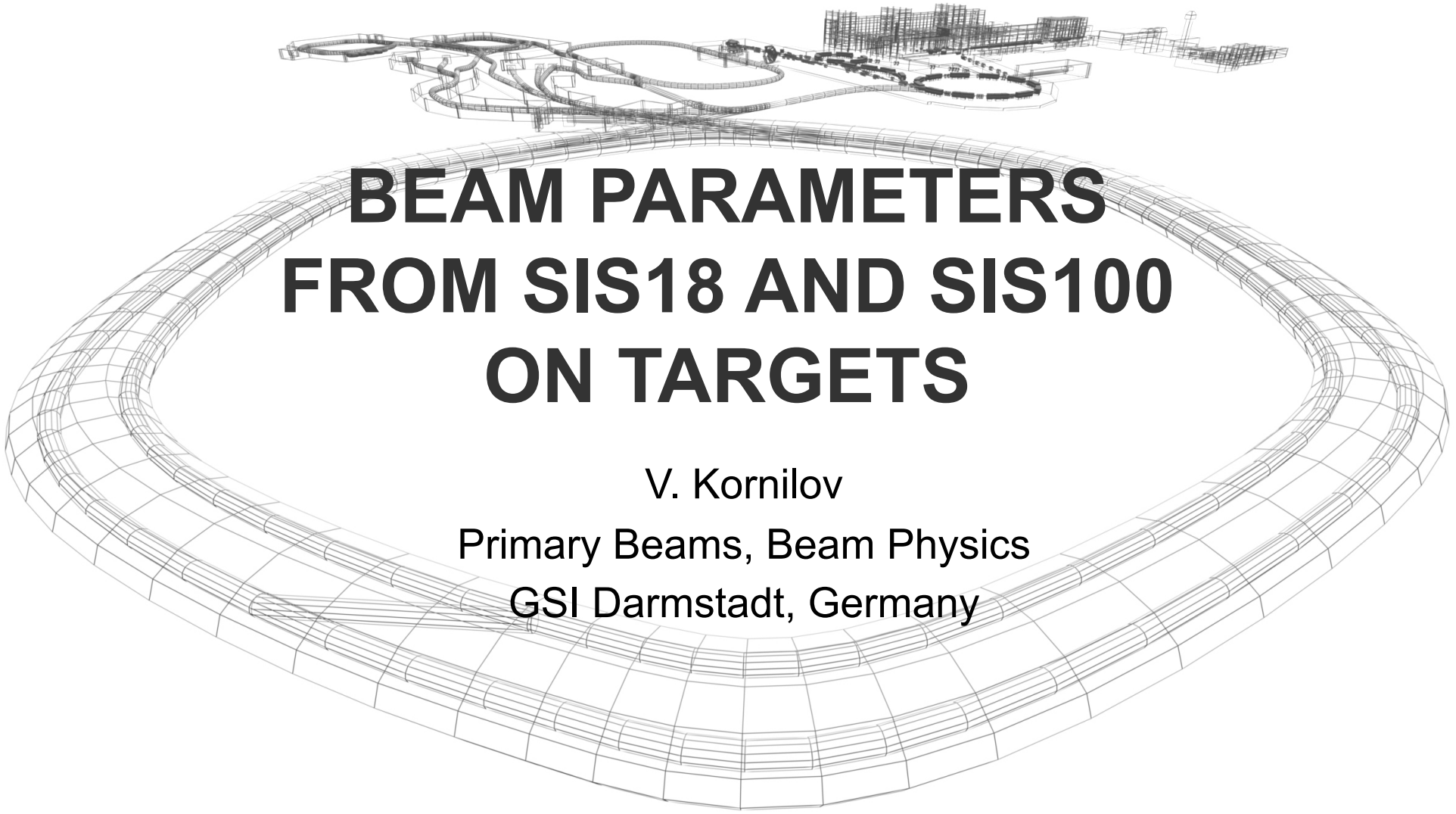


BEAM PARAMETERS FROM SIS18 AND SIS100 ON TARGETS

V. Kornilov

Primary Beams, Beam Physics

GSI Darmstadt, Germany

FAIR: BEAM PARAMETERS

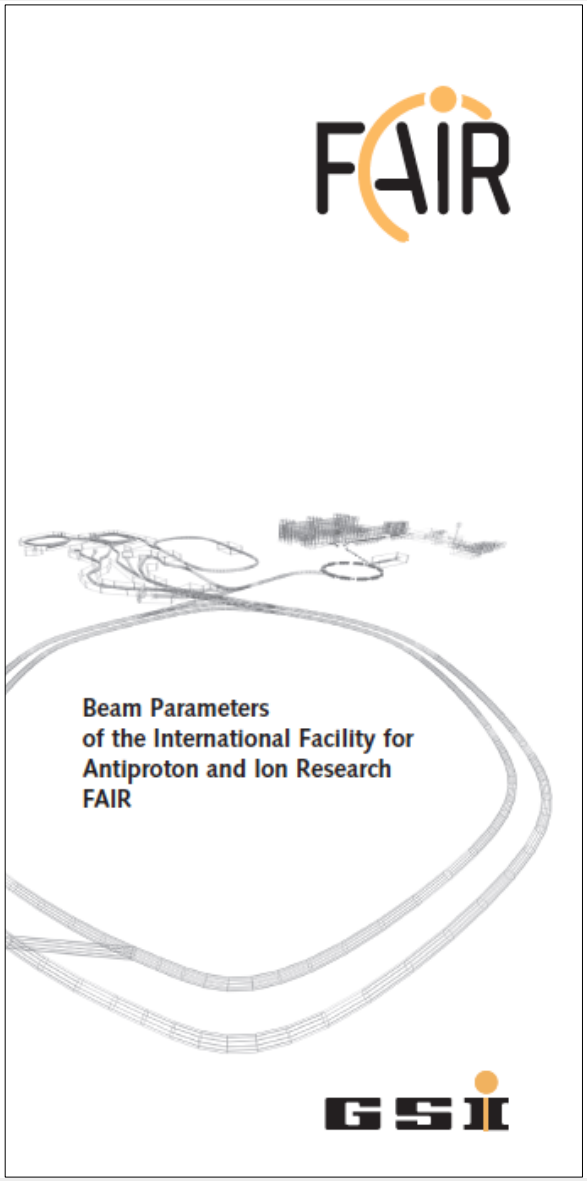
2007: Brochure by O. Boine-Frankenheim, A. Lehrach, P. Spiller, M. Steck

after this, many tables/lists by O.Boine-Frankenheim

2015: “FAIR Operation Modes” by P.Schütt, O.Geithner, P.Forck

Presently: many changes, discussions, extremely scattered information.

This talk: the limited aspects of the comparison for beams from SIS18 and SIS100



11@22+PANDA and BEAM PHYSICS

- NUSTAR
  - R^3B
  - HISPEC/DESPEC
  - MATS
  - LASPEC
  - ILIMA
  - EXL
- APPA
  - SPARC
  - HEDGEHOB
  - BIOMAT
- CBM-HADES
  - CBM
  - HADES
- Antiprotons
  - PANDA

Working package “SIS100 Beam Dynamics”

Long lists of ion types, beam parameters, scenario

We need the main challenges for the beam physics and accelerator technology

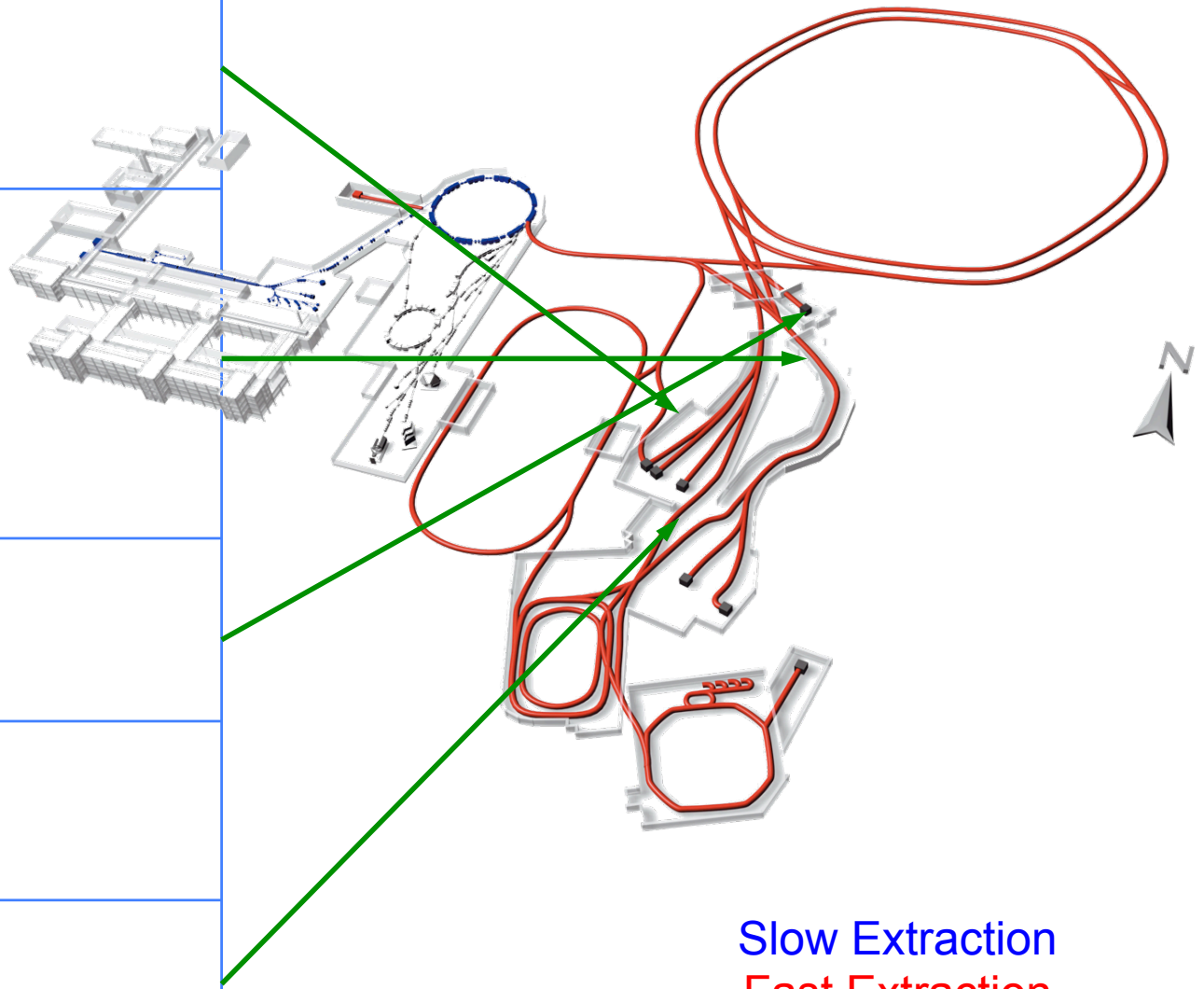
This talk: try to simplify but keep the essence

Reference beams: extreme A/Z, Z^2/A, beam intensities, etc

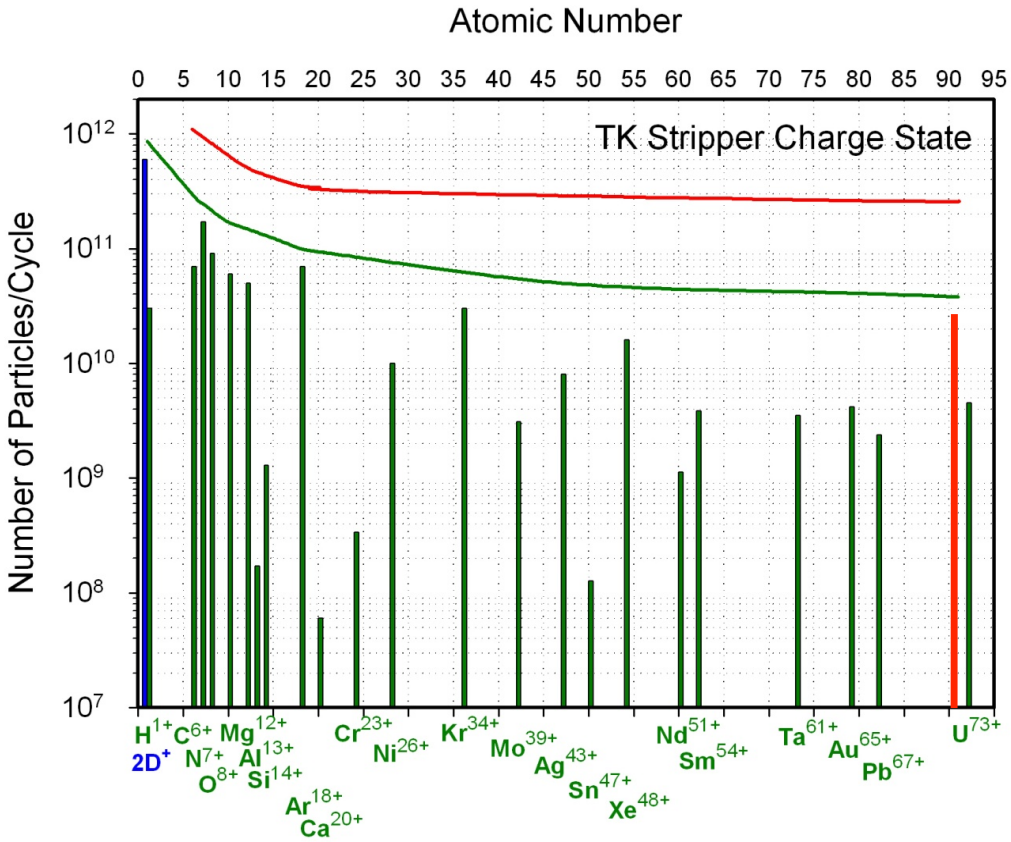
Reference beam parameters for the challenges

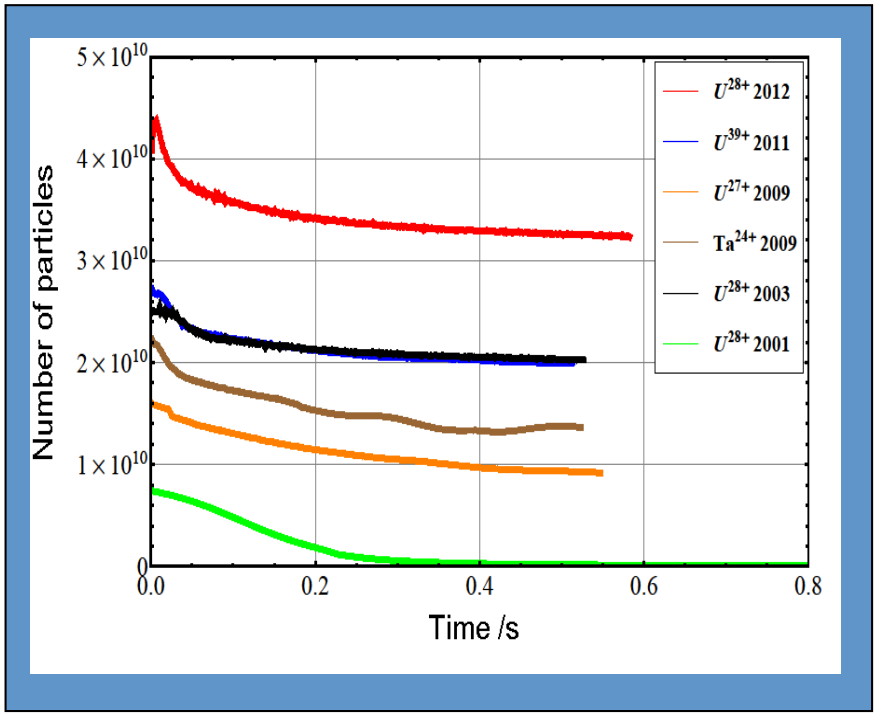
TARGETS

- APPA Cave
  - Hedgehob, BIOMAT
  - SPARC fixed-target
- Super-FRS Target
  - LEB NUSTAR
  - HEB NUSTAR
  - ILIMA NUSTAR
  - EXL NUSTAR
- CBM Cave
  - CBM & HADES
- Strip-Foil
  - SPARC storage-ring
- Pbar Target
  - PANDA



SIS18: THE BOOSTER AND THE PROVIDER





Ar^{18+} 8×10^{10} ppp: at the space-charge limit now

U^{28+} 1.3×10^{11} ppp: further upgrade

P.Spiller, 2013

BEAM PARAMETERS

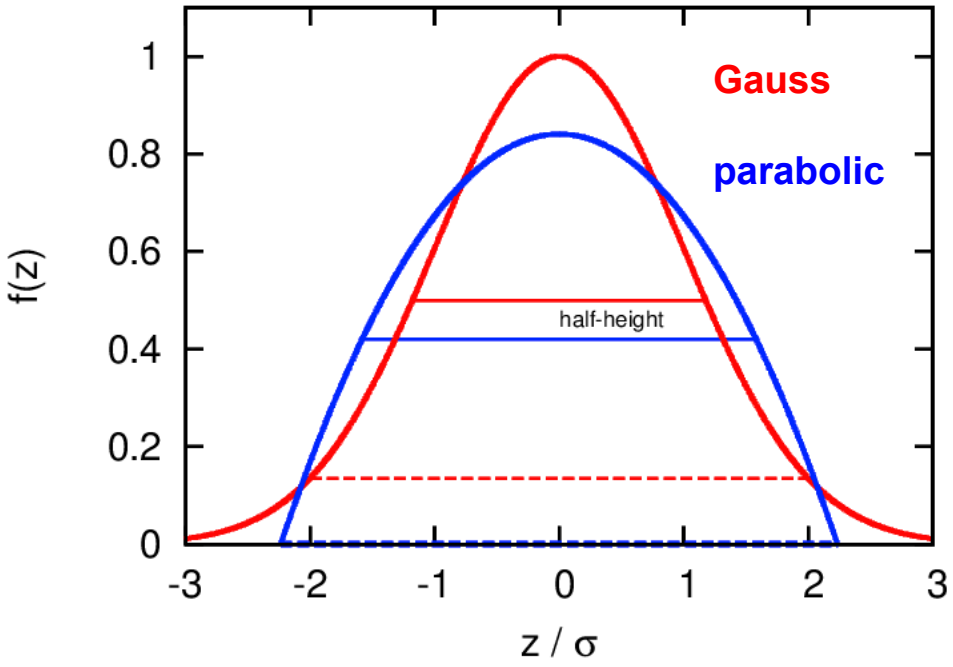
Different distributions:
The concept of the rms-equivalent beams

Bunch length

Total length:
- Gauss L = 4 σ
- parabolic L = 4.47 σ

Half-height length:
- Gauss L = 2.35 σ
- parabolic L = 3.16 σ

Different definitions: twice the difference



Transverse emittance

horizontal, vertical.

$\varepsilon_{total} = 4\ \varepsilon_{rms}$

$a_{total} = 2\ a_{rms}$

HEDGEHOB: APPA Cave, Fast Extraction

With the beam line from SIS18, both operations SIS18/SIS100 are possible

Stage Ib:
- conditions: the conditions of Stage Ia, (optionally) running pLinac and successful optimization of UNILAC and SIS-18 performance
- may be expected in 2020 – 2022

	Ion	Max. energy, AGeV	Max. intensity, per pulse	Focal spot size, (2*σ) mm	Pulse duration, ns	
1	U28+	0.2	4e10	1.3	100	
2	U39+	0.35	4e10	1.2	100	excl
3	U73+	1.0	1e10	0.9	100	
4	p	4.5	5e12	–	100 – 800	

Stage II: SIS-100 "early" beams
- conditions: civil construction is finished, SIS-100 is operating, HEDgeHOB beam line including the FFS are ready; the HEDge shielding
- may be expected in 2020 – 2022

	Ion	Max. energy, AGeV	Max. intensity, per pulse	Focal spot size, (2*σ) mm	Pulse duration, ns	
1	U28+	2.0	1 - 2e11	0.8	100	
2	U92+	8.4	2 – 3e10	0.4	100	stripping
3	p	10.0	1 – 2e13	–	50 – 3400	if pLinac 5e11; pr increased up to 29 GeV

SIS18	SIS100
U^{28+} 0.2 GeV/u 1.3×10^{11} ppp	U^{28+} 2 GeV/u 5×10^{11} ppp
p 4.5 GeV 3×10^{11} ppp	p 10 GeV 2×10^{13} ppp
bunch length 100 ns	bunch length 100 ns later 50 ns

acknowledgments:
D.Varentsov

- Very low rep-rate (hours), thus ppp (particles per pulse) important
- For higher energies from SIS18: U^{73+} cooled, but low intensities 3×10^{9} ppp

Stag
- conc
the HI
- may

	Ion	Max. energy, AGeV	Max. intensity, per pulse	Focal spot size, (2*σ) mm	d
1	U28+	2.0			
2	p	10.0			

Requirement: compressed, high-intensity bunches

SIS100 needed for high intensities, high energies, short bunches

BIOMAT: APPA Cave, Slow/Fast extraction

With the beam line from SIS18, both operations SIS18/SIS100 are possible

	SIS18	SIS100
MAT	U^{73+} 0.7 GeV/u 1×10^{10} ppp	U^{73+} 0.7 GeV/u 4×10^{10} ppp
BIO	U^{73+} 0.1-1 GeV 10^{8} ppp	U^{73+} 1-10 GeV 10^{8} ppp

acknowledgments:
D.Severin

- Radiation protection issues limit 5×10^{10} ppp U at 0.7 GeV/u
- MAT: machine max intensity, fast extraction 50 ns
- BIO: low intensities, 0.1-10 GeV/u, slow extraction, spill quality

Requirement: compressed bunches / high-quality spill

MAT: SIS100 needed for higher intensities
BIO: SIS100 needed for higher energies

LEB/HEB: S-FRS target, Slow Extraction

Both operations SIS18/SIS100 are possible

SIS18	SIS100
Ar^{18+} 0.4 GV/u 8×10^{10} ppp	Ar^{18+} 0.4-2.7 GeV/u 3×10^{11} ppp
U^{28+} 0.2 GeV 1.3×10^{11} ppp	U^{28+} 1.7 GeV 5×10^{11} ppp
1×10^{11} p/s	2×10^{11} p/s

acknowledgments:
H.Weick

- High-quality beam spill needed (integration times 1-10 μs), small spot size
- Slow extraction 1 sec, a large variety of ions
- Requirements Ar^{10+} 8×10^{12} ppp: above the space-charge limit (1×10^{12} ppp)

Requirement: high-quality spill, high-intensity bunches

SIS100 needed for high energies

SPARC fixed-t: APPA Cave, Slow Extraction

Primary path is from SIS18.
Under discussion: another strip-foil from SIS100.

SIS18	SIS100
U^{73+}	U^{73+}
1 GeV/u	2-10 GeV/u
1×10^{10} ppp	4×10^{10} ppp

- E > 1 GeV up to 10 GeV
- U^{92+}–U^{88+} for the cave, 10^8 ppp
- small spot size needed
- Higher intensities needed (low U^{91+} production rate)

acknowledgments:
Y.Litvinov

Requirement: high-quality slow extraction

SIS100 needed / not needed ?

SPARC storage-r: strip-foil, Fast Extraction

Only the operation from SIS18

SIS18
U^{73+}
0.2-1 GeV/u
1×10^{10} ppp

acknowledgments:
Y.Litvinov,
A.Dolinsky

- Stable ions
- With HESR: rep rates of 10 sec – 1 min
- CR: cooling up to 10^8 at 0.74 GeV/u, 1.5 sec cycle
- With CR: limited by the Bρ = 13 Tm
- Avoiding CR: many combinations with HESR Bρ = 5-13 Tm (5-50Tm)

Requirement: high-intensity bunches

SIS100 not needed, beam line SIS18−(FRS/ESR)−HESR needed

ILIMA: S-FRS target, Fast Extraction

Only the operation from SIS100

SIS100
U^{28+}
1.5 GeV/u
5×10^{11} ppp

acknowledgments:
Y.Litvinov,
A.Dolinsky

- Very low production rates of short-living ions, thus high rep rates needed
- No special requirements on bunch length, sizes, …
- SFRS-like requirements
- Large variety of ions
- Physics discoveries depend on intensity

Requirement: high-intensity, high rep-rate bunches

SIS100 needed

EXL: S-FRS target, Fast Extraction

Only the operation from SIS100

SIS100
U^{28+}
1.5 GeV/u
5×10^{11} ppp

acknowledgments:
Y.Litvinov,
A.Dolinsky

- Very low production rates of short-living ions, thus high rep rates needed
- Because of cooling in the CR, 50 ns bunches needed

Requirement: high-intensity, high rep-rate, compressed bunches

SIS100 needed

CBM-HADES: CBM cave, Slow Extraction

No SIS18 beam line: first SIS18 operations (precomm) then SIS100 operation

SIS18 (HADES only)	SIS100
N^{7+}, Au^{65+} 1 GeV/u 10^7 ppp	Au^{79+} 2-11 GeV/u 10^{10} ppp
	p 5-29 GeV 10^{12} ppp

acknowledgments:
C. Sturm,
J. Pietraszko

- Requirements on the transverse spot size (2 mm)
- Requirements on the transverse tails/halo (<10^{-5} beyond 5 mm)
- High quality requirements on the spill structure (30 ns time scale) shaping times

Requirement: high-quality spill

SIS100 needed for the CBM program: high energies

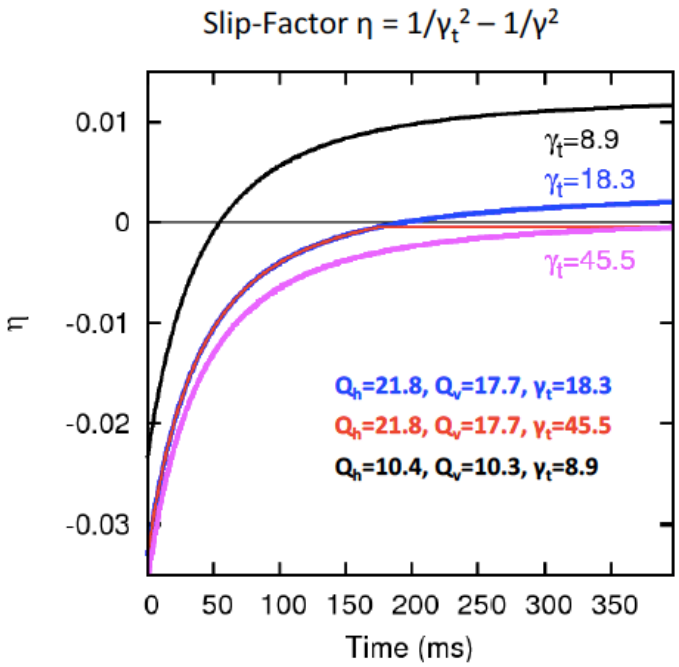
SLOW EXTRACTION

KO Slow Extraction:
more stable beam spot,
better control of the beam time structure

Simulations Slow Extraction SIS100
extracted beam is not the cirulating beam.
emittances at 2.7 GeV (simulations S.Sorge):
horizontal: 1.0 mm mrad (0.4−3)
vertical: 0.6 mm mrad (0.4−1.3)
Given by the main magnets field errors.

Further effects: space-charge

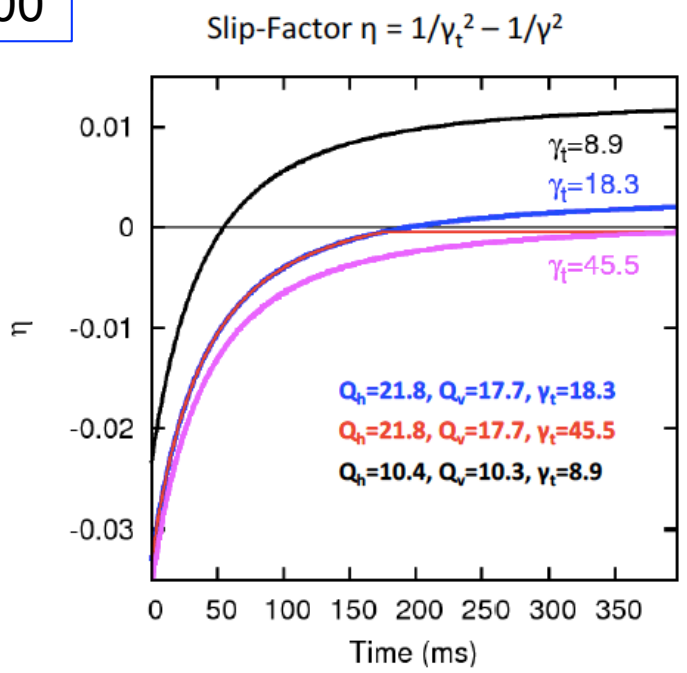
Proton slow extraction:
with the low−γ_t lattice not possible.
Thus the operation with the ion-type lattice
(γ_t−transition without jump)



PANDA: Pbar-target, Fast Extraction

Only the operation from SIS100

SIS100
p 29 GeV 2×10^{13} ppp
bunch length 50 ns



- Transition crossing (shifting) in SIS100
- Involved RF manipulations, ξ− compensation, …
- Rep-rate 10s

acknowledgments:
A.Dolinsky

Requirement: compressed, high-intensity bunches

SIS100 needed for high energies protons

BEAMS FROM SIS18 AND SIS100

		accelerator challenges		
BEAMS FROM SIS100 ONLY	**ILIMA**	**HI**		
	EXL	**HI**	**CO**	
	CBM			**SP (p)**
	PANDA	**HI**	**CO**	
BEAMS FROM SIS18 & SIS100	*SIS100 critical for energies / intensities*			
	HEDGEHOB	**HI**	**CO**	
	BIOMAT		**CO**	**SP**
	Comparable beams from SIS18 & SIS100			
	LEB / HEB	**HI**		**SP**
BEAMS FROM SIS18 ONLY	**SPARC stor-r**	**HI**		
	SPARC fixed-t			**SP**

Slow Extraction, Fast Extraction

HI: High Intensity, CO: compressed bunch, SP: high-quality spill