A Combined NF-IDS and EUROnu Targets Work Programme

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Intention is to:

(i) Outline required target and target station programme for IDS
(ii) Record 'target community' individual and group work plans and status
(iii) Identify gaps in work programme
(iv) Identify priorities
(v) Call for volunteers and support funding applications
(vi) Generate an agreed set of criteria by which to assess relative merits of competing target and target station technologies
(vii) Prompt people to say what we have missed out / got wrong!

1 Deliverables

IDS-NF Target system specification

Del. No.	**Deliverable name**	**Estimated staff months**	**Delivery dd-mm-yyyy**
	The target task encompasses: • the liquid-mercury-jet delivery and recirculation system; • the proton-beam/mercury jet interaction region; • the collection of nested solenoids that collects the pions and produces a pion beam with a large energy spread in three 2 ns bursts		
CDR	Conceptual (Seminal?) Design Review – the 'start of the engineering'		10-04-2009
IDR	Cost estimate at 50-75% level		31-03-2011

EUROnu WP2 Superbeam

Del. No.	**Deliverable name**	**Estimated staff months**	**Delivery dd-mm-yyyy**
D1	Requirements for proton driver for delivering a high intensity neutrino beam for oscillation studies *assessing special requirements for Superbeam using SPL*	12	31-03-2009
D10	Target and collector design report, assessing the options for neutrino production *NB required to determine preferred solutions for a SuperBeam and Neutrino Factory*	175	31-03-2011
D15	Target/Collector integration, showing how the target and collector will be integrated together in the target station *for both a SuperBeam and Neutrino Factory*	50	31-09-2011
D16	Beam characteristics of the neutrino beam, using the designs of the SPL, target and horn from the other tasks	31	31-09-2011
D22	Final Report		31-09-2012

EUROnu WP3 (selected)

Del. No.	**Deliverable name**	**Estimated staff months**	**Delivery dd-mm-yyyy**
D18	[…] Evaluation of reference design for spent proton-beam handling system, including a performance analysis. Recommendation of reference design	56 [part]	31-11-2011

2 Basis of Cost Estimates

In order to achieve the stated requirement of a cost estimate to 50-75%, it will be necessary to:

1. Determine the scope of the costing and division of responsibilities with the rest of the facility, e.g.
    a. Scope: build only; build and operate; or build, operate and decommission
    b. Required lifetime of facility (20 years?)
    c. Envelope definitions with proton driver and muon front end
    d. Level of detail required for civil engineering specifications etc
    e. Regulatory issues and costs – site specific
2. State basis of estimate with reference to above scope
    a. statement of assumptions, effect of location, existing infrastructure etc.
    b. use of previous studies and facility costs e.g. SNS, J-SNS, LHC, ITER
3. Determine cost model
    a. Pricing model for civil engineering, building, materials, construction, installation and commissioning
    b. Shared infrastructure costs
    c. Costing of institute staff
4. Assess uncertainties, contingency
    a. Technical risks and cost implications
5. Cost implications for alternative target and beam dump technologies

3 Selection criteria for choice of target technology for a Neutrino Factory and a Superbeam

	Criteria	Driving factors	Inputs & Issues (Nufact)	Inputs & Issues (Superbeam)
1.	Performance (I) Pion production and capture efficiency	i. Material Z ii. Beam-target interaction geometry	High Z favoured for pion production Low Z favoured for engineering, secondary production	Low Z favoured
2.	Performance (II) Proton beam parameter limits (energy, power, pulse structure)		Baseline accelerator parameters 4 MW, 10±5 GeV	Baseline accelerator parameters SPL: 4 MW, 3-5 GeV CERN PS2: ? MW, 30-50 GeV
3.	Performance (III) Engineering practicality, reliability	i. Integration with capture solenoid system ii. Integration with beam window iii. Integration with Beam Dump iv. Time to repair/replace target system, Remote	i. Integration with capture solenoid ii. Near or far dump?	i. Magnetic horn outline design geometry & target location ii. Far dump?

		Handling complexity v. Maintenance intervals vi. Failure scenarios & consequences of target failure		
4.	Cost	i. Target system active volume – civil engineering, shielding and building costs ii. Remote handling complexity iii. Target replacement and disposal cost iv. Target replacement and disposal frequency	Need cost models: refer to ILC, SNS, JSNS, LHC, ITER	Need cost models: T2K costs
5.	R&D requirements (I) Off-line	i. Feasibility, reliability ii. Time and investment	i. MERIT@ORNL ii. RAL shock tests iii. RAL powder jet plant	
6.	R&D requirements (II) On-line	i. beam interactions with materials ii. radiation damage iii. radiochemistry	Need to use existing facilities: MERIT data, SPS@CERN? AP-0@FNAL? SNS, JSNS, BNL	Need to use existing facilities: T2K, BNL, SPS@CERN? AP-0@FNAL?
7.	Regulatory, safety,	i. Liquid metal, solid, powder	SNS, J-SNS, Eurisol	SNS, J-SNS, Eurisol

	environmental issues	ii. Site	experience	experience

4 Neutrino Factory Target Station Work Programme

4.1 Generic / Target Station / Capture solenoid	**Involvement / responsibility**	**Priority**	**FTE pa funded**	**FTE pa required (estim.)**	**Status**
4.1.1 Make statement of IDS-NF baseline specifications		H			Done
4.1.2 Incorporate HARP data into MARS/FLUKA/GEANT4 simulations	NM, GP	M			Ongoing
4.1.3 Beam window study	JB, CJD, MR, MDF	H	0.1	0.5	Started
4.1.4 **Capture solenoid system (technical)**	RAL Technology + university consortium?	H	0.3	5	Stalled
a) Studies of irradiation, heat loads and cooling of decay solenoid	JB, PL				Started
b) Heat loads and cooling of inner shielding and integration with solenoid and target systems	PL				TBD
c) Solenoid system engineering, magnetic loads	PL				Stalled
d) Determine relevant current 'state of the art' parameters (ITER / LHC)	PL				Started
e) Compare field, heat load density, radiation damage, mechanical loads, quench protection etc. with 'state of the art' parameters.	??	H			TBD
f) HTC solenoid studies (e.g. MgB2)	??	M			TBD
g) NC solenoid studies	??	L			TBD
h) Identify routes to a technically defensible complete outline target and capture solenoid system e.g. consider: Low Z target material Larger, lower field solenoids		H			TBD

4.1.5	**Costing (baseline)**: Evaluate in light of IDS-NF scenario revisions, involving estimating:	ORNL, FNAL	H	0	1?	Stalled
a)	Active volume of target station					
b)	Mass and cost of steel and concrete shielding					
c)	Cost of solenoid system (ref. above)					
d)	Cost of civil engineering, building and services					
e)	Cost of mercury system					
f)	Cost of remote handling systems including shielding required					
g)	Any other significant costs					
4.1.6	Pion/muon acceptance studies	HK, SB, JB (Warwick), GS, XD, GP	M	?	?	Ongoing

4.2 Baseline liquid mercury target and beam dump	Involvement / responsibility	Priority	FTE pa funded	FTE pa required (estim.)	Status
4.2.1 Evaluate mercury handling infrastructure requirements, in particular revisions from Study2		M	0	0.5?	Stalled
4.2.2 Continue analysis of MERIT data on proton beam/liquid metal jet interactions Particle detector data	HK, KM, GS	H			Done? Ongoing
4.2.3 Extend MERIT MHD simulations	RS	M			Ongoing
4.2.4 Mercury nozzle studies	RE, HK	M			Just starting?
4.2.5 Mercury erosion experiments for bore & nozzle	VG	H	0	0.5	Stalled
4.2.6 Baseline liquid mercury beam dump studies including:					
a) Beam interactions with liquid beam dump, options for mitigation of splashing, erosion etc	TD	H			Stalled
b) CFD studies of mercury jet interactions (splash) with dump & containment	TD	H			Stalled
4.2.7 Develop engineering layouts for target station including:	ORNL/FNAL/RAL	M			
a) Mercury handling and recirculation system	VG				Stalled
b) Integration of mercury jet with capture solenoid, containment and shielding including concepts for remote maintenance	VG				Stalled
c) Integration of beam dump with decay solenoid, containment and shielding including concepts for remote maintenance	VG				Stalled
Material compatibility with Hg	VG				To compile
4.3.11 StudyII vs studyIIa implications on target/solenoid capture system	CR, GP				Ongoing

	Involvement / responsibility	Priority	FTE pa funded	FTE pa required (estim.)	Status
4.3 Alternative target technologies (I) re-circulating solid tungsten target		L	2 ?	?	
4.3.1 Interpretation of RAL off-line shock tests	JRJB, GS, RE				Done
4.3.2 On-line tungsten experiments (BNL?)	JRJB, RE, NS				Submit-ting?
4.3.3 Conceptual design for target recirculation system	JRJB				Ongoing
a) Chain drive (stopped) or 'Helmholtz'					
b) Radiation or water cooling					
c) Drive & support system					
d) Beam window integration (or no beam windows)					
4.3.4 Development of 'Helmholtz' type geometry					
4.3.5 Develop a conceptual structure design for the Helmholtz magnet, which provides an entry/exit route for a solid target.	JRJB				Ongoing
4.3.6 Develop concept for beam dump within solenoid coils					TBD
4.3.7 Remote dump: investigate the possibility to engineer the solenoid coils in such a way to let the beam pass through a gapN to reach a remote beam dump.					TBD
a) Study heating/cooling of coils & shielding due to disrupted beam					
4.3.8 Investigate factors affecting the (huge) inter-coil forces, and how to reduce/handle these.	PL				No
4.3.9 Estimate active volume of system and cost implications for TS					TBD

shielding					
4.3.10 Investigate remote handling concepts, reliability and cost	RE				Started

	Involvement / responsibility	Priority	FTE pa funded	FTE pa required (estim.)	Status
4.4 Alternative target technologies (II) flowing tungsten powder	**CJD, OC, PL**	**L**	**1.2**	**2.5**	
4.4.1 Agreed comparison of pion capture efficiency for reduced density powdered target with optimised system including accelerator and target geometry.	+ JB				Done
4.4.2 Carry out tungsten powder handling and erosion tests using RAL test plant.					Ongoing
4.4.3 Develop concepts for integration with capture solenoid, proton beam entry and exit windows of (i) open powder jet and (ii) contained powder jet					Ongoing
4.4.4 Develop and investigate concept for stopping target					Starting
4.4.5 Develop concept for complete powder target recirculation system					Done
4.4.6 Estimate active volume of system and cost implications for TS shielding					TBD
4.4.7 Investigate remote handling concepts, reliability and cost					TBD
4.4.8 Powder jet density measurements					Ongoing
4.4.9 On-line shock test of tungsten powder in helium at CERN	+ IE				To submit

	Involvement / responsibility	Priority	FTE pa funded	FTE pa required (estim.)	Status
4.5 Alternative target technologies(III) Low Z target		??	0		TBD
4.5.1Investigate and re-optimise Front End for Low Z target and compare performance cf High Z target	?		0	1	
4.5.2 Study implications on solenoid system engineering (radiation and heat load from secondaries)	?		0	0.5	
4.5.3 Investigate concepts for graphite, Be, AlBeMet targets	?		0	1	

5 Superbeam Target System Work Programme

This study will concentrate on the 2.2 - 5 GeV SPL option for a Superbeam operating at 4 MW total beam power. There is currently no baseline design concept for a Superbeam target and collection system suitable for operation at this power. Consequently the first stage of this Work Programme will be to consider the candidates below and determine a baseline. A costing will then be initiated of this baseline. There is direct synergy for much of this work with the Neutrino Factory work programme described above.

5.1 4-horn system – static target, graphite or Be?		**Responsibility**	**Staff-years**	**Priority**	**Status**
4.1.1	Determine power deposited in graphite as function of beam energy including 2.2 – 5 GeV range	AL, MZ		H	Done
4.1.2	Assess pion production +collection from graphite target as function of beam energy including 2.2 – 5 GeV range	MD, AL			Advanced
4.1.3	Repeat above 2 items for beryllium target?	AL, MZ			New
4.1.4	Assess pion production+collection as function of graphite dimensions and position within baseline horn1	AL			Advanced
4.1.5	Quadruple horn+target system: investigate implications on proton driver (beam splitter) and decay volume	MD (Strasbourg)		H	Baseline
4.1.6	Solid graphite, helium cooled - determine power dissipation, thermal stress, shock wave limits including bunch micro-structure effects	CJD, MR, MDF, TD	0.2	M	Started
4.1.7	Solid graphite, Be or Be alloy target integrated with horn inner conductor – water spray cooled. Investigate concepts, determine power dissipation, thermal stress, shock wave limits for different materials	CJD, PL, MR, MDF	0.75	H	Needs funding
4.1.8	Integrated target and horn concepts: study of magnetic forces including transients, combined magnetic and thermal stresses	CJD, PL, TD, PC	1.0	M	Needs funding
4.1.9	Investigate target station concepts for integration of target within magnetic horn,	PC, PL	1.0		Needs

	including rapid horn & target replacement	CJD, MDF, MR			funding
4.1.10	Assessment of vibrations + thermal transients in target/horn system including off-axis beam effects	PC, PL			Underway ?

4.2	**Other static solid target concepts**	**Responsibility**	**Staff-years**	**Priority**	**Status**
4.2.1	Investigate other concepts for solid/pebble bed graphite/Be helium/water spray/2-phase water/chilled water (low CTE) cooled. Consider power dissipation, thermal stress, shock waves in target and coolant, integration with windows and horn	All	??	L?	Needs funding

4.3	**Flowing powder target (Single horn)**	**Responsibility**	**Staff-years**	**Priority**	**Status**
4.3.1	Investigate possible powder materials in terms of pion production, secondary particle loads on magnetic horn (c.f. graphite)	MD, MZ, AL		L	?
4.3.2	Carry out candidate powder handling and erosion tests using RAL test plant	CJD, OC, PL (RAL)	0.7		Underway
4.3.3	Develop design concepts for integration of contained powder jet with magnetic horn, proton beam entry and exit windows	CJD, OC, PL (RAL)	0.3		Underway
4.3.4	Study heating and cooling of powder pipe wall	GS, CJD, PL, OC			Stalled
4.3.5	Develop concept for complete powder target recirculation system (NF synergy)	CJD, OC, PL	0.2		Underway
4.3.6	Investigate target station concepts for remote maintenance	CJD, OC, PL			Needs funding

4.4	**Generic Superbeam studies**			**Date**
4.4.1	Beam window engineering study – investigate thermal, pressure and shock	CJD, MR, MDF (RAL)	M	

	wave stress limits (NF synergy)			
4.4.2	Study beam heating of (Ti6Al4V?) beam window material (NF synergy)	MZ, AL (CEA)	M	
4.4.3	Investigate heating, shock wave and radiation damage effects of secondary particle interactions with magnetic horn	MZ, AL (CEA), MD		
4.4.4	Investigate potential beam dump concepts	CJD (RAL)		
4.4.5	Develop Target Station concepts for complete horn+target system changeover	RAL, Cracow		

4.5	**Baseline target choice**	**EUROv WP2**	
4.5.1	Review above options and select target technology baseline		
4.5.2	Carry out cost estimate of target station for baseline technology choice		

Glossary of contributors		FTE EUROnu WP2 and IDS Target	Funding source(s)
AL	Andrea Longhin (CEA Saclay)	1	CEA/EUROnu
CB	Christophe Bobeth (Strasbourg)	1	Strasbourg/EUROnu
CJD	Chris Densham (RAL)	0.3	ASTeC/EUROnu
CR	Chris Rogers (RAL)	?	ASTeC
GP	Gersende Prior (CERN)	1	CERN
GS	Goran Skoro (Sheffield)	1	UKNF
HK	Harold Kirk (BNL)	?	BNL
IE	Ilias Efthymiopoulos (CERN)	?	CERN
JB	John Back (Warwick)	0.5	UKNF
JRJB	Roger Bennett (RAL)	0.5	UKNF
KM	Kirk MacDonald (Princeton)	?	Princeton
MD	Marcos Dracos (Strasbourg)	?	Strasbourg/EUROnu
MDF	Mike Fitton (RAL)	0.1	EUROnu
MR	Matt Rooney (RAL)	0.1	EUROnu
MZ	Marco Zito (CEA Saclay)	?	CEA/EUROnu
NM	Nikolai Mokhov (FNAL)	?	FNAL
NS	Nick Simos (BNL)	?	BNL
OC	Otto Caretta (RAL)	0.8	ASTeC
PC	Piotr Cuprial (Cracow)	?	/EUROnu
PL	Peter Loveridge (RAL)	0.5	UKNF/ASTeC/EUROnu
RE	Rob Edgecock (RAL)	?	UKNF/EUROnu
RS	Roman Samulyak (FNAL)	?	FNAL
SB	Steven Brooks (RAL)	?	
TD	Tristan Davenne (RAL)	0.2	ASTeC/EUROnu
VG	Van Graves (ORNL)	?	ORNL