nToF11: The Multi-MW target experiment in TT2A

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http://cern.ch/proj-hiptarget

APC, June 2005

Outline

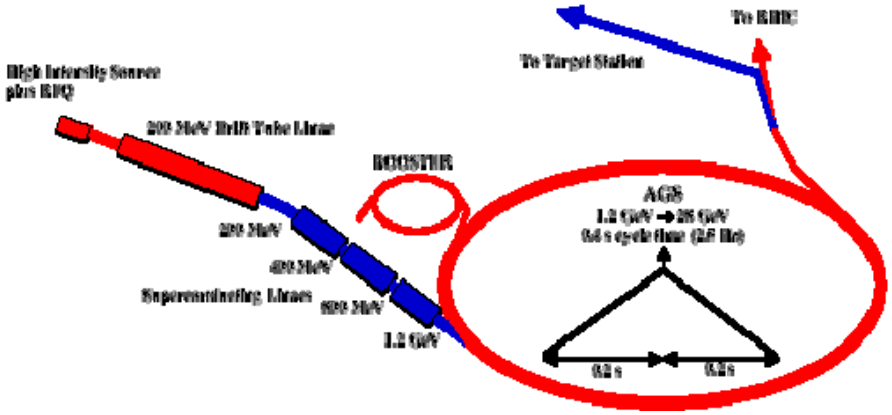
- Collaboration
- Target concept of liquid metal jet
- Installation in TT2A
  - Mercury loop (target), solenoid, beam line, power, cryogenics, safety
- PS beam request
- Time schedule

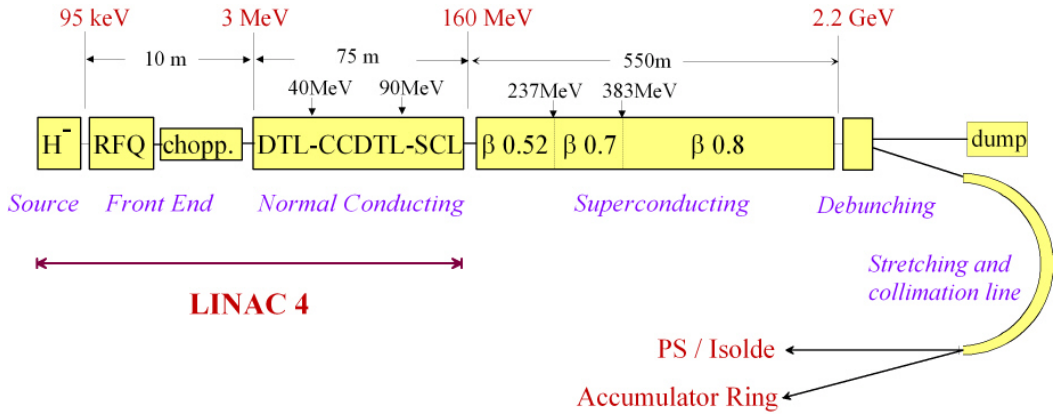
http://cern.ch/proj-hiptarget

nTOF11 (MERIT) collaboration

- BNL, CERN, KEK, ORNL, Princeton Univ., RAL
  - Spokespersons: K. Kirk (BNL) and K.McDonald (Princeton)
  - Local CERN contact: **A. Fabich**, H. Haseroth, J. Lettry
- Experiment approved as nToF11
  - installed on FTN beam line upstream of nTOF target
  - No scientific correlation with nTOF (1-10)
- also referred to as MERIT experiment
  - **MER**cury **I**njected **T**arget
  - study feasibility of the liquid jet target!

4MW Proton drivers



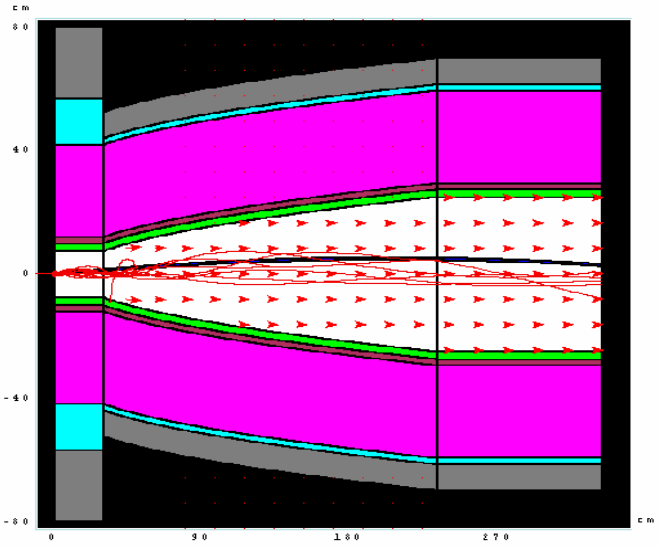


	BNL AGS	CERN SPL
Energy [GeV]	24	2.2
Proton intensity/pulse	$3\ 10^{13}$	$24\ 10^{13}$
$t_{\text{bunch-to-bunch}}$ [ms]	20	20
Pulse length [ns]	5	3200
Focusing element	20 T solenoid	Magnetic horn

- R&D of target concepts for these multi-MW proton beams needed

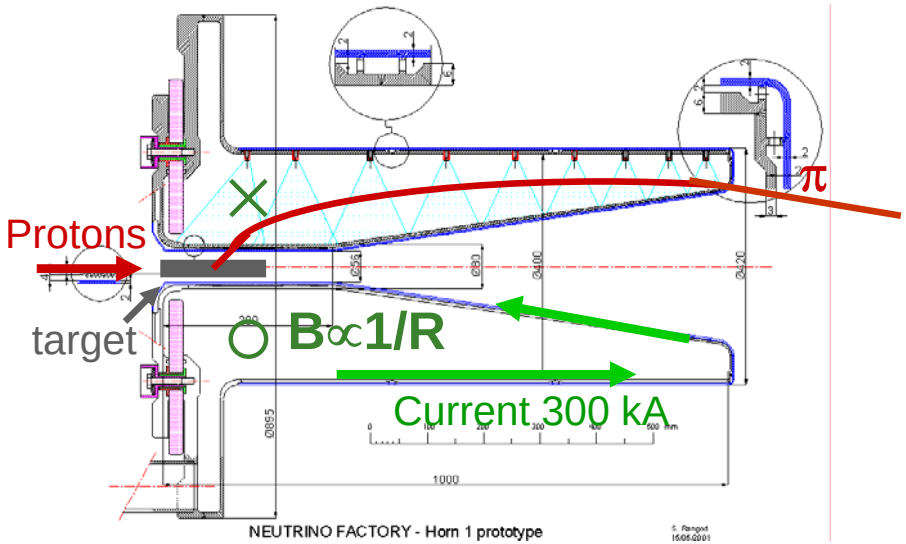
Focusing options

- Solenoid (US)



- B = 20 T at target
- Adiabatic focusing channel
- Two charges collected can be separated by RF

- Magnetic Horn (CERN)

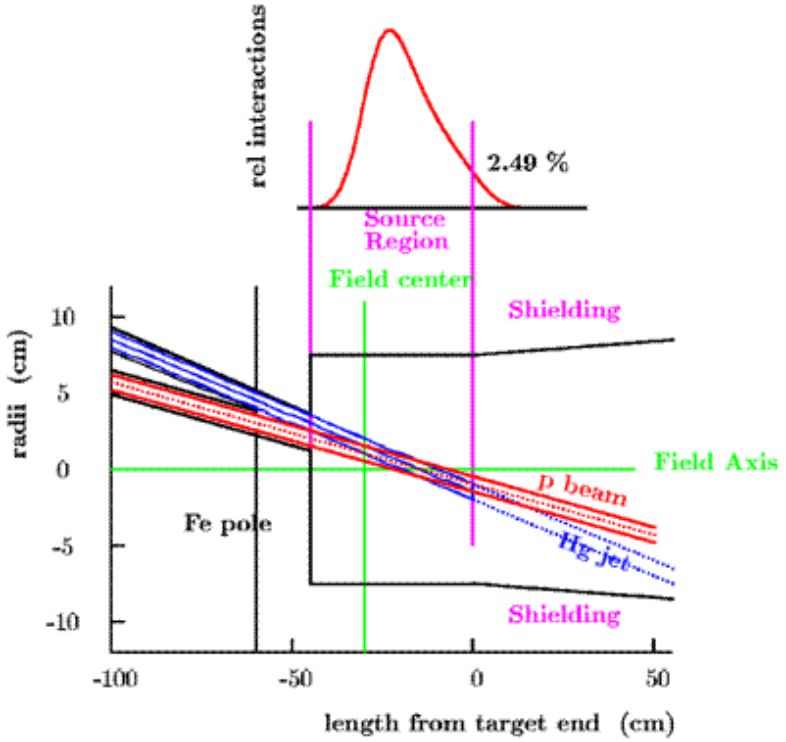


- B=0 T at target
- Focuses only one charge state (required for super-beam)
- highly restricted space

Jet Target Concept

- Provide target system for a multi-MW proton beam
- Target volume replaced at the p-pulse repetition rate
  - Deal with thermal management, radiation damage, thermal shock
- NO beam windows in contact with target material!

- Jet target
  - Mercury
    - High Z
    - Liquid at STP
    - Toxic
  - v = 20 m/s
  - d = 1cm
  - α = 100 mrad



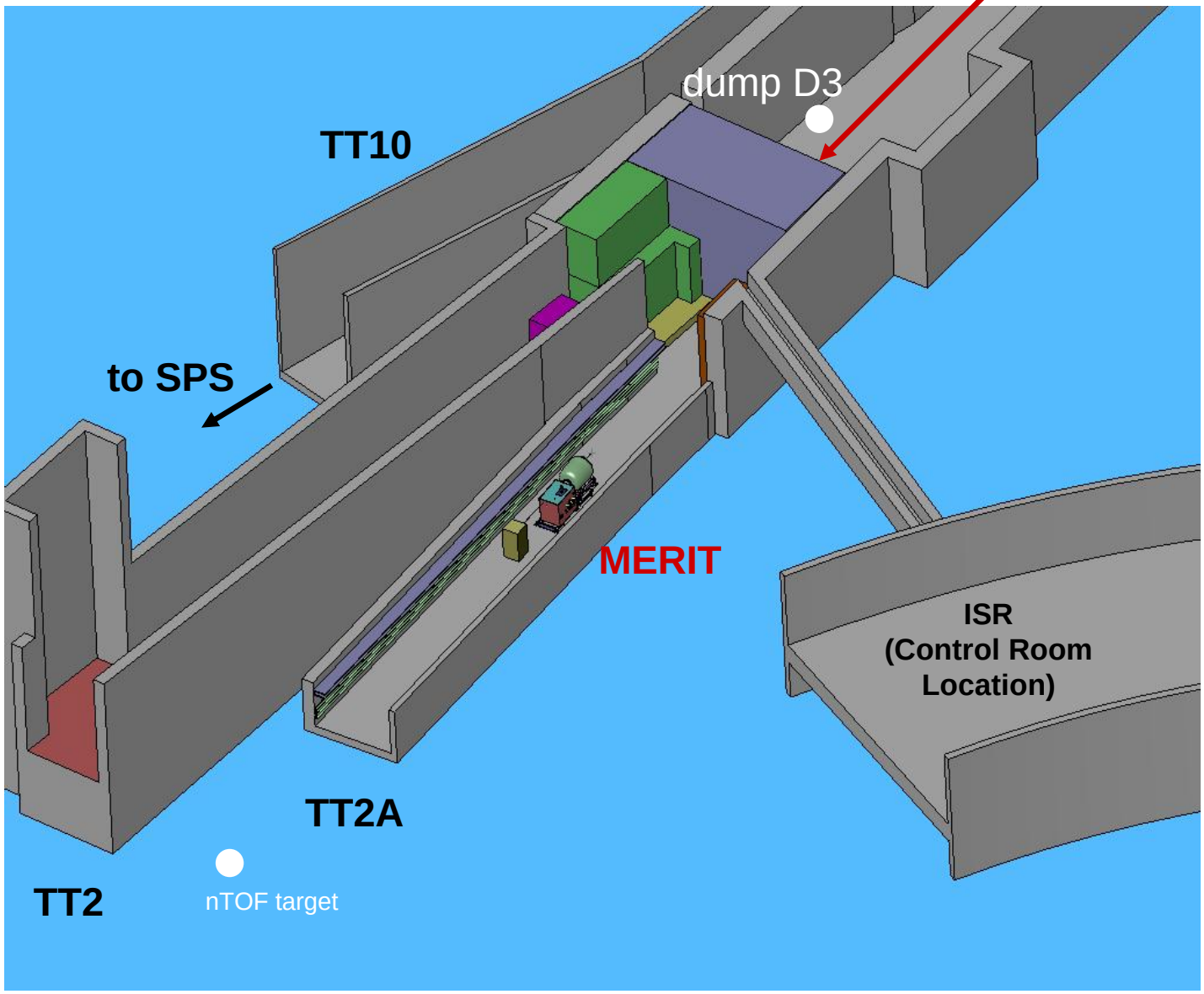
Experimental history

	ISOLDE	GHMFL	BNL	TT2A	NuFact
p+/pulse	3 10^{13}	----	0.4 10^{13}	2.5 10^{13}	3 10^{13}
B [T]	---	20	---	15	20
Hg target	static	15 m/s jet (d=4mm)	2 m/s jet (d=10mm)	20 m/s jet (d=10mm)	20 m/s jet (d=10mm)
	DONE	DONE	DONE	2007	DESIGN

What is the impact on the jet target by a 4 MW proton beam & 20 T field?

- Measure behavior of mercury jet and particle production as a function of beam parameters and magnetic field strength!
- Proof-of-principle test of a mercury jet target for MMW proton beams
- Bench mark for simulation codes

Installations



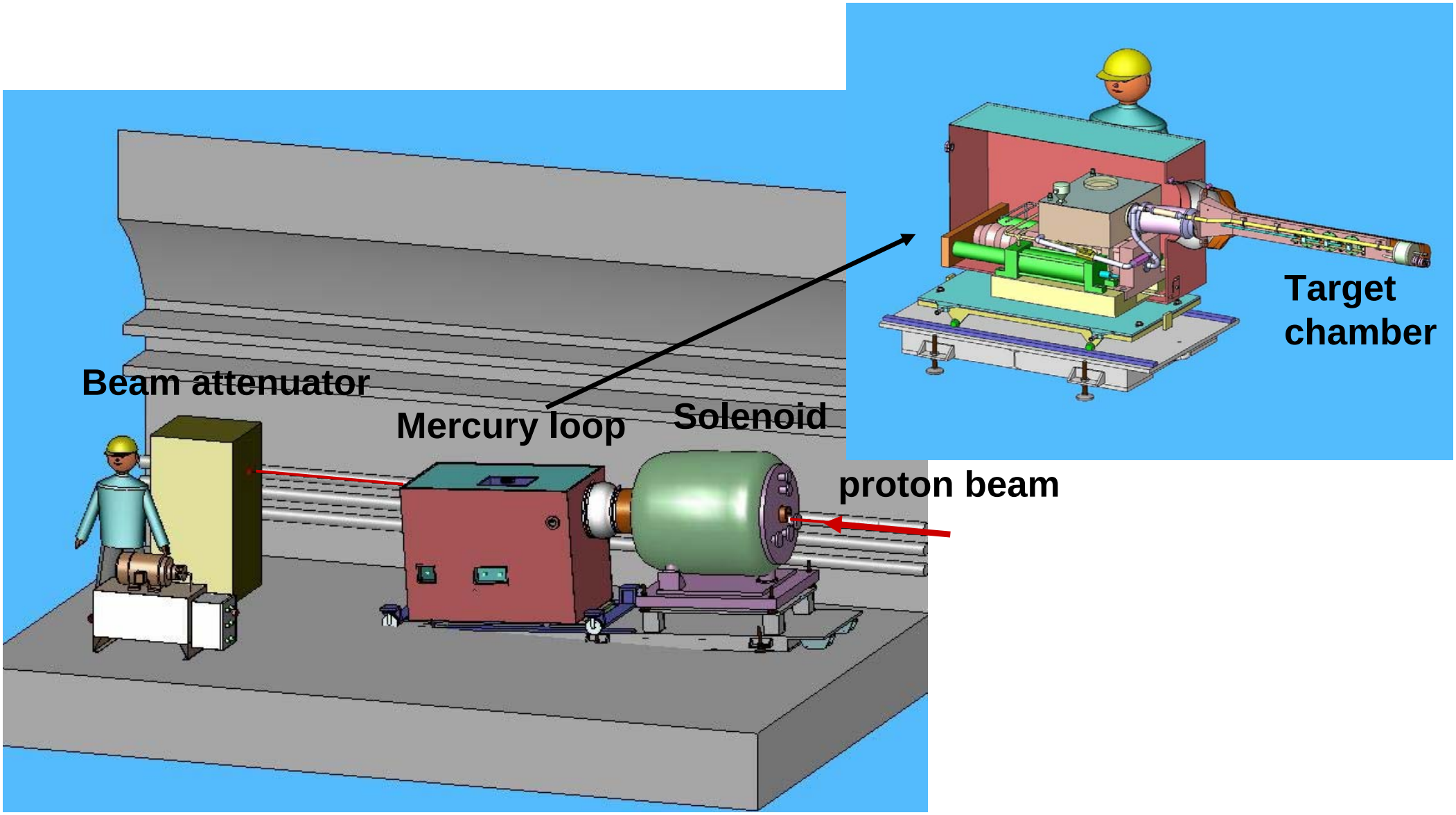
Cryogenics

- Solenoid
- Hg loop
- attenuator

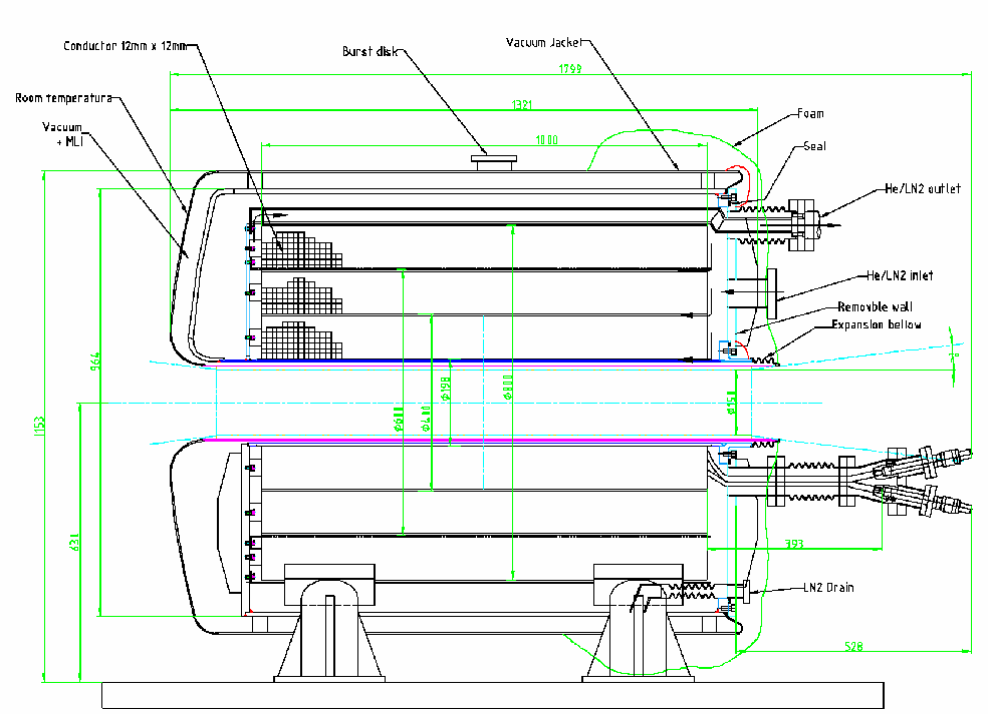
Power supply

Control room

On the Beam Line

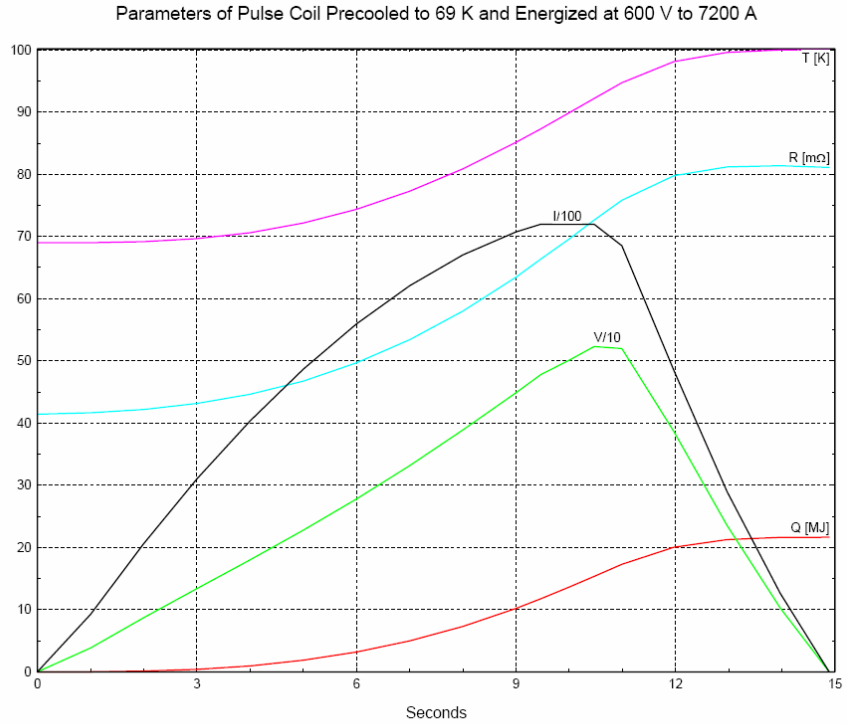


High Field Pulsed Solenoid



- collecting device for mesons
- 80 K Operation to optimize for costs
- 15 T with 4.5 MW Pulsed Power
- 15 cm warm bore (L=1m)
- 4.5 ton

Peter Titus, MIT

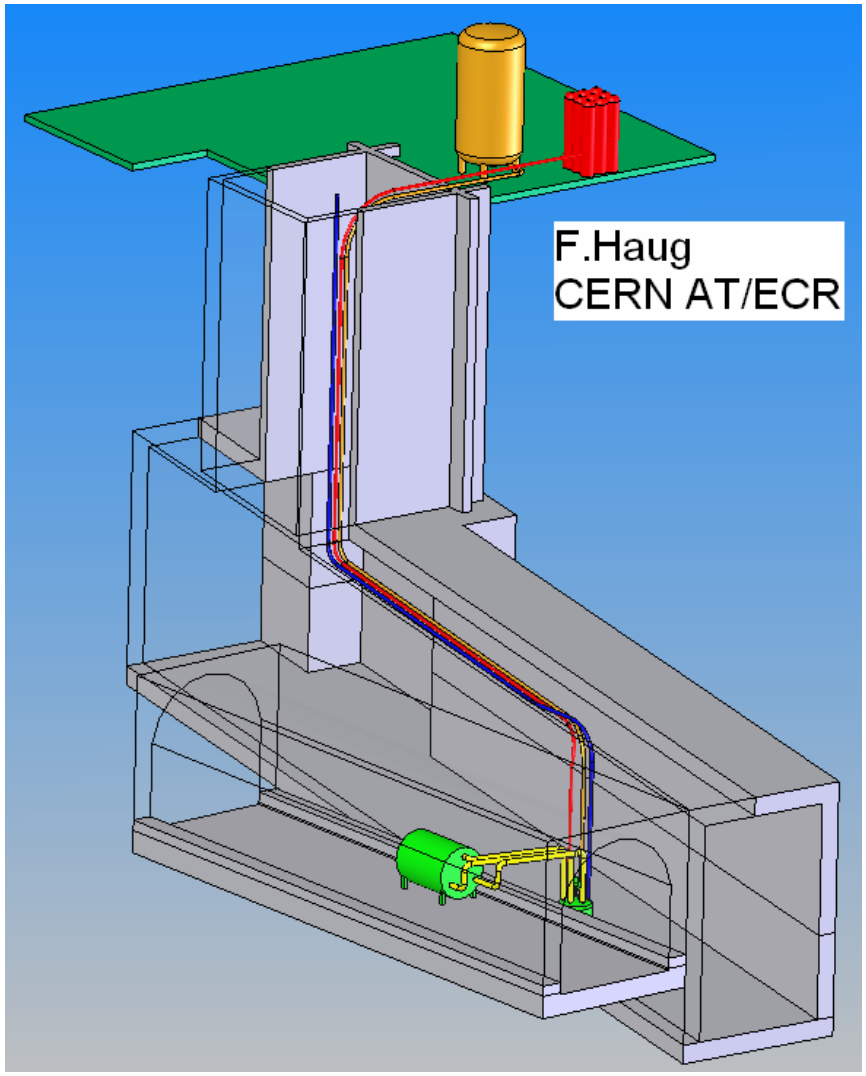


Bob Weggel's 10-14 analysis of the LN2 magnet operation

• power cycle 15 seconds

• Cooling cycle of solenoid limits to a minimum repetition time of 30 minutes between two pulses!

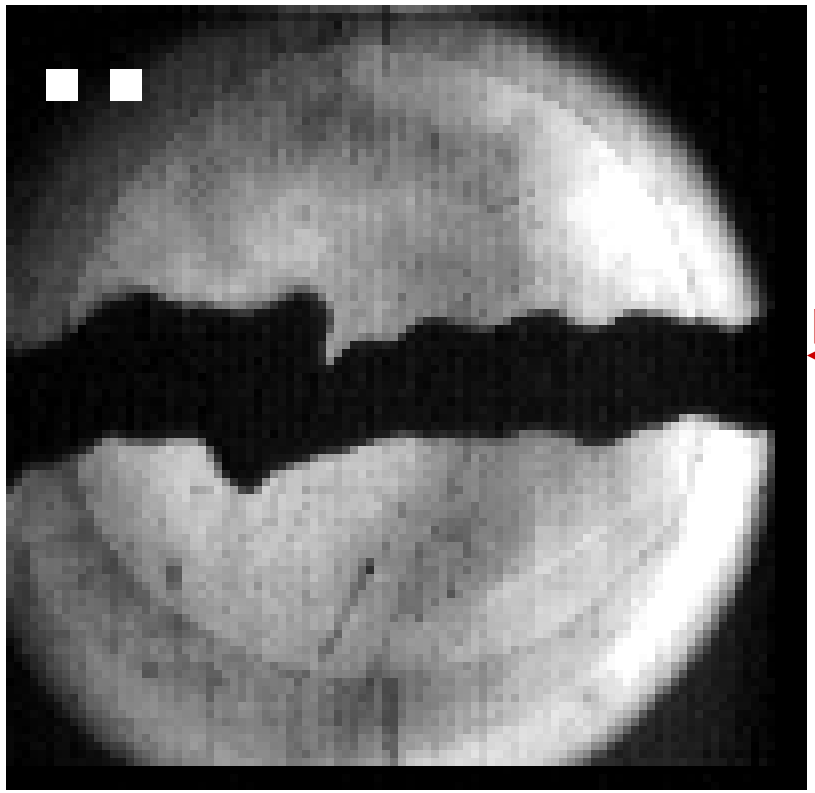
Power supply & Cryogenics



- Reuse power converter from SPS extraction system towards West area
- To be installed in AD hall

Diagnostics

- **Optical System**
  - Direct observation of jet behavior



BNL E951, H.Kirk et al.

- **Particle detector**
  - Simple scintillator(s)
  - Covering small solid angle
  - No particle ID
  - measure rel. particle yield
  - Interaction efficiency
  - Does cavitation reduce the secondary particle yield?
  - Pump-probe method

Safety

- Radiation
- Access
- Mechanical safety
- Mercury
- LN2 cooling
- High magnetic field
- …
- “Waste” management
- Decommissioning

SAFETY CONTACT PERSON FOR ALL MATTERS: Bruno Pichler Tel.: 160889	
	Responsible
DSO of AB	Paolo CENNINI
General Safety	Bruno PICHLER
Radiation	Thomas OTTO
Gas and Chemicals	Jonathan GULLEY
Electricity	Fritz SZONCSO
Emergency stops	
Magnetic Field	
Laser	
Fire	Fabio CORSANEGO (material also J.Gulley)
Material	
Mechanical safety	Alberto DESIRELLI
-- --- --- --- ---	also Maurizio BONA
Cryogenics	Gunnar LINDELL

- Passed through safety reviews prior to approval

The PS beam request of MERIT

- Based on nominal values of ν-fact design
  - CERN SPL design
  - US scenario: study IIA
- Range specifications allow systematic studies
  - Magneto-hydrodynamics
  - cavitation
  - extrapolate to higher beam power
  - Benchmark simulation codes

- Momentum
  - 24 GeV/c
- Pulse intensity
  - Up to $32*10^{12}$ p^+/pulse
- Pulse length
  - 0.05 to 10 microseconds
- Pulse repetition
  - 20 ms
- Spot size
  - 1.3 mm < r_{rms} < 4 mm
- Beam position scan
  - -5 mm < Dx/y < 5 mm

Magneto-hydrodynamics

Magnetic forces on eddy currents induced by inhomogeneous B-filed

Aim: Study surface oscillations induced by proton beam.

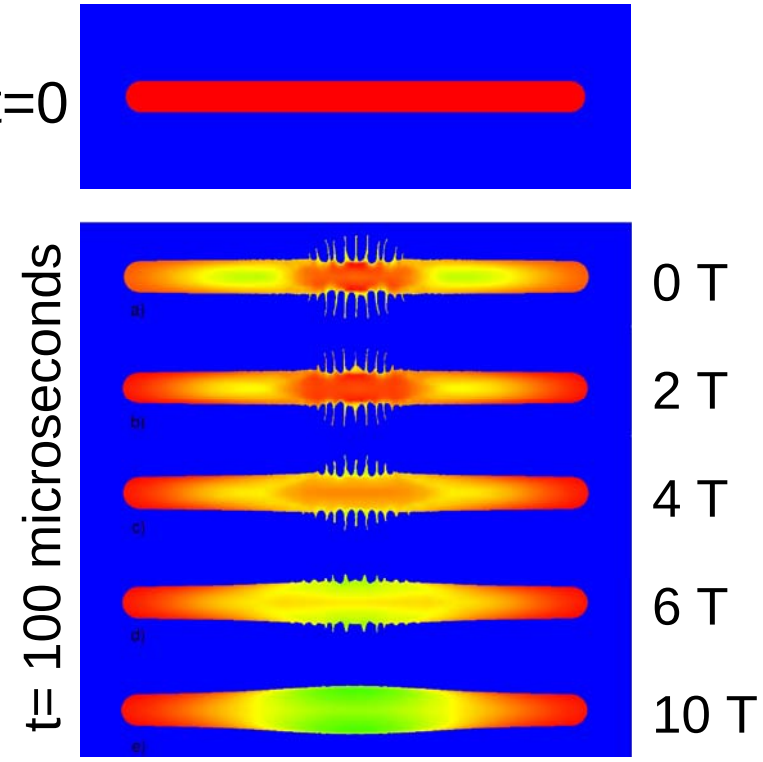
(and other MHD effects)

Parameters:

- 0 T < B < 15 T
- B=0 corresponds to magnetic horn!

PS beam:

- 24 GeV/c
- 4 bunches
- Minimum spacing
- 1- maximum *10^{12} p^+/bunch



Frontier code, R. Samulyak et al.

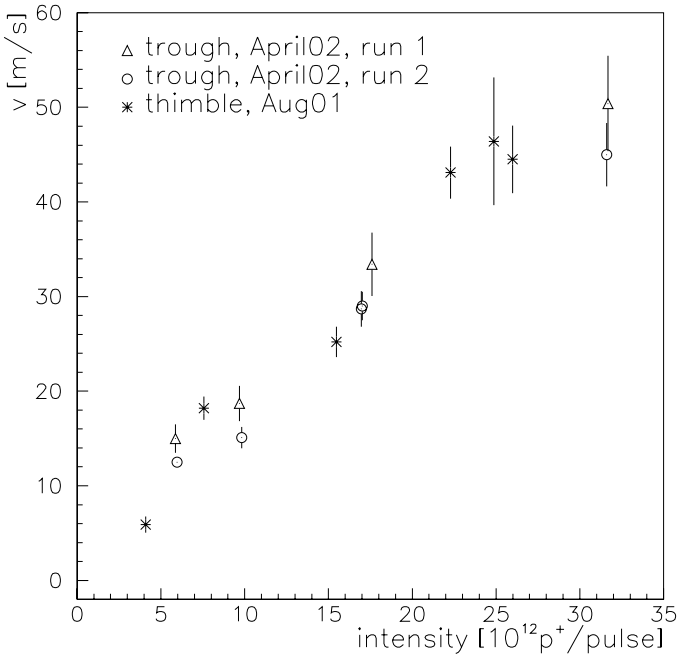
Beam Momentum

- Requested: 24 GeV/c
  - US design is 24 GeV/c
  - achieve similar shower profile
  - achieve necessary energy deposition density

Machine	Energy	r spot rms	Intensity	dE/dx peak
	GeV	mm	p+	J/g
AGS 4MW	24	1.5	32	206
CERN SPL	2.2	3	260	181
CERN PS	24	1.2	28	215

Intensity/bunch

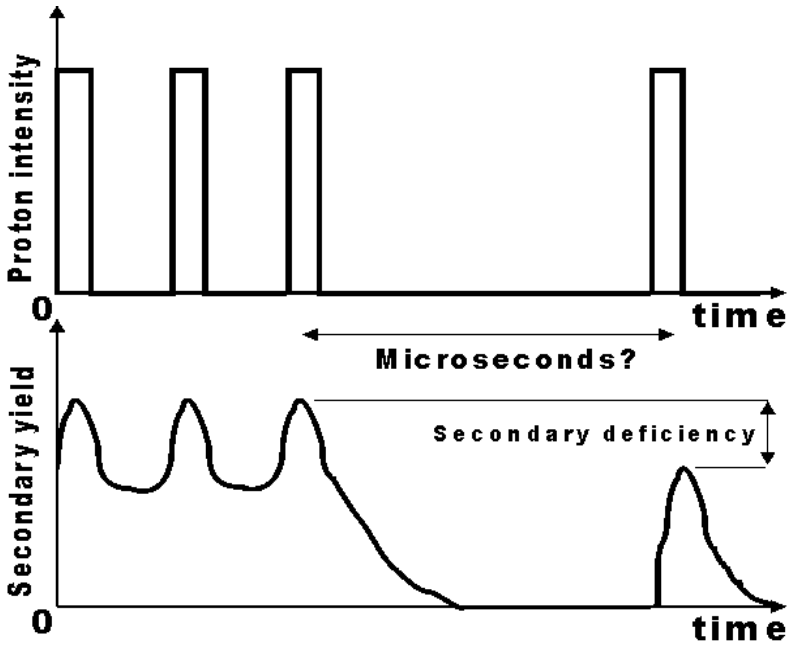
- Requested:
  - ν-fact design is $32*10^{12}$ protons/pulse
- "promised"
  - 4 bunches à $5*10^{12}$ protons
- Profit from
  - Double batch injection: 8 bunches at h=8?
  - CNGS improvement?
  - Other advancements?



Isolde, 2002

Pulse length

- Aim: Study cavitation process
  - Pulse length 0.05 - 10 μs



- PS machine
  - h=8
  - Bunch length 50 ns
  - Bucket distance n*250 ns
  - Limited to 2μs pulse length
    - kicker strength: no two kicks at 24 GeV/c
  - > 2μs pulse length
    - Operate at 14 GeV only and Multi-kick mode

Pulse repetition rate

- Aim: study 50 Hz operation
  - Extract two batches of high intensity separated by 20 ms
- PS machine
  - h=8
  - repetition rate of PS complex (1.2 s) not convenient
  - Bucket distance n*250 ns
  - Extract two batches in multi-batch mode
    - Operate at 14 GeV/c only
    - Multi-kick mode

Beam Spot

Aim: achieve nominal beam spot size and/or energy density

- Nominal r_{rms}=1.5 mm (US scenario)
- Requested: r_{rms}=1.2 mm
  - Reach SPL energy density

Machine	Energy	r spot rms	Intensity	dE/dx peak
	GeV	mm	p+	J/g
AGS 4MW	24	1.5	32	206
CERN SPL	2.2	3	260	181
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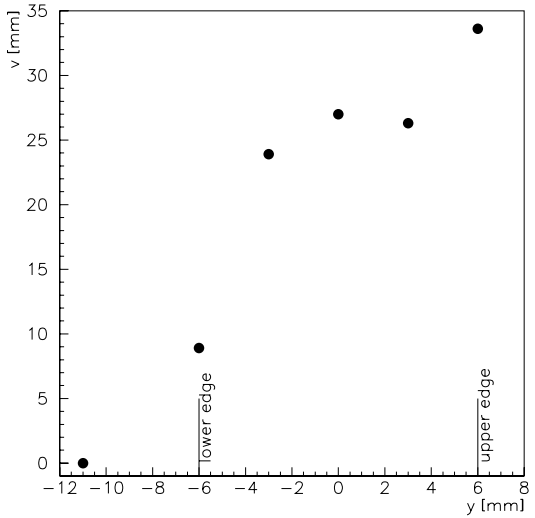
Beam position scan

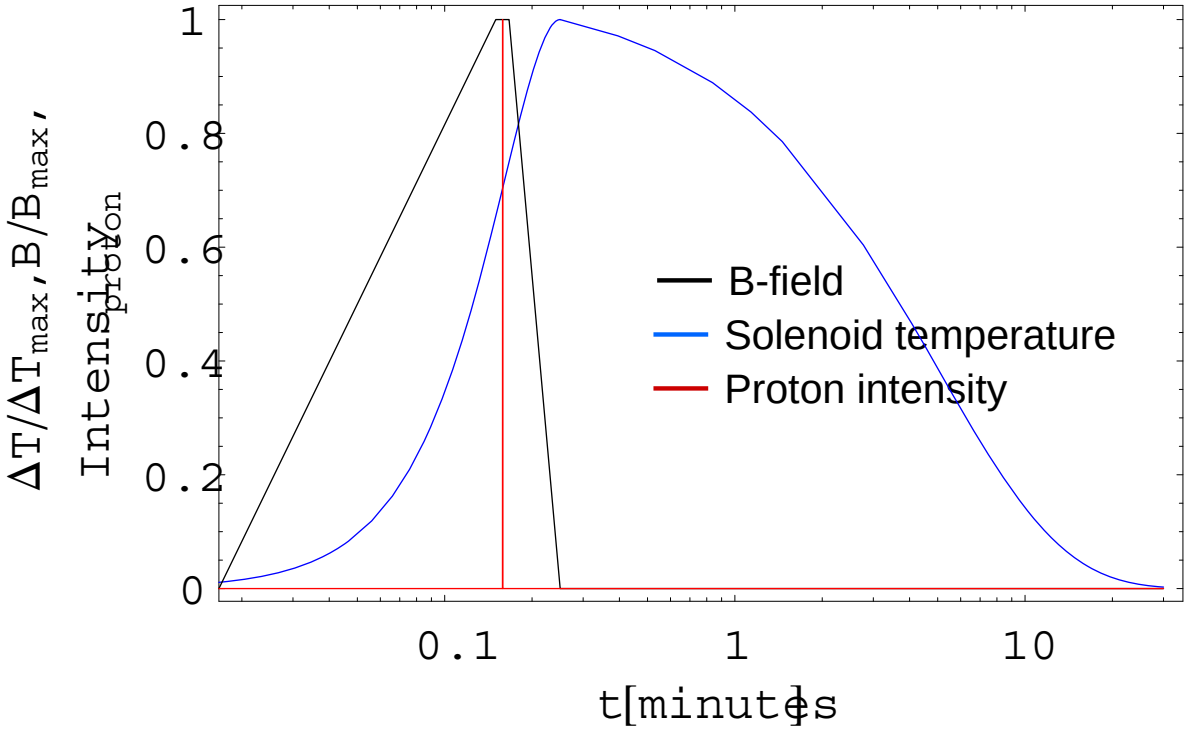
- Aim: study effect of misalignment
- Vary position of beam in the range of the target radius
  - -5 mm < Δx/y < 5 mm
  - Both planes needed
    - as diagnostics are in one plane only



Isolde, 2002

Operation Scenario (1)

- Single pulse experiment
  - About 150 extractions (integrated intensity < 3 10^{15} protons)
  - One extraction every ~30 minutes



and repeat

- Proton beam properties change from pulse to pulse
  - Repetitions possible

Operation Scenario (2)

#	bunch/pulse	PS (h=8) buckets filled	…	B-field [T]	…	Hor. displaced [mm]	repetition
9	4	1-2-3-4	.	0	.	0	2
11	4		.	5	.		2
13	4		.	10	.		2
15	4		.	15	.		2
17	4		.		.	5	2
19	4		.		.	+2.5	2
21	4		.		.	-2.5	2
23	4		.		.	-5	2
.	..	..	.	..	.	..	..
45		1-2-3-6	.		.		2
47		1-2-3-7	.		.		2
49		1-2-3-8	.		.		2
.	..	..	..	..	..	..	.
150							

Not all beam properties and variations shown.

- Full program needs ~3 weeks of beam time
  - No night shifts: release of accumulated oxygen
  - Does not include time for initial beam tuning

Time schedule

- **2003**
  - Autumn LOI
- **2004**
  - Spring proposal to INTC
  - Summer detailed study at CERN (ongoing)
  - Summer solenoid construction launched
- **2005**
  - January solenoid delivered to MIT
  - Spring purchase of power supply
  - Summer solenoid test finished
- **2006**
  - January Construction of mercury loop
  - Winter installation at CERN during shut-down
- **2007**
  - spring final run at PS start-up
  - 3 weeks of PS beam time
    - Does not include beam tuning
  - 3 weeks of removal and reinstallation for nToF operation

approx 2.5 MChF excl. staff

Summary

- proof-of-principle target test
  - Designed for multi-MW proton beams
  - jet target in a high magnetic field exposed to a proton beam
- Broad spectrum of beam properties requested
  - Profit from the enormous PS capabilities
- Envisaged run date: spring 2007