



# **Indigenous Development & Manufacturing of Steels for LBNF-DUNE**

**Indira Gandhi Center for Atomic Research (IGCAR)  
Kalpakkam – 603102, Tamilnadu, INDIA.**



# Outline of Presentation

**About IGCAR, Kalpakkam**

**Long Baseline Neutrino Facility (LBNF) – FNAL**

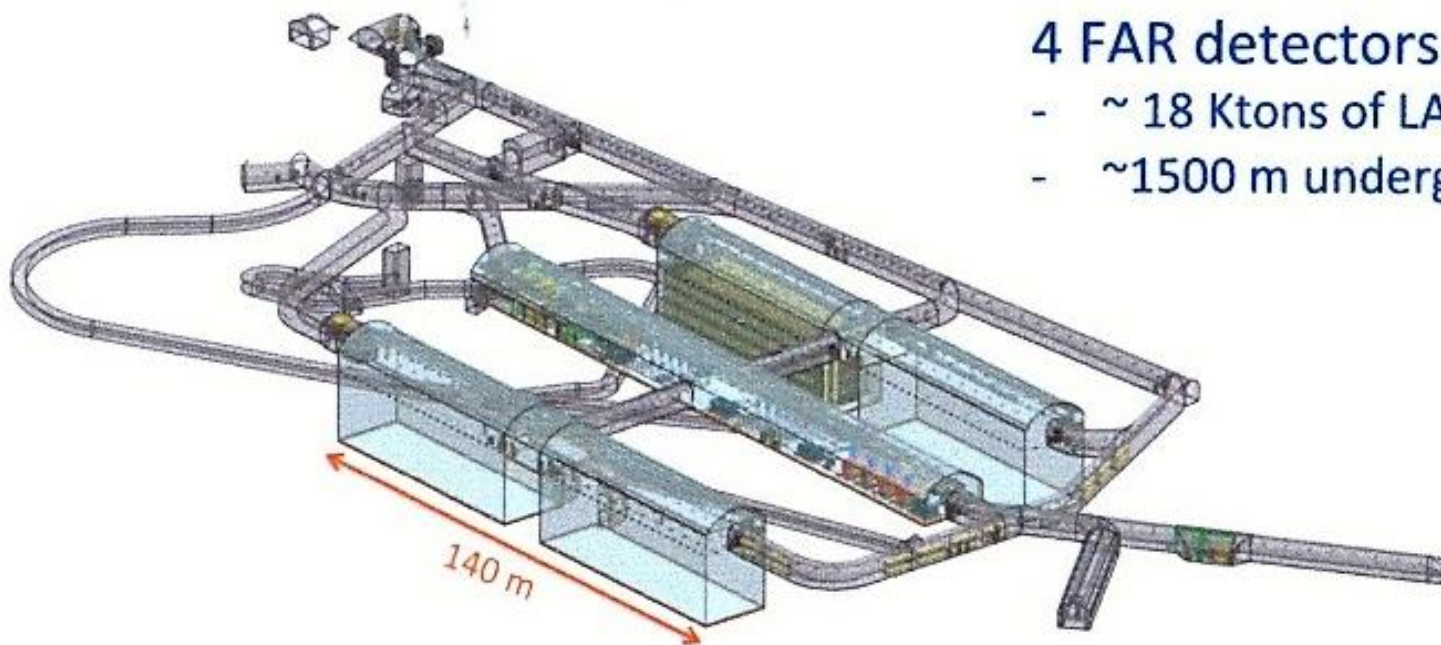
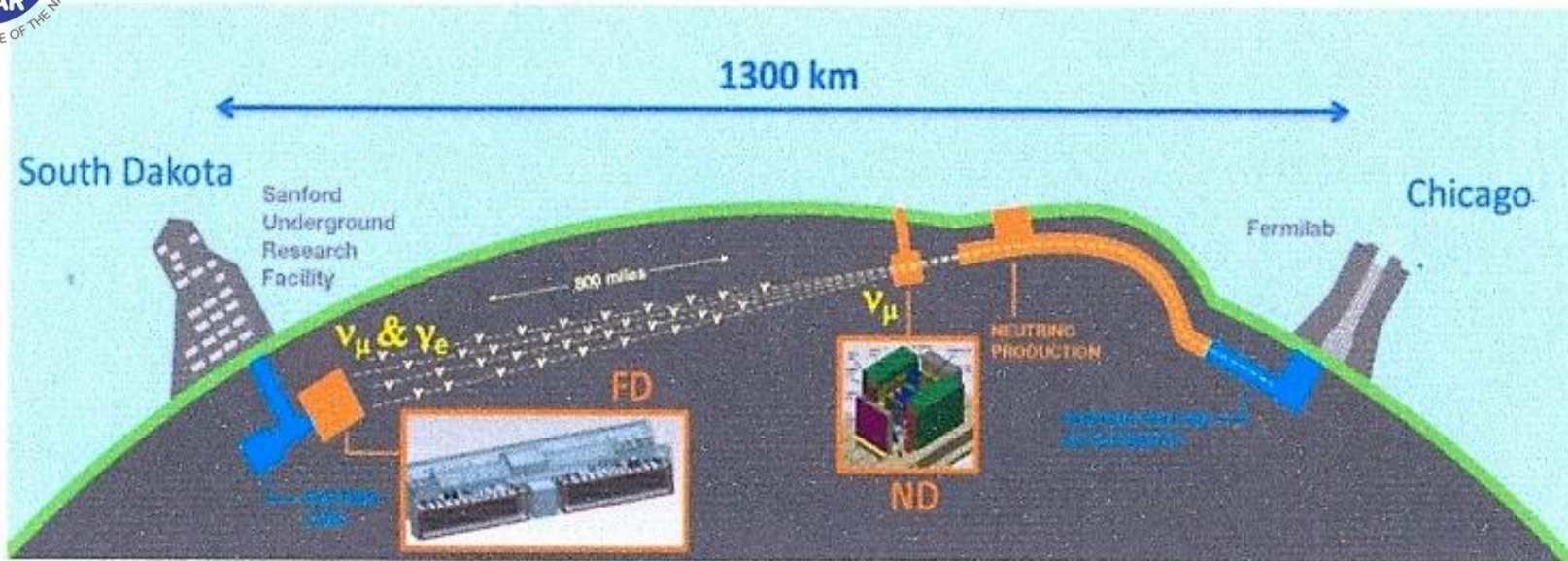
**LBNF Cryostat Warm Vessel**

**Materials for LBNF Cryostat Warm Vessel – S460ML**

**Indigenous Manufacturing Feasibility of LBNF Warm Vessel**

**Summary**

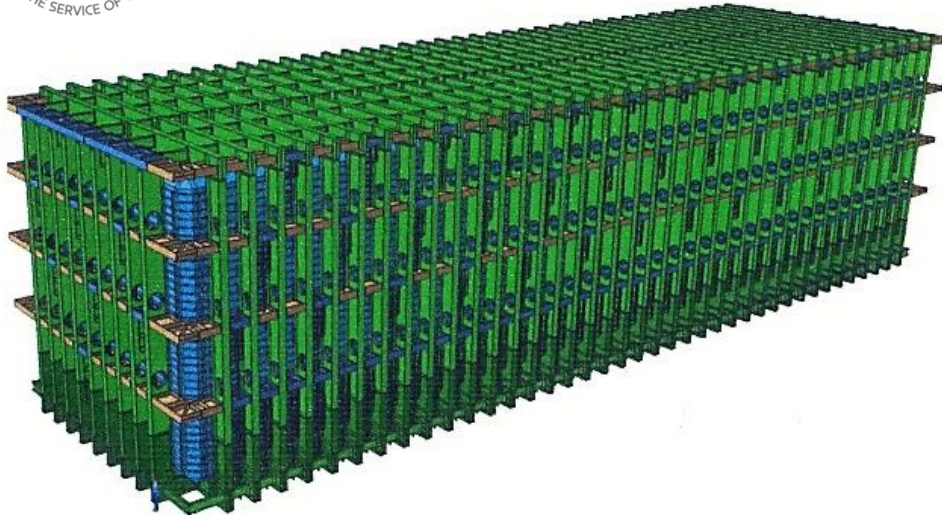
# LBNF & Its Cryostats



## 4 FAR detectors:

- ~ 18 Ktons of LAr in each one
- ~1500 m underground

# LBNF CRYOSTAT – Warm Vessel



## Alternative:

### •US section:

**W 44 x 16 x 290**

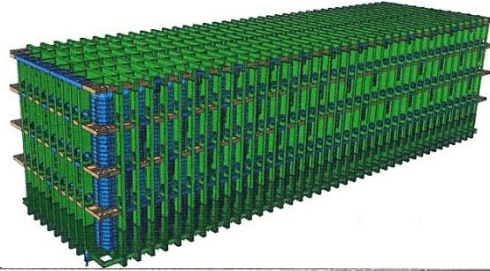
•Dimensions, tolerances and surface condition as per ASTM A 6/A 6M – 16.

• The **two main components** of the warm structure of the cryostat: **I-beam: HL1100M** and **I-beam: HE600B**

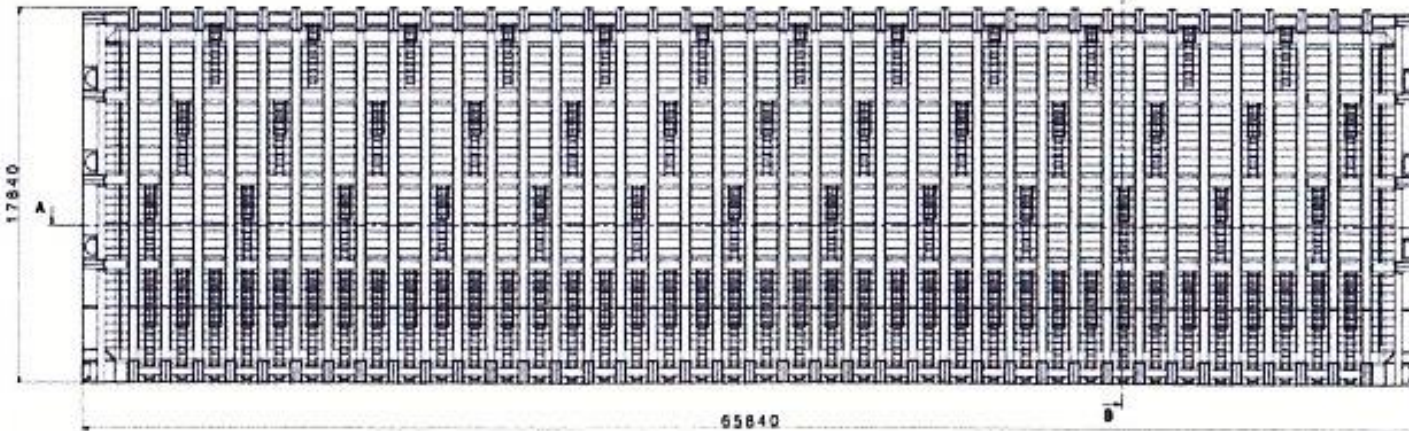
### • Standards Applicable:

- Section properties in accordance with EN 10365:2017
- Steel making process in accordance with EN 10025-1
- Dimensions in accordance with EN 10365:2017
- Tolerances in accordance with EN 10034:1993
- Surface condition in accordance with EN 10163-3:2004, class C, subclass 1

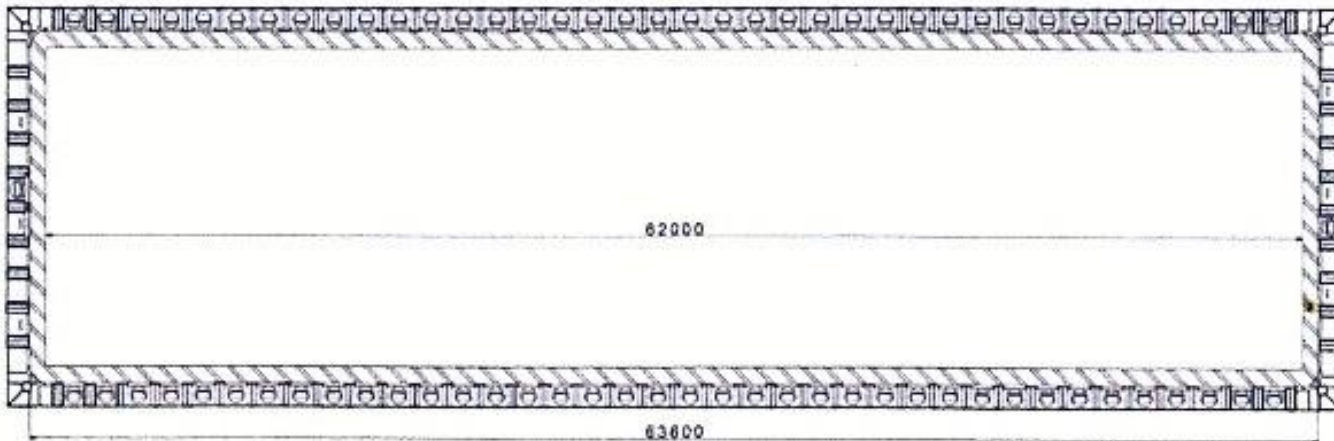
# LBNF CRYOSTAT WARM VESSEL - Sections



Front view  
1:80



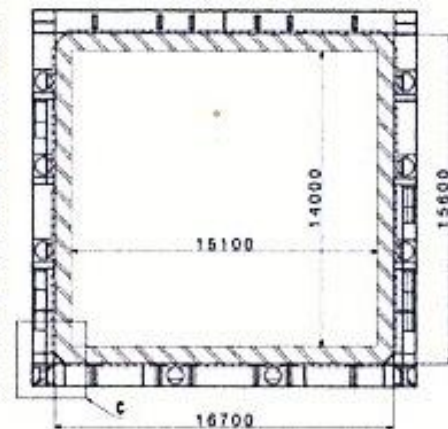
A-A  
1:80



Left view  
1:80

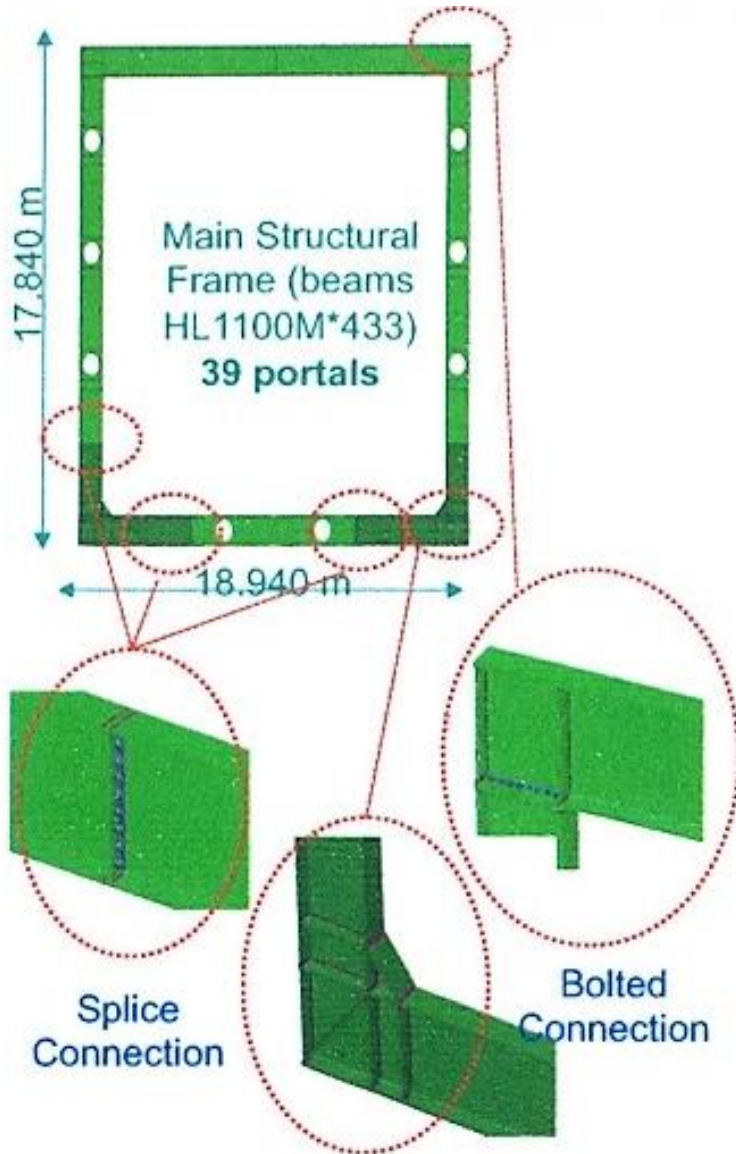


B-B  
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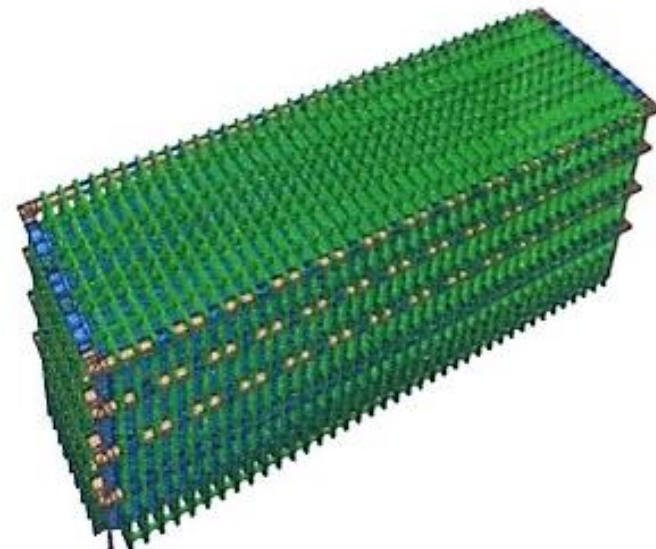
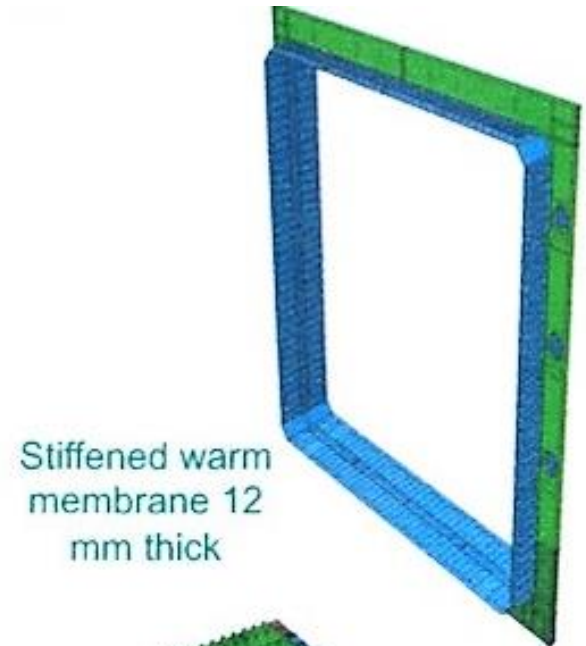


# LBNF CRYOSTAT WARM VESSEL

## - Unit Building Sections



Unit Cell  
(1.6m pitch)







# APPROXIMATE MATERIAL REQUIREMENT

I-Beams		
Profile	Length [m]	Mass [T]
<b>Quantities / Cryostat</b>		
HL1100M	3,800	1,650
HE600B	360	80
<b>Total for 4 Cryostats</b>		
<b>HL1100M</b>	<b>15,200</b>	<b>6,600</b>
<b>HE600B</b>	<b>1,440</b>	<b>320</b>
<i>Total</i>		<i>6,920</i>

Plates		
Thickness [mm]	Area [m <sup>2</sup> ]	Mass [T]
<b>Quantities / Cryostat</b>		
12	6,150	583
25	117	23
30	118	28
35	224	62
40	299	94
45	993	353
<b>Total for 4 Cryostats</b>		
<b>12</b>	<b>24,600</b>	<b>2,332</b>
<b>25</b>	<b>468</b>	<b>92</b>
<b>30</b>	<b>472</b>	<b>112</b>
<b>35</b>	<b>896</b>	<b>248</b>
<b>40</b>	<b>1,196</b>	<b>376</b>
<b>45</b>	<b>3,972</b>	<b>1,412</b>
<i>Total</i>		<i>4,572</i>

**Total Projected Requirement:**  
**S460ML Steel: 11,492 T**  
**1<sup>st</sup> Delivery: July 2020**  
**+ 3 six monthly deliveries**





# Material Specifications – LBNF Warm Vessel

The materials for the beams and the plates is: **S460ML** (EN 10025-1; EN 10025-4).

Element	Wt. %
C (max.)	0.18
Mn (max.)	1.7
Si (max.)	0.6
P (max.)	0.03
S (max.)	0.025
Al (Total min.)	0.02
Nb (max.)	0.05
V (max.)	0.12
Ti (max.)	0.05
Cr (max.)	0.3
Mo (max.)	0.2
Ni (max.)	0.8
Cu (max.)	0.55
N (max.)	0.025
Fe (max.)	Balance

## Mechanical Properties: EN 10025-4:2004

Minimum yield strength $R_{eH}$ per nominal thickness [MPa]		Tensile strength $R_m$ per nominal thickness [MPa]	
$\leq 16\text{mm}$	460	$\leq 40\text{mm}$	540-720
$> 16\text{mm}$ $\leq 40\text{mm}$	440	$> 40\text{mm}$ $\leq$ 63mm	530-710
$> 40\text{mm}$ $\leq 63\text{mm}$	430		

Minimum elongation: 17 [%]

Minimum values of absorbed impact energy

Longitudinal		Transverse	
[°C]	[J]	[°C]	[J]
+20	63	+20	40
0	55	0	34
-10	51	-10	30
-20	47	-20	27
-30	40	-30	23
-40	31	-40	20
-50	27	-50	16



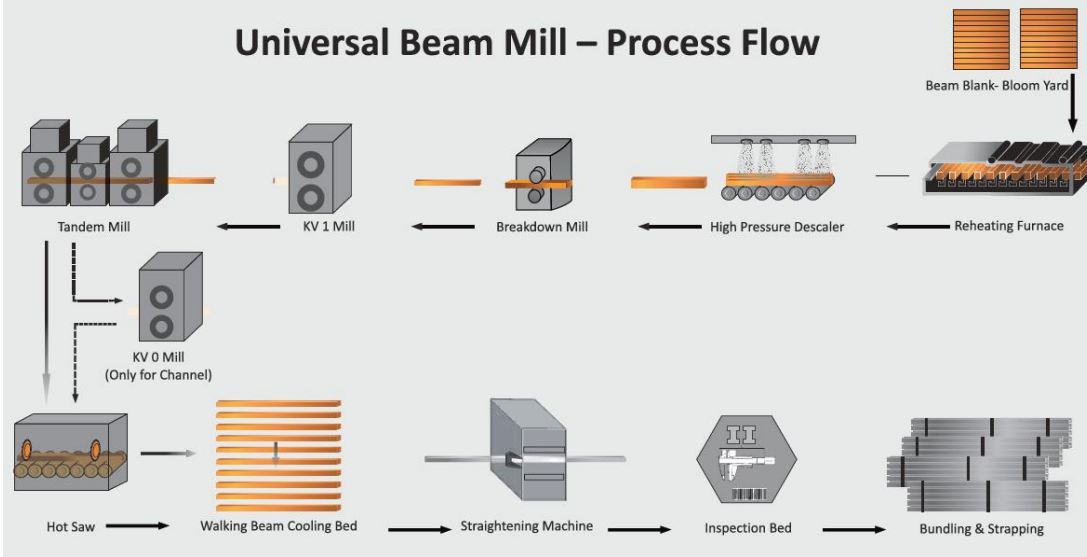
# Indigenous Manufacturing Feasibility at RUBM, Jindal Steel & power Limited (JSPL)

*Dr. S. Raju and Utpal Borah from IGCAR visited JSPL, Raigarh on 17<sup>th</sup> and 18<sup>th</sup> January 2018 along with officials from HEC, Ranchi to assess feasibility of indigenous manufacturing of LBNF warm vessel components. Manufacturing the Alloy S460ML steel, plates and beams up to 900 mm deep are of no concern.*

Beam Profile / Plate Thickness	Feasibility	Comments
Beam - HE600B	Yes	In regular production
Plates – 12, 25, 30, 35, 40 & 45 mm	Yes	In regular production
Beam - HL1100M	Currently up to 900 mm deep x 300 mm flange Beams	The JSPL Rail and Universal Beam Mill (RUBM) is rated for profile rolling up to 1000 mm deep x 400 mm flange beams

# RUBM in JSPL, Raigarh, INDIA

Universal Beam Mill – Process Flow



- i. *Shape rolling technology is used for beams.*
- ii. *900 mm deep beams are in regular production in JSPL*
- iii. *The rolling mill is capable of rolling up to 1000 mm deep x 400 mm flange beams*

- A. *1000 mm deep beams have not yet been manufactured at JSPL as there have been no order yet for this size.*
- B. *For manufacturing 1000 mm deep beams new beam blank to be developed with associated backward integration of the continuous casting facility.*
- C. *New rolls and roll pass need to be developed.*
- D. *Query has been sent by JSPL to the RUBM designer/supplier in Germany regarding capability of the mill to manufacture HL1100M beams. Response from the mill supplier is awaited by JSPL.*



# S460 ML Steel Chemistry: ✓

Lead time of about a year for standardization of steel development & beam product rolling out is required. Backward Integration of production line right from casters, beam blank making and rolling mill reengineering (HL1100 size only) etc., are needed. **JSPL Can Deliver, if commercial terms are worked out.**

## Product Development ✓

**Technology Reengineering Needed:**

**For beams deeper than 900 mm, if rolled product is preferred**

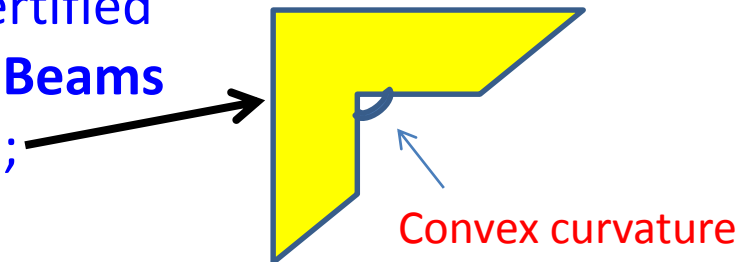
If welded beams are acceptable:

**NOT AN ISSUE; any shape & dimension can be fabricated**  
Property equivalence of rolled versus welded products certified

### **IMPORTANT Technical Issue with Welded Beams**

Welded beams will have convex curvature ;

**implications in final assembly ?**





# SUMMARY

**Timeline for delivery can be met, based on the production capacity of JSPL; 12,000 T or upwards is easily possible**

**Comprehensive, Q&A; based on ISO standards (equivalent Euro norms); Mechanical and Impact properties at -40°C on product possible at JSPL**

**JSPL has their own shipping & transportation logistics**



***Thank You***