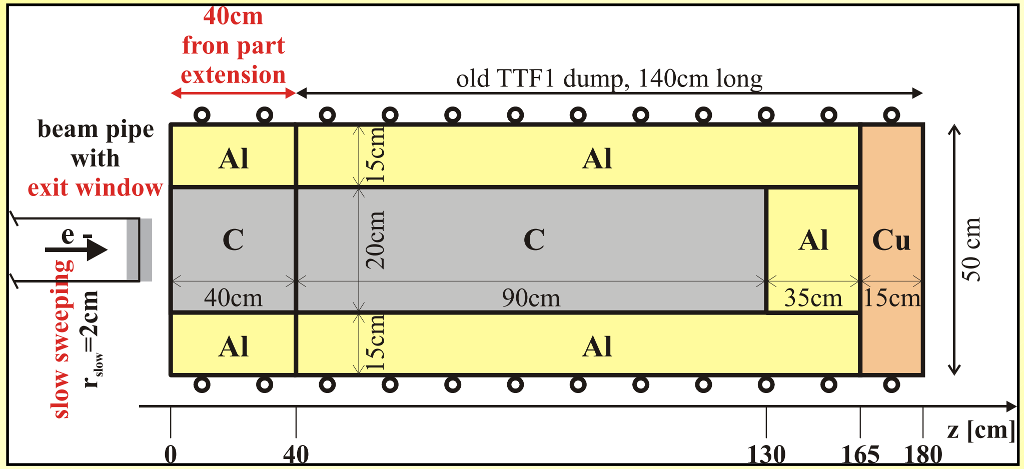
- **design on basis of 2GeV / 130kW**

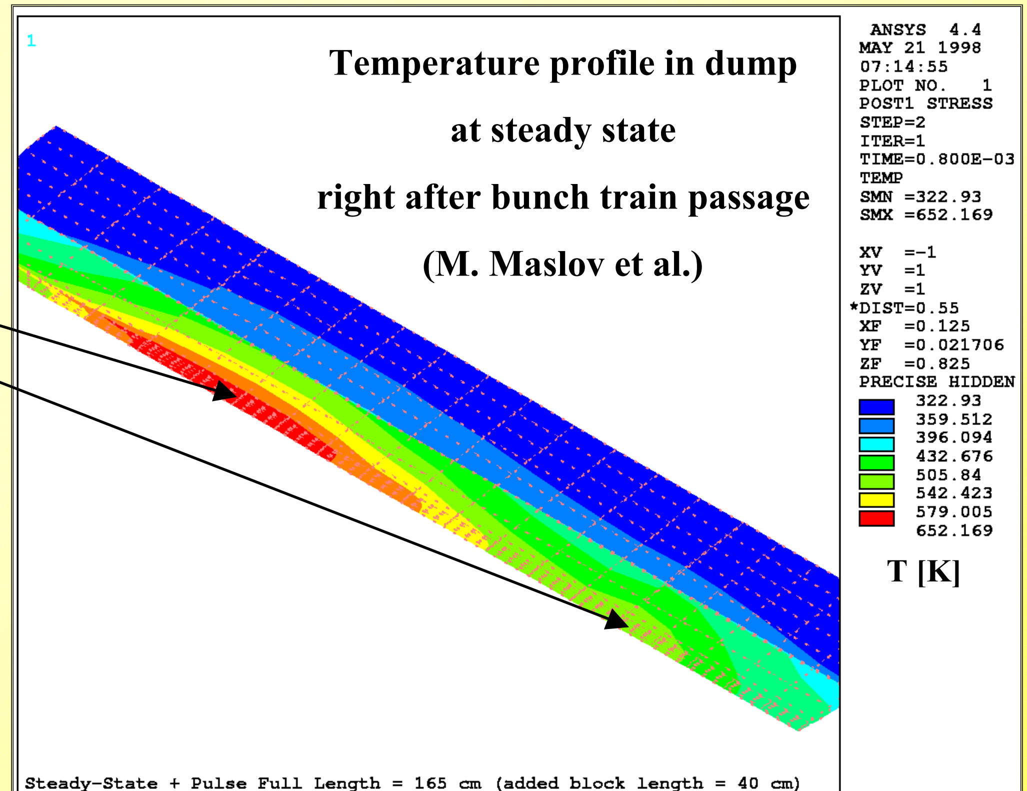
  ⇒ limit for P_{ave} at const. power density:

E_0 [GeV]	0.4	0.8	1.2	1.6	2
limit of P_{ave} [kW]	87	108	120	125	130

- **2 (1 + 1 spare) modified absorbers ready**

  1 absorber is installed in place





B: Beam Exit Window (1)

1.) General Design Concept (M. Maslov, Protvino)

- **C-Ti-C sandwich**

  Ti: + for cyclic stress & vacuum tight, bad thermal conductor

  C: supports Ti and transports heat to external cooling

- **Limits:** $(\Delta T_{inst})_{max} \leq 250K$ **in Ti,** $T_{abs} \leq 400°C$ **in C & Ti**

2.) Instantaneous Heating

$$\left(\Delta T_{inst}\right)_{max} = \frac{1}{\rho}\frac{dE}{dz}\cdot\left(\frac{dN}{dA}\right)_{max}\cdot\frac{1}{c}; \quad \left(\frac{dN}{dA}\right)_{max} = \frac{N_t}{2\pi\cdot\sigma^2}$$

lower limit of spot size at window with factor 5 safety

$\Rightarrow (dN/dA)_{max} \leq 1.3\cdot10^{12}$ e-/mm² $\Leftrightarrow \sigma_x\cdot\sigma_y \geq 5mm^2$

3.) Equilibrium Heating

a) with 2cm sweep

$$\left(\Delta T_{eq}\right)_{max} = \frac{1}{\rho}\frac{dE}{dz}\cdot\rho\cdot\frac{I_{ave}}{e}\cdot\frac{1}{2\pi\cdot\lambda}\cdot\ln\left(\frac{R_{window}}{R_{sweep}}\right)$$

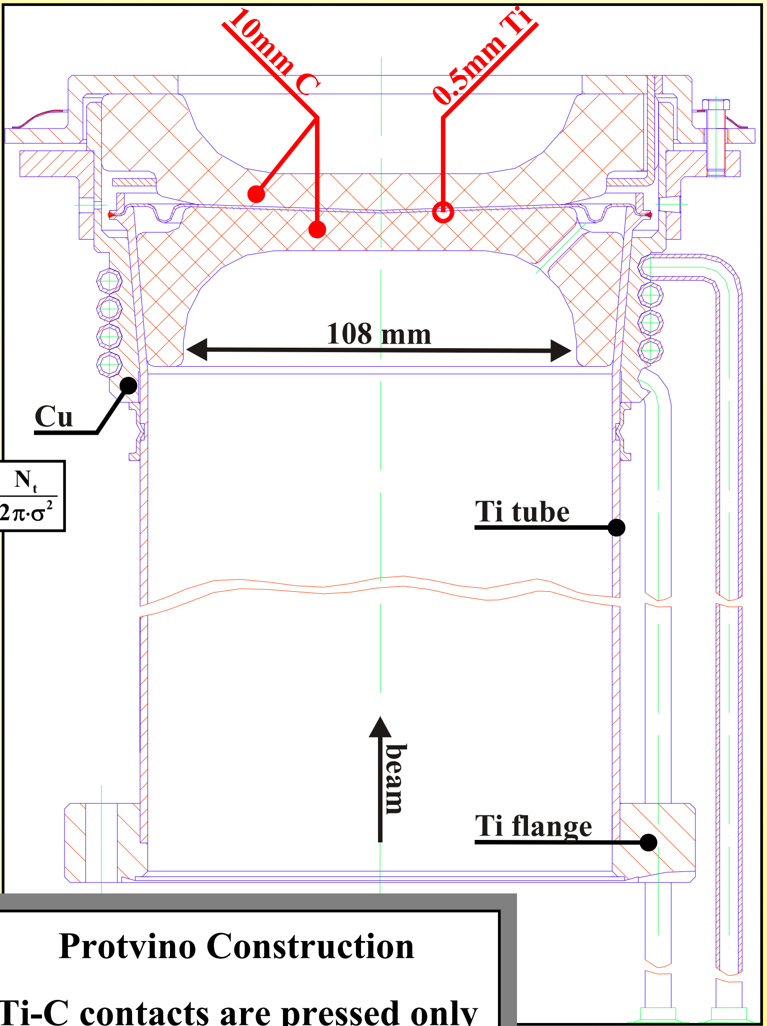
b) without sweep

$$\left(\Delta T_{eq}\right)_{max} = \frac{1}{\rho}\frac{dE}{dz}\cdot\rho\cdot\frac{I_{ave}}{e}\cdot\frac{1}{4\pi\cdot\lambda}\cdot\ln\left(1+\frac{(R_{window})^2}{2\cdot\sigma^2}\right)$$

* $\Rightarrow$ **good thermal contact between Ti-C important**

	$(\Delta T_{inst})_{max}$ [K]		$(\Delta T_{eq})_{max}$ [K]			Power dissip. [W/mm]
			with sweep	without sweep		
σ^2	5mm²	1mm²		5mm²	1mm²	
C	39	195	41	109	139	16.3
Ti	57	285	(444)*	(1190)*	(1500)*	43.2

* assumes no heat transfer to C



Protvino Construction

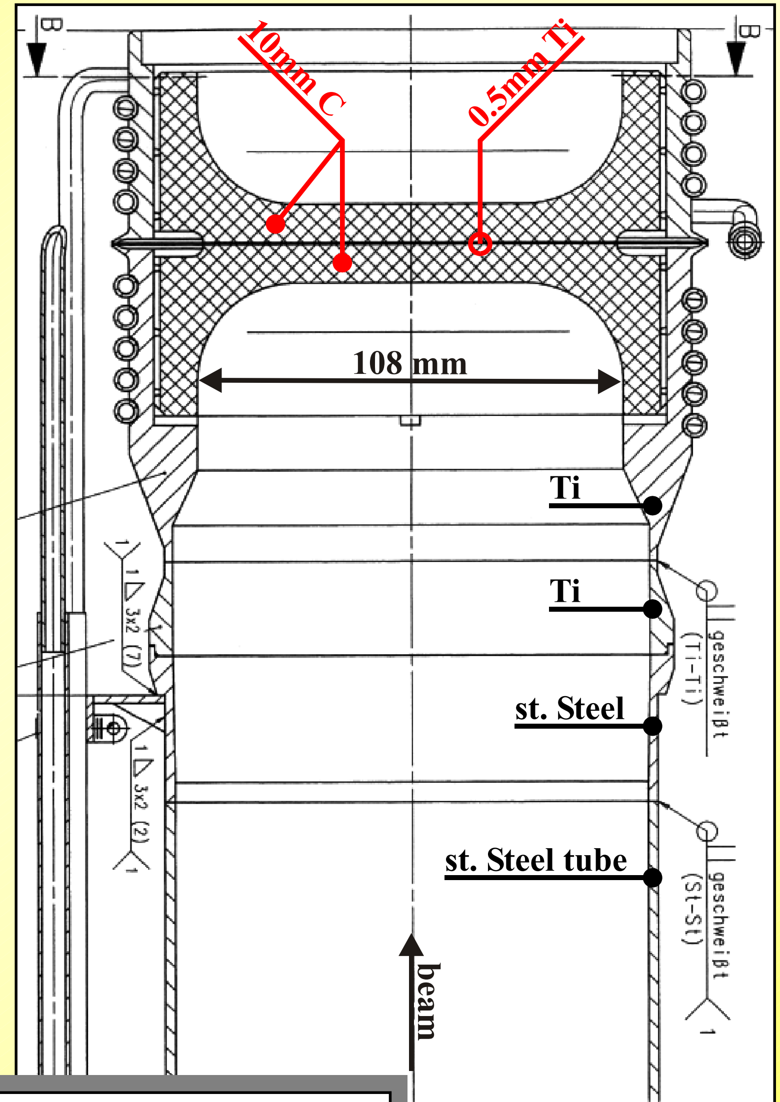
Ti-C contacts are pressed only

	ρ [g/cm³]	c [J/(g·K)]	λ [W/(m ·K)]
C	1.7	0.8	70
Ti	4.5	0.55	17

B: Beam Exit Window (2)

4.) DESY exit window construction (T. Wohlenberg)

- take geometry from Protvino design, but
  braze Ti and C together instead of pressing
  - pressed: ≈ 0.14 – 0.25 W/(cm²·K)
  - brazed: ≥ 0.8 W/(cm²·K)
  - ⇒ improved and long term stable thermal contact
- all brazing pre-tests were successful
- construction finished
  all parts manufactured for 2 windows
  - ⇒ brazing of 1. final window starts now
- venting the small volume between dump and window with dry nitrogen gas, ≈ 1-10 l/day
  - ⇒ protection of atmosphere side of window against aggressive substances like ozone or NO_x
- 1 complete Protvino window is at DESY and serves as fall back solution



DESY Construction
Ti-C contacts are brazed

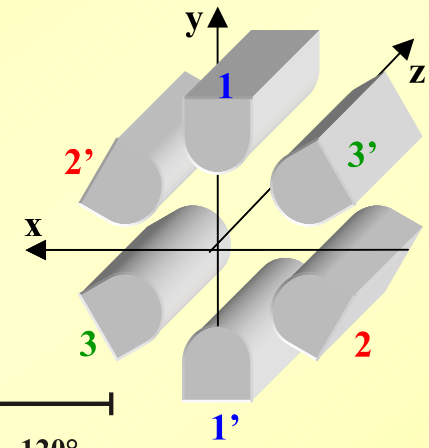
B: Slow Sweeper

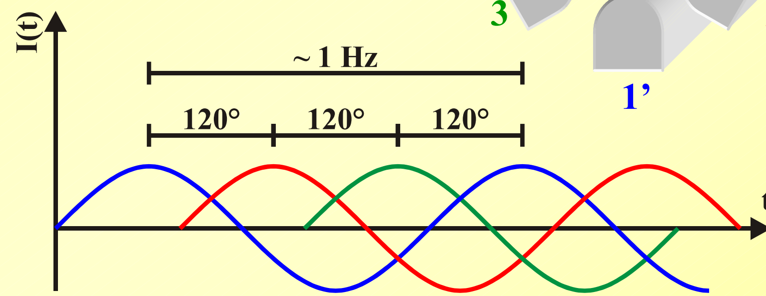
- a sextupole magnet is modified,
  to give 3 dipoles (1-1‘, 2-2‘, 3-3‘) rotated by 120°
  ⇒ space saving rotating dipole field

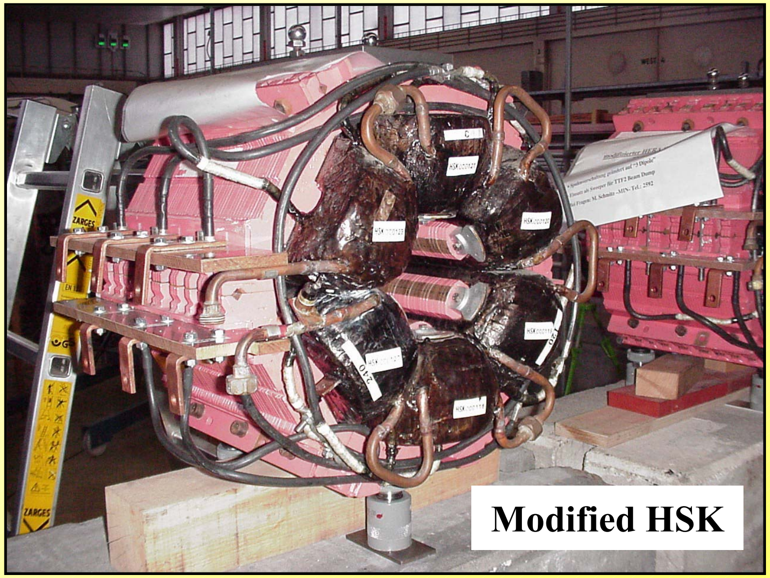
- driver for the 3 power supplies is built by MKK
  3 outputs 120° shifted in phase but same amplitude
  sweep frequency ≈ 1Hz, but of course
  not synchronous with bunch train repetition

- a HERA-e sextupole type HSK is used
  bore Ø=96mm, l_{iron}=280mm, I_{max}=45A

- B-field measurement and calculation done,
  but not evaluated yet

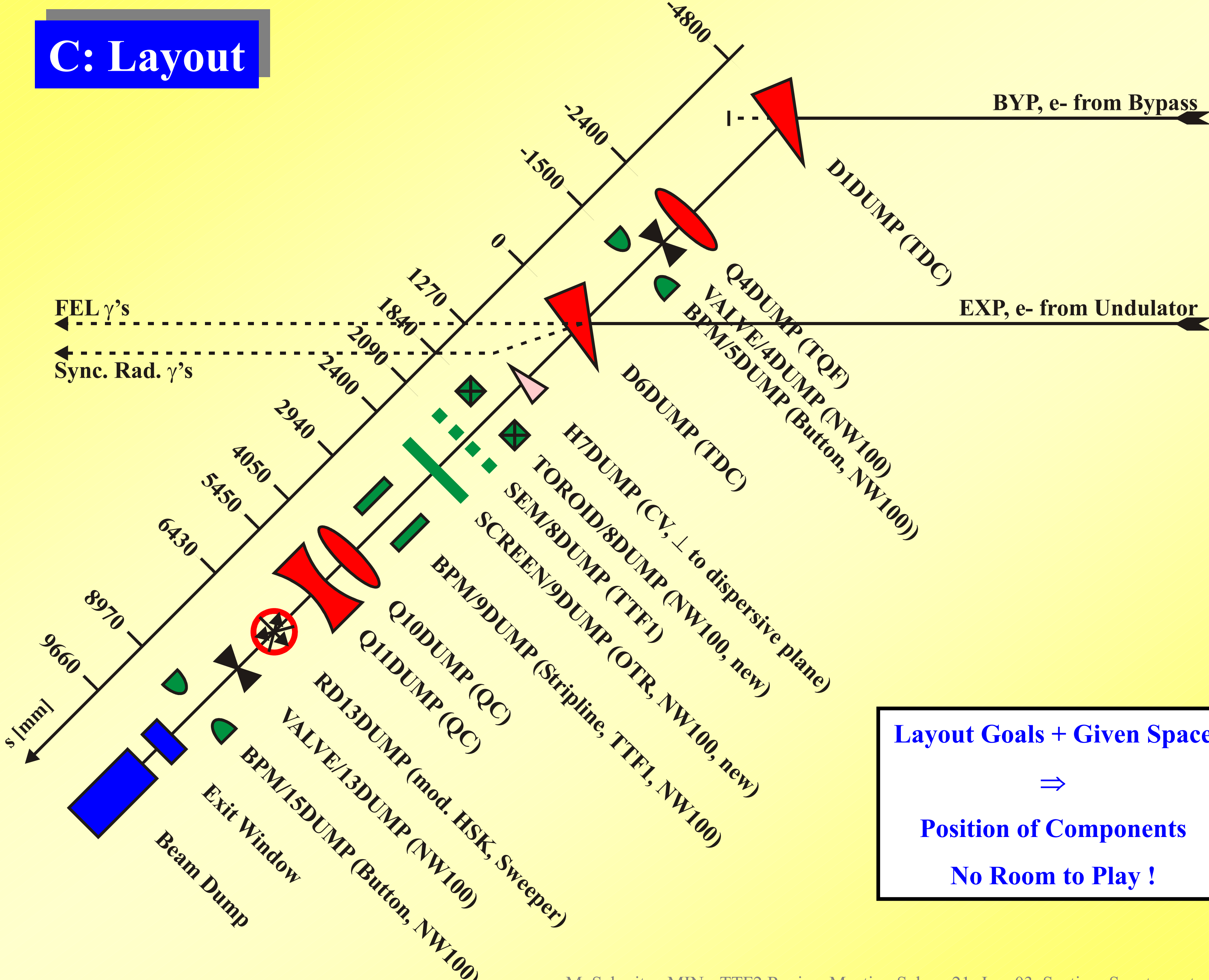






Modified HSK

C: Layout



Layout Goals + Given Space

⇒

Position of Components

No Room to Play !

C: Layout Goals

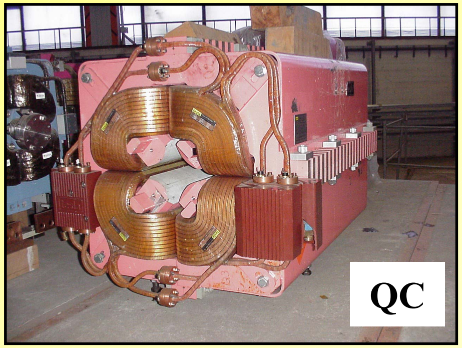
1.) Dispersion at Diagnostics: No Quad Influence & as Large as Possible

⇒ diagnostics in drift as far as possible from D6DUMP

OTR res. ≥ 50µm & $(\Delta p/p)_{rel} \leq 1\cdot10^{-4} \rightarrow D_{OTR} \geq 0.5m \Leftrightarrow$ **s ≥ 1.5m**

2.) Momentum Acceptance ≥ ±3% ⇒ Dispersion limiting Quad Q10DUMP as close as possible to D6DUMP

45mm aperture radius → $D_{max} \leq$ 45mm/3%=1.5m ⇔ **s ≤ 4.5m**



3.) Beam Conditions at Window:

a) D ≈ 0 (beam pos. independent of dipole variation)

b) $(dN/dA)_{max} \leq 1.3\cdot10^{12}$ **e-/mm²** (inst. heating)

⇒ 2 large apert. Quads Q10DUMP & Q11DUMP behind diagnostics

use **QC**: bore Ø=100mm, l_{iron}=1m, I_{max}=350A, $(k\cdot l)_{max}$=2.76/m @1.6GeV/c

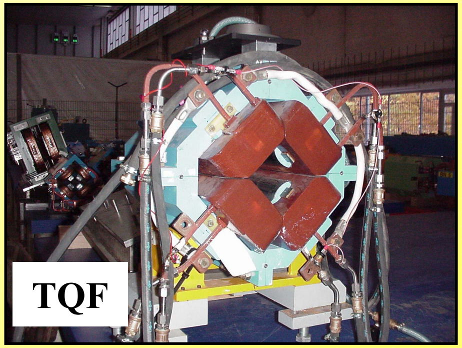
4.) Pure Drift ≥ 2.5m between Sweeper and Dump ⇒ Sweeper is last Magnet

5.) Dispersive Behaviour of Spectrometer (except sign) independent of whether the beam comes from EXP or BYP

⇒ 1 Quad Q4DUMP exactly between D1DUMP and D6DUMP

requires **fixed strength** of **k·l=0.83/m** ⇔ g·l=5.6T @2GeV/c

use **TQF**: bore Ø=70mm, l_{iron}=340mm, I_{max}=250A, $(g\cdot l)_{max}$=6.38T



6.) β-Focus at OTR at least in dispersive plane, required only during Δp/p measurement at reduced N_t !

C: Optics Philosophy

- **Q10/Q11DUMP should also have fixed strength (like Dipoles, Sweeper and Q4DUMP)**

  ⇒ Field of all Spectrometer Magnets scales linear with Momentum

- **2 Operation (Optics) Modes**

  Mode A: Full Intensity Mode without OTR screen measurement requires

  A1 a: D(window) ≈ 0m, b: D(D6DUMP**) = 0m & D'(**D6DUMP**) = –D'(**D1DUMP**)** b) is task of Q4DUMP

  A2: $(\beta_x \cdot \beta_y)^{0.5} \approx$ 8000m at window, because $\left(\frac{dN}{dA}\right)_{max} = 1.3 \cdot 10^{12} \frac{e}{mm^2} \geq \frac{N_t}{2\pi \cdot \sigma_x \cdot \sigma_y} \Rightarrow \sqrt{\beta_x \cdot \beta_y} \geq \frac{N_t \cdot \gamma}{2\pi \cdot \varepsilon_n \cdot \left(\frac{dN}{dA}\right)_{max}}$

  for $\varepsilon_n = 2 \cdot 10^{-6}$m, γ=3200 (1.6GeV/c), $N_t = 4 \cdot 10^{13}$

  Mode B: OTR Δp/p Measurement, few bunches → N_t strongly reduced (e.g. 30 bunches=30·4nC= $7.5 \cdot 10^{11}$)

  B1: same as A1)

  B2: $(\beta_x \cdot \beta_y)^{0.5} \approx$ 150m at window, for $\varepsilon_n = 2 \cdot 10^{-6}$m, γ=3200 (1.6GeV/c), $N_t = 7.5 \cdot 10^{11}$

  B3: beam size at OTR must be dominated by dispersion, i.e $D_{OTR} \cdot (\Delta p/p)_{min} >> \sqrt{\beta_{OTR} \cdot \varepsilon_n / \gamma}$

  ⇒ $\beta_y \approx$ 0.1m at OTR, for D_{OTR}=0.8m, $\Delta p/p = 10^{-4}$, $\varepsilon_n = 10 \cdot 10^{-6}$m, γ=400 (200MeV/c)

- **Optics at the output of EXP or BYP has to be adjusted, in order to fulfill Mode A or B**

  beam from EXP: optics calc. (M. Koerfer) show feasibility

  Q10: k·l=const=-1.04/m, Q11: k·l=const= +2.68/m !

  → more detailed studies necessary:

  e.g. beam from BYP, tolerances wrt. energy- and optic-error

	at OTR		at window		
	β_x	β_y	β_x	β_y	D [m]
Mode A	90 m	300 m	≈ 8000 m		≈ 0
Mode B	≈ 0.2 m		≈ 2000 m		

D: Status (1)

SUPPORTS

Region D1Dump to D6Dump

- construction not finished, expected by end feb.02

Region D6Dump to Q10Dump, i.e. Diagnostics Area

- construction not yet started ! → perhaps need help here
  expected start mid feb.03,
  but overlap with DESY shut-down activities

Q10&11Dump

- construction finished end aug.02
- both supports are manufactured and at DESY

Region RD13Dump to Exit Window

- construction almost finished
  completion expected by mid feb.03

MAGNETS

- all magnets are at DESY (TDC, QC, TQF, mod. HSK, CV)
- alignment of survey marks wrt. poles: TDC, CV to be done
- B-measurements finished by end of feb.03

DIAGNOSTICS

OTR, (SCREEN/9Dump)

- chamber ready and cleaned
- 2 opt. windows NW100 exist
- mover & opt. system not ready yet

Stripline BPM, (BPM/9Dump)

- complete unit (+2 bellows) from TTF1 exists

Button BPM's, (BPM/5&15Dump)

- chambers constructed (→ remaining vac. syst)
  order for manufacturing pending
- delivery buttons beg. mar.03

TOROID, (Toroid/8Dump)

- chamber construction ready
  manufacturing status ?

SEM, (Sem/8Dump)

- installation not decided
- chamber exists from TTF1
  but grid may be modified (45°, 2 planes)
- dummy chamber is foreseen alternatively

D: Status (2)

VACUUMCHAMBERS (except Diagn)

for D1&6DUMP, TDC

- construction finished jun.02
- presently manufactured at FMB (Berlin)
- delivery expected end jan.03

EXIT WINDOW

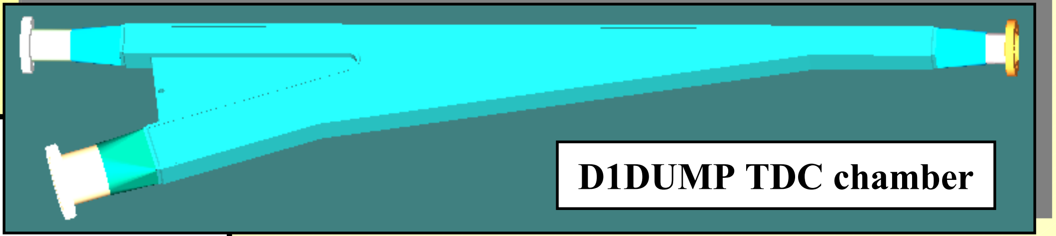
- first DESY window expected mid mar.03
- Protvino window exists at DESY since feb.02

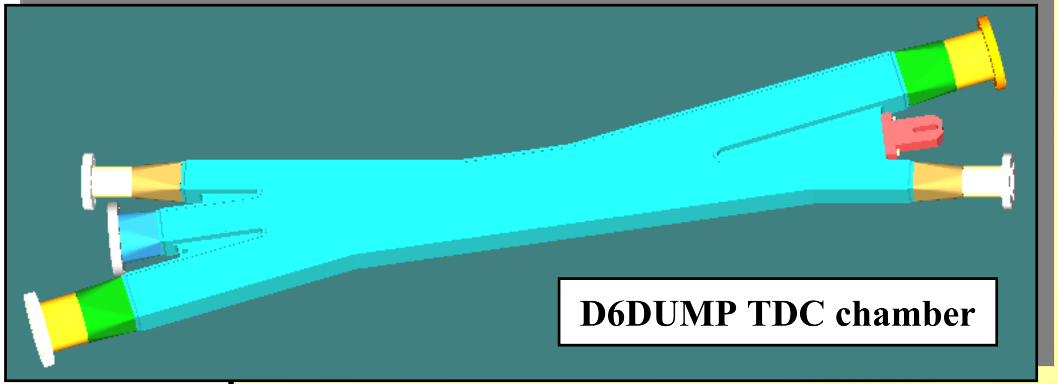
Remaining SYSTEM

- construction of all chambers finished end nov.02
- order for manufacturing pending

ALL vacuum parts must undergo special cleaning procedures

DUMP section has to fulfill standard: „particle-free“





D: Status (3)

associated with ext. costs not yet approved

Rough Schedule, Status:Jan03 Section: TTF2-DUMP,	JAN 03	FEB 03	MAR 03	APR 03	MAY 03	JUN 03	JUL 03
SUPPORTS							
Region D1Dump to D6Dump	construction	construction	manufacturing	manufacturing	install in tunnel		
Diagnostics Region !		construction	construction	construction / manufacturing	manufacturing	manufacturing / install in tunnel	install in tunnel
Q10&Q11Dump					install in tunnel		
Region RD13Dump to Exit Window	construction	construction / manufacturing	manufacturing	manufacturing	install in tunnel		
MAGNETS	B-measurements	B-measurements	install chamber (see chamber)	install chamber (see chamber)	install chamber (see chamber)	install in tunnel	
	align survey. marks	align survey. marks					
VACUUMCHAMBERS (except Diagn.)							
for TDC	manufacturing	clean & vac. test					
for Q10&Q11Dump		deinstal / clean & vac. test	clean & vac. test				
for Q4Dump and RD13Dump		manufacturing	manufacturing	clean & vac. test			
remaining chambers		manufacturing	manufacturing	manufacturing / clean & vac. test	clean & vac. test		
Exit Window	manufacturing 1. window	manufacturing 1. window	clean & vac. test				
DIAGNOSTICS							
OTR (Screen/9Dump) chamber	clean & vac. test						
mover & screen ?							
optical system ?							
Stripline BPM (BPM/9Dump)		clean & vac. test					
Button BPM's (BPM/5&15Dump)		manufacturing	manufacturing	clean & vac. test			
Toroid, (Toroid/8Dump) ?							
SEM, (Sem/8Dump) ?							

D: Questions, Next Steps

Main Questions

- **How are we really sure that the beam size at the window is not too small ?**
  - → **rely on optics and magnet settings**
  - → **measure window temperature at position of beam by IR-radiation**

- **How are we really sure that the beam is cleanly guided to the dump ?**
  - → **BPM's (BPM/15Dump directly in front of exit window)**
  - → **beam loos detection in combination with dedicated limiting apertures**

Next Steps

- **Work on optics**

- **Concentration on controls**