

**CORE Meeting, GSI, June 1<sup>st</sup> 2005**

# **L**aser **S**PECTroscopy of **R**adioactive Atoms at the **L**ow Energy Beamline

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University of Tübingen  
GSI Darmstadt

## **Content**

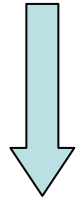
- Introduction and Motivation
- Experimental Setup
- Costs Overview

# Nuclear Ground State Properties

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## Laser Spectroscopy

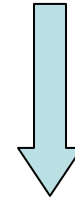
### Isotope Shift (IS)



Mean Square Charge Radii

$$\delta \langle r^2 \rangle^{AA'}$$

### Hyperfine Structure (HFS)



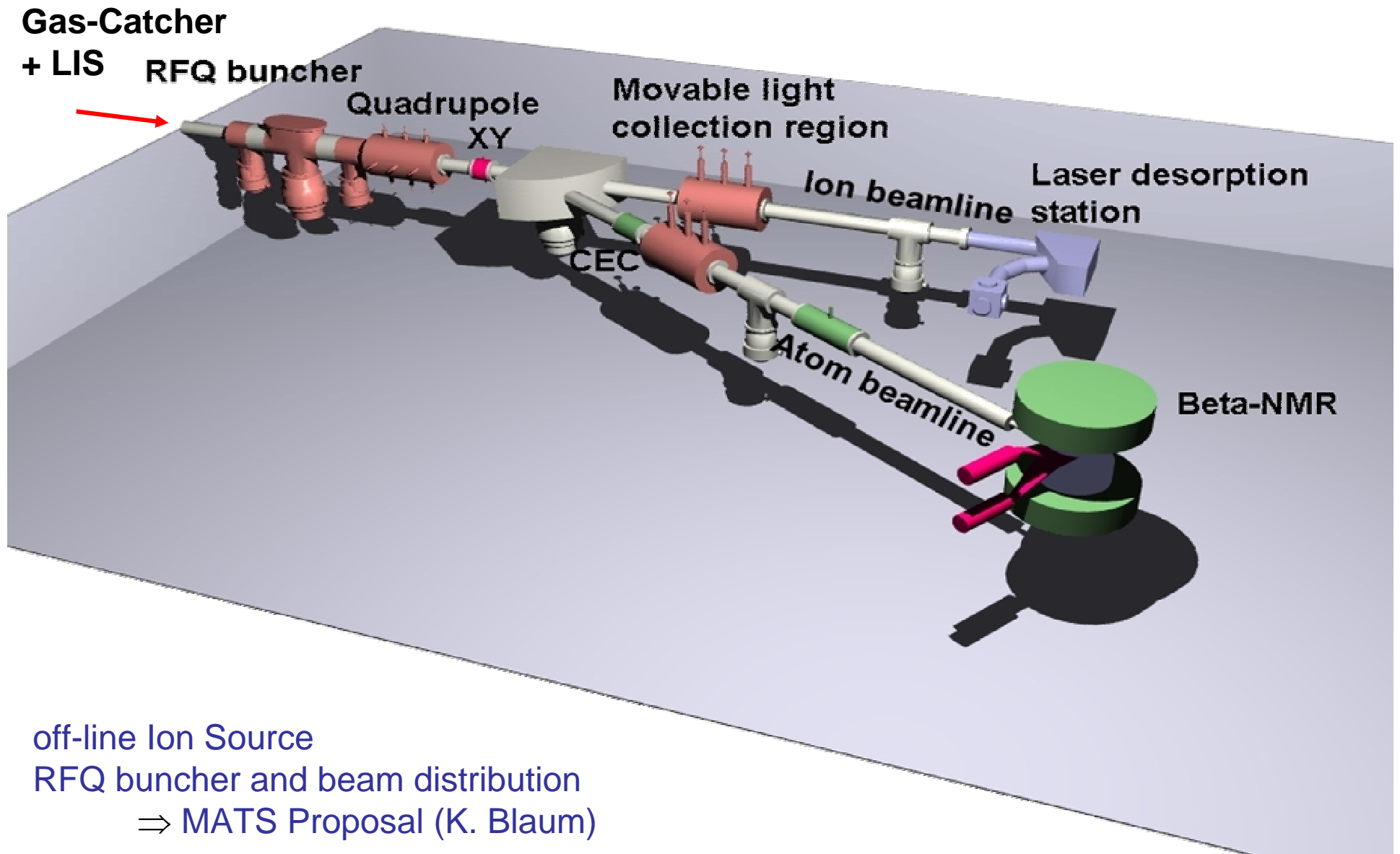
Nuclear Spin  $I$

Magnetic Dipole Moment  $\mu_I$

Electric Quadrupole Moment  $Q_s$

Hyperfine Anomaly

# The Setup



# Sub-Projects

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- LaSpec Beam Distribution Switchyard
- Collinear Spectroscopy of Ions (CLIS)
- Optical Pumping and Atomic Beam Spectroscopy
- $\beta$ -NMR
- Resonance Ionization Ion Source (RILIS)
- Laser-Desorption Resonance Ionization (LDRIS)
- Laser Housing and Laser Beam Transport

# Timeline

Project	Milestone	Year 1				Year 2				Year 3			
		Quarter 1	2	3	4	1	2	3	4	1	2	3	4
<b>RFQ</b>	Construction	■	■	■									
	Tests				■								
Resp.: JYFL	Installation				■	■							
IN2P3	Tests with OLIS						■	■					
	On-Line Experiments							■	■	■	■	■	■
<b>CIB</b>	Design	■	■										
	Optical Detect. Region				■	■							
Resp.: UM	Particle Detector			■									
	Installation					■	■						
	Tests with OLIS							■	■				
	On-Line Experiments							■	■	■	■	■	■
<b>LDRIS</b>	Design	■											
	Construction		■	■									
Resp.: UMz	Tests				■								
IN2P3	Installation						■						
	Tests with OLIS								■				
	On-Line Experiments									■	■	■	■
<b>Optic. Pump.</b>	Design	■	■	■									
	Charge Exchange Cell				■								
	Optical Detect. Region			■									
Resp.: UL	Beampipe					■	■						
GSI	Beamline Installation							■	■	■			
	Tests with OLIS									■	■		
	On-Line Experiments										■	■	■
<b>b-NMR</b>	Design	■	■										
	Magnet Purchase			■									
Resp.: UL	Cooling-System				■								
GSI	Vacuum Chamber					■	■						
	Installation							■	■				
	On-Line Experiments										■	■	■
<b>RILIS</b>	Design	■	■										
	Construction			■	■								
	Tests at Jyväskylä					■	■						
Resp.: JYFL	Installation								■	■	■		
UMz	Commissioning											■	
	On-Line Experiments											■	■
<b>LASER</b>	R & D	■	■	■	■								
	Installation					■	■	■	■	■	■		
	operation						■	■	■	■	■	■	■

Legend: Design & Construction ■ Tests, off-site ■  
 Installation ■ Commissioning (OLIS) ■  
 Commiss. (radioactive beam) ■ Operation ■

# LaSpec Beam Distribution Switchyard

**Purpose:** Kicker, Beam Distribution between the two LaSpec beamlines

**Basis of cost evaluation:** Similar devices operating at other low-energy facilities.

**Responsibility:** IN2P3, CNRS

Pos.	Item	Model	Provider	No.	Single Price	Total
<b>Switchyard</b>						<b>39210</b>
1	Vacuum Chamber		Workshop	1	8000	8000
2	Deflector electrode		Workshop	1	500	500
3	High Voltage Power Supply	Typ: 590-231	NSE Elektronik	4	400	1600
4	Scanner / Faraday Cup / MCP System			1	3000	3000
5	HV Feedthroughs			1	500	500
6	Pump System (Item 7-13 Collinear Ion)			1	23110	23110
7	Support Frame		Workshop, AI	1	2500	2500
<b>Beampipe</b>						<b>8000</b>
8	Beampipe (without pumping)		Workshop	1	5000	5000
9	Quadrupole		Workshop	1	3000	3000
<b>Sum</b>						<b>47,210 €</b>

# Collinear Ion Spectroscopy (CLIS)

**Purpose:** Charge radii and electromagnetic moments of medium heavy nuclei from spectroscopy of ions

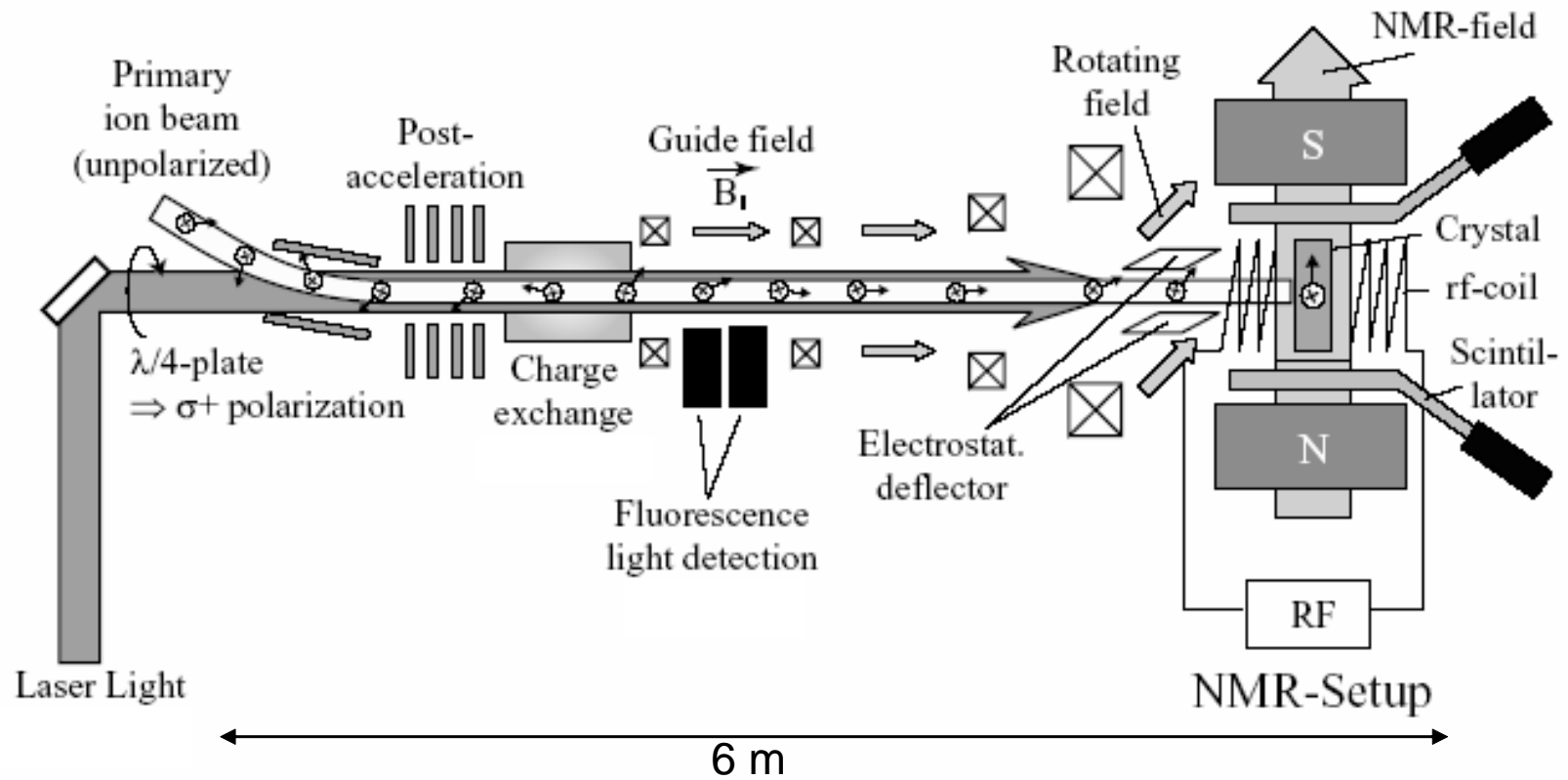
**Basis of cost evaluation:** The University of Manchester is building an identical item for ISOLDE.

**Responsibility:** Construction costs and effort will be covered by the University of Manchester.

Pos.	Item	Model	Provider	No.	Single Price	Total
<b>Optical Detection</b>						<b>28200</b>
1	Photomultipliers	R5900P-03-L16	Hamamatsu	10	1800	18000
2	UV lenses		Melles Griot - Edmund	20	255	5100
3	Fresnel lenses		FresnelTech	20	255	5100
<b>Ion detector</b>						<b>3400</b>
4	Channelplates, 1 inch 47 MOhm plates		Hamamatsu	4	850	3400
<b>Electronics</b>						<b>12900</b>
5	Fast Timing Amplifiers	FTA 820A	Ortec	2	1600	3200
6	Constant Fraction Discriminators	CFD 935	Ortec	2	3700	7400
6	Time-Amplitude Converter	TAC/SCA	Ortec	1	2300	2300
<b>Vacuum</b>						<b>43070</b>
7	Angle valve, pneumatic	PFA48-582	Pfeiffer	1	790	790
8	Pneumatic valve	PFE38-501	Pfeiffer	1	2820	2820
9	Roughing pump, oil-free	POP0160	Pfeiffer	1	3060	3060
10	Turbomolecular pump incl. power supply	PMPO03-670	Pfeiffer	1	13900	13900
11	Full range vacuum gauge	PKR 261	Pfeiffer	2	1190	2380
12	Cables for vacuum gauges		Pfeiffer	2	80	160
13	Vacuum gauge controller Maxi-Gauge	PTG28-760	Pfeiffer	1	1660	1660
14	Beampipe		Hositrad	1	4300	4300
15	Scanner / Faraday Cup / MCP System			1	3000	3000
16	Digital Picoamperemeter		ELCAL	1	3500	3500
17	Support Frame		Workshop	1	2500	2500
18	Transport, Installation, Alignment			1	5000	5000

**Sum** 87,570 €

# Beamline for Atom Spectroscopy and $\beta$ -NMR



# Optical Pumping and Fast Atomic Beam Spectroscopy

**Purpose:** Spectroscopy of neutral atoms (more spectral lines are accessible)  
Optical pumping for  $\beta$ -NMR

**Basis of cost estimation:** Experience with construction and operation of a similar device at ISOLDE

**Responsibility:** University of Tübingen, University of Mainz

Pos.	Item	Model	Provider	No.	Single Price	Total
<b>Beampipe</b>						<b>66040</b>
1	Beampipe		Hositrad	1	5000	5000
2	Pump Systems (Item 7-13 CLIS)		Pfeiffer	2	24770	49540
3	Scanner / Faraday Cup / MCP System			1	3000	3000
4	Support Frame		Workshop	1	3500	3500
5	Transport, Installation, Alignment			1	5000	5000
<b>Light Detection Region</b>						
6	included in Collinear Ion Spectroscopy	-	-	-	-	-
<b>Retardation Lenses</b>						<b>4750</b>
7	Lenses		Workshop	1	650	650
8	High-voltage supply			1	3350	3350
9	High-voltage cage		Workshop	1	750	750
<b>Charge Exchange Cell</b>						<b>5000</b>
10	Cell	analog to ISOLDE	Workshop	1	3800	3800
11	Power Supply for heating			1	1200	1200

**Sum** 75,790 €

# $\beta$ -NMR

**Purpose:** Precise electromagnetic moments, especially for light nuclei.

**Basis of cost evaluation:** Experience with construction and operation of a similar device at ISOLDE.

**Responsibility:** University of Leuven

Pos.	Item	Model	Provider	No.	Single Price	Total
<b>Magnet</b>						<b>50000</b>
1	Magnet		Walker LDJ Scientific	1	40000	40000
2	Power Supply		Walker LDJ Scientific	1	10000	10000
<b>Vacuum System</b>						<b>31770</b>
3	Chamber		workshop	1	5000	5000
4	Pump system (Item 7-13 Collinear Ion)		Pfeiffer	1	24770	24770
5	Support Frame		Workshop	1	2000	2000
<b><math>\beta</math>-Telescope</b>						<b>16800</b>
5	Plastic Scintillators			1	3000	3000
6	Photomultiplier		Hamamatsu	4	1500	6000
7	Readout Electronics (NIM)		Ortec	1	7800	7800
<b>Cooling System for Crystal</b>						
8	Cooling System		Oxford Instruments	1	60000	60000
<b>RF Generators</b>						
9	RF generators		National Instruments	4	2250	9000
<b>Sum</b>						<b>167,570 €</b>

# Resonance Ionization Laser Ion Source

**Purpose:** Precise electromagnetic moments, especially for light nuclei.

**Basis of cost evaluation:** Resonance Ionization in a Laser Ion Source Trap (LIST)  
Prototypes working at Mainz and Jyväskylä

**Responsibility:** University of Jyväskylä, University of Mainz

Pos.	Item	Model	Provider	No.	Single Price	Total
<b>Expendable items and wearing parts per year</b>						<b>3820</b>
1	Titanium:Sapphire Crystal		GWU	1	2500	2500
2	Channeltron Detector	702 A-H	Masscom, Bremen	1	770	770
3	Flashlamp for pump laser		Horiba Jobin Yvon	1	550	550
<b>Laser ionization, Adaption for LaSpec/GSI</b>						<b>13860</b>
4	Laser mirror sets for new elements		Layertech	1	4000	4000
5	Multi-layer-mirrors for beam transport		Newport	1	4000	4000
6	Optomechanical components		Owis	1	2000	2000
7	Non-linear LBO Crystals for frequency doubling		GWU	1	800	800
8	Non-linear BBO Crystals for frequency quadrupling		Döhrrer	1	700	700
9	Building a puls stabilization for pulsed lasers		Workshop Uni Mz	1	400	400
10	Broadband Lamda-Half Waveplate for pulsed lasers		Alphas	2	980	1960
<b>Laser-Ion source &amp; trap, Adaption of existing prototyp for LaSpec/GSI</b>						<b>24770</b>
11	High Frequency Amplifier		ENI	1	4000	4000
12	Ion trap		Workshop Uni Mainz	1	4000	4000
13	Power supply 600 A	XDC 20-600	Xantrex	1	6990	6990
14	Special materials for Ta Oven similar to online-sources			1	4200	4200
15	Manufacturing costs for directly heated Ta source		Workshop Uni Mz	1	2500	2500
26	Fast high-voltage switch	HTS-5106	Behlke	2	1040	2080
27	Control unit for Q switches		Electrical workshop Uni Mainz	1	1000	1000
<b>Chamber, Creation of pure ion beams</b>						<b>35350</b>
17	Vacuum chamber, tubes and cross pieces		Hositrاد	1	3000	3000
18	Angle valve, pneumatic	PFA48-582	Pfeiffer	4	790	3160
19	Pneumatic valve	PFE38-501	Pfeiffer	2	2820	5640
20	Roughing pump, oil-free	POP0160	Pfeiffer	1	3060	3060
21	Turbomolecular pump incl. power supply	PMPO03-670	Pfeiffer	1	13900	13900
22	Full range vacuum gauge	PKR 261	Pfeiffer	3	1190	3570
23	Cables for vacuum gauges		Pfeiffer	2	80	160
24	Vacuum gauge controller Maxi-Gauge	PTG28-760	Pfeiffer	1	1660	1660
25	Gas exchange cell		mech. workshop Uni Mainz	1	1200	1200
<b>Sum</b>						<b>77,800 €</b>

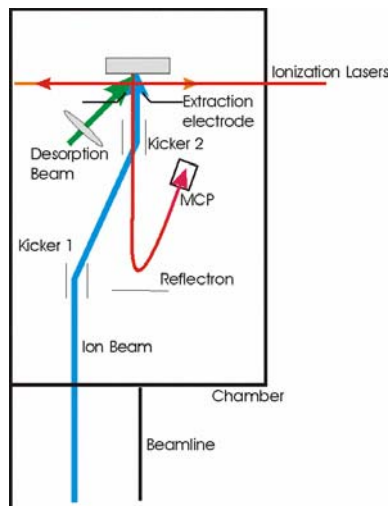
# Laser Desorption RIS Setup

**Purpose:** Charge Radii and Electromagnetic moments of heavy elements with extremely low production rates

**Basis of cost evaluation:** Adaption of an existing setup from the University of Mainz, which can be easily adapted at the end of the CLIS beamline

**Responsibility:** University of Mainz

Pos.	Item	Model	Provider	No.	Single Price	Total
<b>High-voltage kicker</b>						
1	High -voltage kicker and vacuum parts		Workshop Uni Mainz	1	4300	4300
2	High-voltage pulser	AMT 10 B 10	HiVolt GmbH	1	8742	8742
<b>Sum</b>						<b>13,042 €</b>



# Laser Housing and Beam Transport System

**Purpose:** Source of laser radiation, controlled environment

**Basis of cost evaluation:**

- a variety of cw and pulsed lasers exists at GSI and the University of Mainz
- frequency doubling for extending cw lasers into the UV region
- universal cw - laser stabilization using inexpensive fringe-offset locking technique

**Responsibility:** GSI, University of Mainz

Pos.	Item	Model	Provider	No.	Single Price	Total
<b>Frequency doubling</b>						<b>43700</b>
1	Frequency doubler, optics for 3 wavelength ranges	FS-SF10	Tekhnoscan	1	37500	37500
2	Spare Set Doubling Crystals		Tekhnoscan	2	1300	2600
3	Mirrors for beam transport		Laser Components	20	180	3600
<b>Universal laser stabilization</b>						<b>12500</b>
4	300 MHz Fabry Perot Interferometer	13 SAS 101	Melles Griot	1	3500	3500
5	Power Supply	13 SAC 001	Melles Griot	1	1500	1500
6	Stabilized He-Neon laser, alternatively Rb stabilized DL		Jenaer Messtechnik GmbH	1	3000	3000
7	Electronics		Home made	1	500	500
8	Computer Control, PC, DAC, ADC, Counter-board			1	4000	4000
<b>General</b>						<b>50320</b>
9	Honeycomb tables 3m x 1,5 m x 0.2	PTQ52514	Thorlabs	2	4740	9480
10	Table support	PTS503	Thorlabs	2	2830	5660
11	Mirrors for beam transport (broadband)		Laser Components	10	300	3000
12	Optical Mounts for beam transport	KS4	Thorlabs	10	218	2180
13	Set of Optical Mounts, Optics		Thorlabs, Laser Components, etc.	1	25000	25000
14	Laminar Flow Box			1	5000	5000

**Sum 106,520 €**

# Additional Data Acquisition

Pos.	Item	Model	Provider	No.	Single Price	Total
1	Control and user PCs, Flat Screen 19", extra HD			2	1500	3000
2	Multi-channel analyzer board	P7882	FAST Comtech	1	3000	3000
3	National Instruments, PCI-GPIB Karte	778032-51	National Instruments	2	645	1290
4	1m GPIB Cable			20	80	1600
5	DAC, ADC, Counter - Boards		FAST Comtech	3	2500	7500

**Sum 16,390 €**

- data acquisition will mainly be based on simple PC systems combined with some fast NIM electronics.
- part of the electronics already exist
- other parts are listed within the sub-projects

# Cost Summary

Item	Sub-Project	Costs	Cost Estimate from TP	Difference
1	Switchyard	47,210 €	50,000 €	-2,790 €
2	Collinear Ion Beamline	87,570 €	80,000 €	7,570 €
3	Optical Pumping	75,790 €	62,000 €	13,790 €
4	$\beta$ -NMR	167,570 €	164,000 €	3,570 €
5	RILIS	77,800 €	80,000 €	-2,200 €
6	LD-RIS	13,042 €	5,000 €	8,042 €
7	Laser Housing	106,520 €	100,000 €	6,520 €
8	Data Acquisition	16,390 €	0 €	16,390 €
	<b>Sum</b>	<b>591,892 €</b>	<b>541,000 €</b>	<b>50,892 €</b>

## Relevant Costs from MATS proposal

Item	Sub-Project	Costs	Cost Estimate from TP
1	RFQ Buncher and Cooler	233,050 €	260,000 €
3	Off-Line Ion Source	61,530 €	60,000 €
	<b>Sum</b>	<b>294,580 €</b>	<b>320,000 €</b>

# Manpower

Item		Design	Construction	Operation
1-3	Beamlines	1 PD	1.5 PD + 2 PhD	1 PD + 2 PhD
4	b-NMR	0.5 PD + 1PhD	0.5 PD + 1 PhD	
5	RILIS	0.5 PD + 1PhD	1 PD + 1 PhD	
6	LD-RIS	0.5 PhD	0.5 PhD	
7	Laser Housing	1.5 PhD	0.5 PD	
1-7	mechanical workshop		1.5 Techn.	

<b>Sum</b>	<b>2 PD 4 PhD</b>	<b>3.5 PD 4.5 PhD 1.5 Techn.</b>	<b>1 PD 2 PhD</b>
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PD = Postdoc; PhD = PhD student; Techn. = Technician;  
all values are given in man years.

Overall: 6.5 PD + 10.5 PhD Man Years + 1.5 Techn

# Estimated Maintenance and Operational Costs

Item	Sub-Project	Costs
1	Switchyard	1,000 €
2	Collinear Ion Beamline	5,000 €
3	Optical Pumping	6,000 €
4	$\beta$ -NMR	10,000 €
5	RILIS	6,000 €
6	LD-RIS	2,000 €
7	Laser Housing	30,000 €
	<b>Sum</b>	<b>60,000 €</b>

These costs include expendable items and maintenance. In the case of the laser housing average costs for a slow upgrade of the laser system are considered.

# Summary

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- LaSpec will provide model-independent measurements of nuclear ground state properties (charge radii, spin, electromagnetic moments)
- The setup is based on experience with similar devices at other on-line facilities.
- No substantial R&D, outside that already being undertaken to improve existing techniques, is required.
- Almost all listed prizes are based on recent company offers or on experience with similar systems in the last few years.
- All numbers are given to our best knowledge!

# The Collaboration

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**Katholieke Universiteit Leuven:** G. Neyens

**JYFL University of Jyväskylä:** J. Äystö, A. Jokinen, T. Kessler, I. Moore, A. Nieminen

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