

**Summary of
Cost Estimates
for
*LASPEC***

*Laser Spectroscopy
Of Short-Lived Nuclei
At FAIR's Low Energy Branch*

Presented at the CORE - Meeting
GSI, Darmstadt
May 31st and June 1st 2005

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LASPEC will provide a multi-purpose laser spectroscopy station for the study of stopped, cooled, and bunched radioactive species produced with the Super-Fragment Separator (S-FRS) at the FAIR facility. A physics case and details of the setup were presented previously in the LaSpec “Letter of intent” and the corresponding “Technical Proposal”. Here, we summarize the cost estimates for the construction and operation of the LaSpec device. For orientation, Figure 1 shows a schematic of the proposed setup. It is divided into the following sub-projects:

- (0) an RFQ buncher for stopping, bunching and cooling of ions delivered from the gas stopper and a switchyard for beam distribution. These devices are part of the MATS proposal and the costs of approximately 260 k€ are not included in this proposal.
- (1) a switchyard for distributing the beam to the two beamlines of the LaSpec setup.
- (2) a setup for collinear ion spectroscopy with fluorescence detection (with ion coincidence for background suppression)
- (3) a second beamline for ion beam neutralization in a charge-exchange cell (CEC) and spectroscopy on a fast atomic beam with fluorescence detection
- (4) a β -NMR spectrometer at the end of the atomic beam line.
- (5) a setup for the element and/or isotope selective ionization of neutral atoms produced in the gas catcher (Resonance ionization Laser Ion Source, RILIS, not included in Fig. 1).
- (6) a station for Laser-desorbed Resonance Ionization Spectroscopy (LD-RIS), attached to the end of the collinear ion beamline.
- (7) a laser housing (Annex building) and laser beam delivery to the experiment.

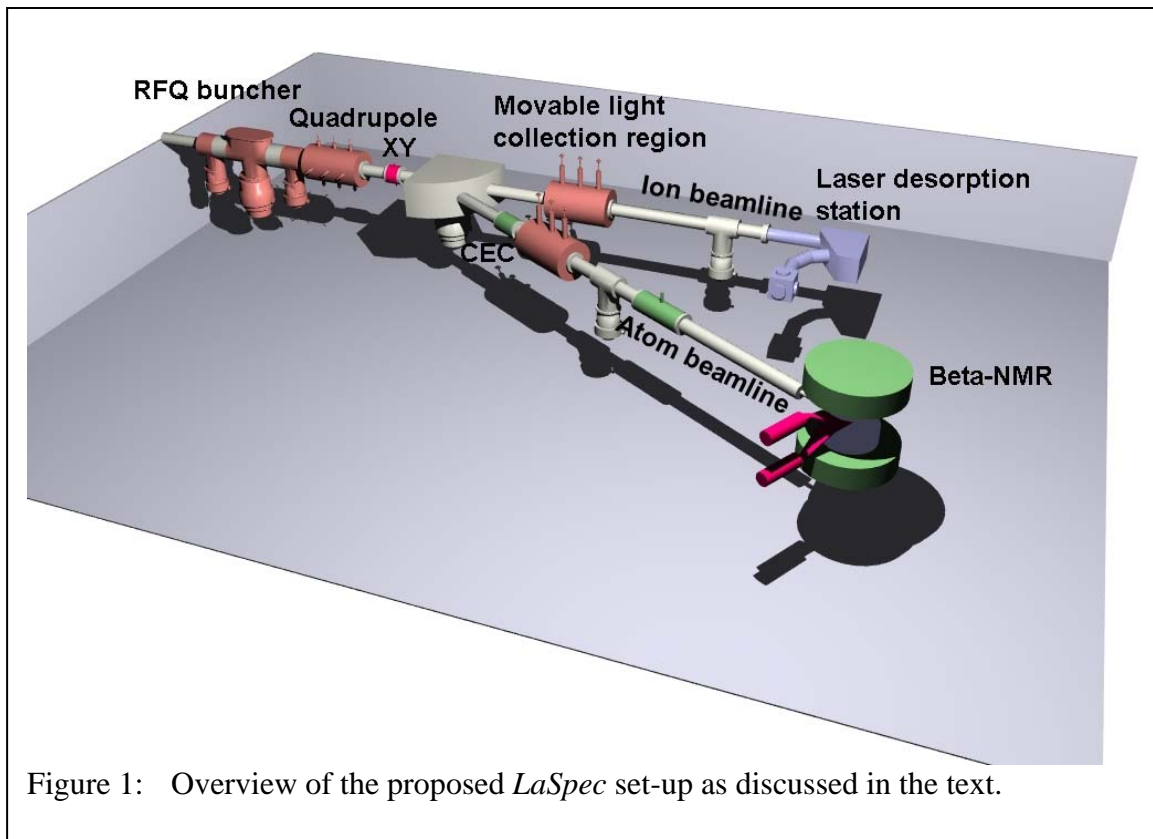


Figure 1: Overview of the proposed *LaSpec* set-up as discussed in the text.

At present the LaSpec Collaboration has 29 members from 12 Institutes and 7 countries.
The responsibilities and obligations are as follows:

Contribution	Institutes										
	UL	UJ	OR	GSI	UMz	MPIK	UT	UM	CERN	LLNL	PNL
RFQ ⁽¹⁾		X	X		X			X			
Collinear Spectroscopy		X						X	X		
Optical Pumping	X			X	X		X				
β -NMR	X			X			X				
RILIS		X			X			X	X		
Laser-desorption RIS			X		X						
Laser system					X		X				X
EBIT Spectroscopy ^(1,2)						X				X	
Investigator / year				0.1			0.3	0.3	0.15		0.1
PhD / year	1			1	1			1			
PostDoc / year	0.5	0.4		0.5	0.5		1	0.3			

Abbreviations:

UJ - University Jyväskylä; UL - University Leuven; OR –Orsay, CSN – CSNSM / IN2P3; GSI - GSI Darmstadt; UMz - University Mainz; MPIK - Max-Planck Institut for Nuclear Physics, Heidelberg; UM - University Manchester; CERN – CERN, Geneva; LLNL -Lawrence Livermore National Laboratory, Livermore; PNL - Pacific Northwest National Lab

⁽¹⁾ joined with MATS; ⁽²⁾ optional.

General Remarks

The cost estimates for the LaSpec setup are based on similar systems which the members of the LaSpec collaboration are presently developing at the different institutes involved or which are already in operation, like e.g., the COLLAPS and COMPLIS setups at ISOLDE and the collinear spectroscopy at Jyväskylä.

No substantial R&D, outside that already being undertaken, is required for the *LaSpec* proposal. All techniques are already employed at ISOL facilities and improvements are going on in other projects, e.g., the installation of an RFQ for beam cooling and bunching at ISOLDE/CERN. Limited R&D will be necessary for advanced laser stabilization systems and upgrade of laser technology. Besides this, mainly technical planning is necessary in the R&D phase.

In the following, we list estimated costs for the individual subprojects. Costs that refer to a specific manufacturer and model are based on catalog prices or company quotes. Those given without a company name are estimates based on experience in purchasing such devices. For parts which are built in the workshop of a participating institute we quote estimated material costs.

The costs given here deviate slightly from what was given in the Technical Proposal. A summary and comparison is provided at the end of this document.

The LaSpec setup as shown in Fig. 1 can be installed and operated for the costs given in this document. However, we want to point out that this technique will provide its ultimate performance only in combination with the RFQ cooler and buncher, which is included in the MATS proposal. Moreover, the off-line ion source listed in the MATS proposal is necessary for off-line commissioning and test experiments to ensure optimum use of beamtime. A costs summary of these items, taken from the MATS cost review, is given in the following table.

Relevant Items 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	61,500 €	60,000 €
	Sum	294,550 €	320,000 €

(1) Switchyard

Pos.	Item	Model	Provider	No.	Single Price	Total
Switchyard						39210
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
Beampipe						8000
8	Beampipe (without pumping)		Workshop	1	5000	5000
9	Quadrupole		Workshop	1	3000	3000

Sum 48,000 €

(2) Collinear Ion Spectroscopy (CLIS):

Pos.	Item	Model	Provider	No.	Single Price	Total
Optical Detection						28200
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
Ion detector						3400
4	Channelplates, 1 inch 47 MOhm plates		Hamamatsu	4	850	3400
Electronics						12900
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
Vacuum						43070
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		Hositrاد	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 88,000 €

This list is based on the current design for a similar item that will be build at ISOLDE.

Engineering – design, construction, commissioning: The University of Manchester is building an identical item for ISOLDE. Construction costs and effort will be covered by the University of Manchester.

Number of spares: Most likely, only 5 photomultiplier tubes and 1 pair of channelplates will be used at a time. Thus, 1 complete set of spars is already included in the list.

Safety: High-Voltage cage around the light collection region.

(3) Optical pumping, and Fast Atomic Beam Laser Line:

Pos.	Item	Model	Provider	No.	Single Price	Total
Beampipe						66040
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
Light Detection Region						
6	included in Collinear Ion Spectroscopy	-	-	-	-	-
Retardation Lenses						4750
7	Lenses		Workshop	1	650	650
8	High-voltage supply			1	3350	3350
9	High-voltage cage		Workshop	1	750	750
Charge Exchange Cell						5000
10	Cell	analog to ISOLDE	Workshop	1	3800	3800
11	Power Supply for heating			1	1200	1200

Sum 76,000 €

Cost estimates based on the existing setups at ISOLDE and TRIUMF.

Responsible institutes are GSI and the Universities of Leuven and Mainz.

(4) β -NMR:

Pos.	Item	Model	Provider	No.	Single Price	Total
Magnet						50000
1	Magnet		Walker LDJ Scientific	1	40000	40000
2	Power Supply		Walker LDJ Scientific	1	10000	10000
Vacuum System						31770
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
β-Telescope						16800
5	Plastic Scintillators			1	3000	3000
6	Photomultiplier		Hamamatsu	4	1500	6000
7	Readout Electronics (NIM)		Ortec	1	7800	7800
Cooling System for Crystal						
8	Cooling System		Oxford Instruments	1	60000	60000
RF Generators						
9	RF generators		National Instruments	4	2250	9000

Sum 168,000 €

Cost estimates based on the existing setup at ISOLDE and a recently build β -NMR at the ISAC facility (TRIUMF, Vancouver). The magnet price is an estimate based on a recent purchase of a similar system and the cooling system is based on a recent quote from Oxford Scientific.

Engineering – design, construction, commissioning: Construction costs and effort will be covered by the University of Leuven.

(5) RILIS:

Pos.	Item	Model	Provider	No.	Single Price	Total
Expendable items and wearing parts per year						3820
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
Laser ionization, Adaption for LaSpec/GSI						13860
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		Alphasas	2	980	1960
Laser-ion source & trap, Adaption of existing prototyp for LaSpec/GSI						24770
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
Chamber, Creation of pure ion beams						35350
17	Vacuum chamber, tubes and cross pieces		Hositräd	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
Sum						78.000 €

This cost estimate is based on the assumption of a Laser Ion Source Trap (LIST) as the device in which laser ionization is performed. It will be different if laser ionization is planned to be carried out inside the gas catcher. LIST's are currently designed at the Universities of Mainz and Jyväskylä and first prototypes are in operation. This table is based on recent experience with these devices and includes also additional costs for an upgrade of the Mainz laser system that will be used for resonance ionization.

Number of spares: Expendable items like laser crystals, flashlamps and channeltron detectors are included in the list with about 3800 €

Safety: The laser ion source must be located in close vicinity to the gas catcher. Shielding of the radioactivity deposited in this device is covered by the costs of the gas catcher device in the NUSTAR TP.

(6) Laser-desorption RIS:

Pos.	Item	Model	Provider	No.	Single Price	Total
High-voltage kicker						
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
Sum						14,000 €

The laser-desorption RIS setup is already existing at the university at Mainz. Only a fast kicker for the ion beam is additionally needed. The TP list did not include a high-voltage pulser which is needed for operation.

Engineering – design, construction, commissioning: Limited to the adaption of the existing apparatus to the collinear laser beamline; will be covered by the University of Mainz.

(7) Laser Housing and Laser Beam Delivery

Pos.	Item	Model	Provider	No.	Single Price	Total
Frequency doubling						
1	Frequency doubler, optics for 3 wavelength ranges	FS-SF10	Teknoscan	1	37500	37500
2	Spare Set Doubling Crystals		Teknoscan	2	1300	2600
3	Mirrors for beam transport		Laser Components	20	180	3600
Universal laser stabilization						
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
General						
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						107,000 €

Safety: Doors with restricted access and interlocks are needed.

The laser house will be equipped with a variety of cw- and pulsed lasers that already exist at GSI and the University of Mainz. More lasers will be provided for beamtimes from other groups. These are not listed here since they come for free.

(8) 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	Rack Fire Detection Safety System	CERN		4	250	1000
6	DAC, ADC, Counter Boards		FAST Comtech	3	2500	7500
Sum						18,000 €

The data acquisition will mainly be based on simple PC systems combined with some fast NIM electronics. Partially these electronics does already exist in the different groups, other parts are listed within the sub-projects (1)-(7).

LASPEC - SUMMARY

Cost Summary

Item	Sub-Project	Costs	Cost Estimate from TP	Difference
1	Switchyard	48,000 €	50,000 €	-2,000 €
2	Collinear Ion Beamline	88,000 €	80,000 €	8,000 €
3	Optical Pumping	76,000 €	62,000 €	14,000 €
4	β -NMR	168,000 €	164,000 €	4,000 €
5	RILIS	78,000 €	80,000 €	-2,000 €
6	LD-RIS	14,000 €	5,000 €	9,000 €
7	Laser Housing	107,000 €	100,000 €	7,000 €
8	Data Acquisition	12,000 €	0 €	12,000 €
	Sum	591,000 €	541,000 €	50,000 €

Estimated Maintenance and Operating Costs

Item	Sub-Project	Costs
1	Switchyard	1,000 €
2	Collinear Ion Beamline	5,000 €
3	Optical Pumping	6,000 €
4	β -NMR	10,000 €
5	RILIS	6,000 €
6	LD-RIS	2,000 €
7	Laser Housing	30,000 €
	Sum	60,000 €

These costs include expendable items and maintenance (mainly of the vacuum system for 1-6). In the case of the laser housing average costs laser maintenance and a slow upgrade of the laser system are considered.

Institute Manpower (not costed)

Item	Sub-Project	Design	Construction	Operation
1-3	Beamlines	1 PD	1.5 PD + 2 PhD	1
4	β -NMR	0.5 PD + 1PhD	0.5 PD + 1 PhD	PD
5	RILIS	0.5 PD + 1PhD	1 PD + 1 PhD	+
6	LD-RIS	0.5 PhD	0.5 PhD	2
7	Laser Housing	1.5 PhD	0.5 PD	PhD
1-7	mechanical workshop		1.5 Techn.	
	Sum	2 PD 4 PhD	3.5 PD 4.5 PhD 1.5 Techn.	1 PD 2 PhD

PD = PostDoc; PhD = PhD student; Techn. = Technician;
Machining is mainly done by technicians; all other work is performed by PhD students and PostDocs. All values are given in man years.
Required manpower for the operation of LaSpec is 1 PostDoc and 2 PhD students per year.