



Assessment of Power Core Parameters and Related Costs

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ARIES-CS Project Meeting

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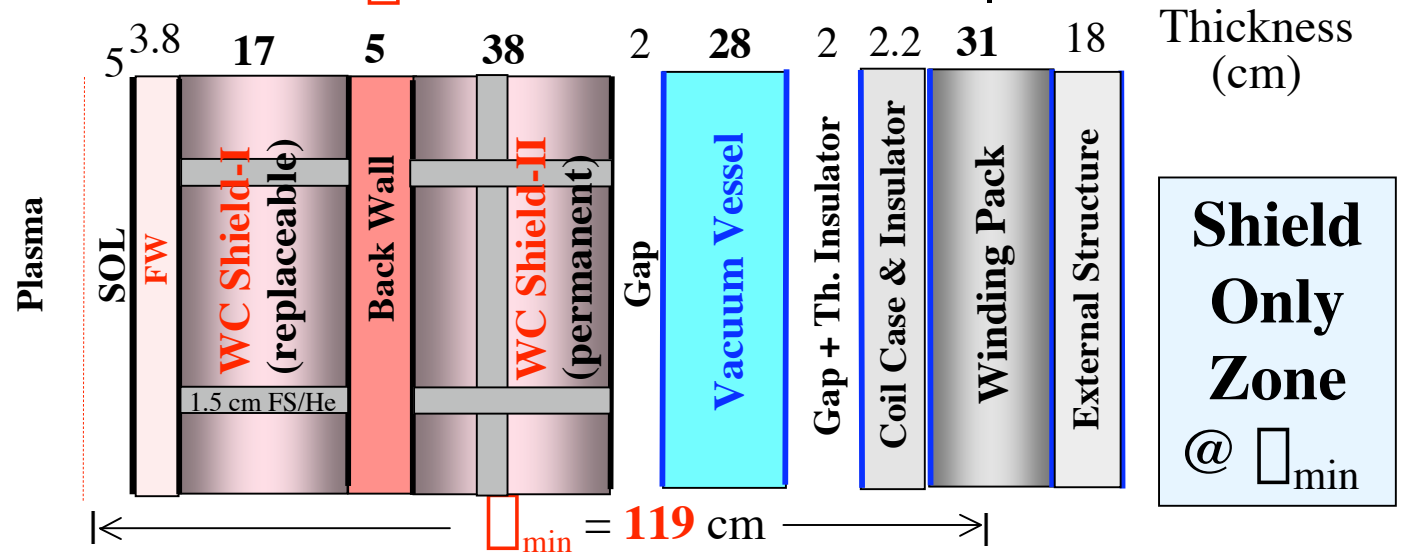
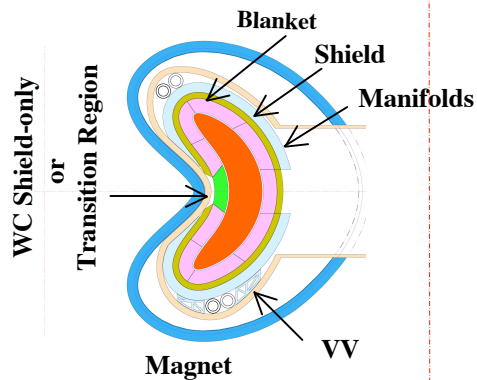
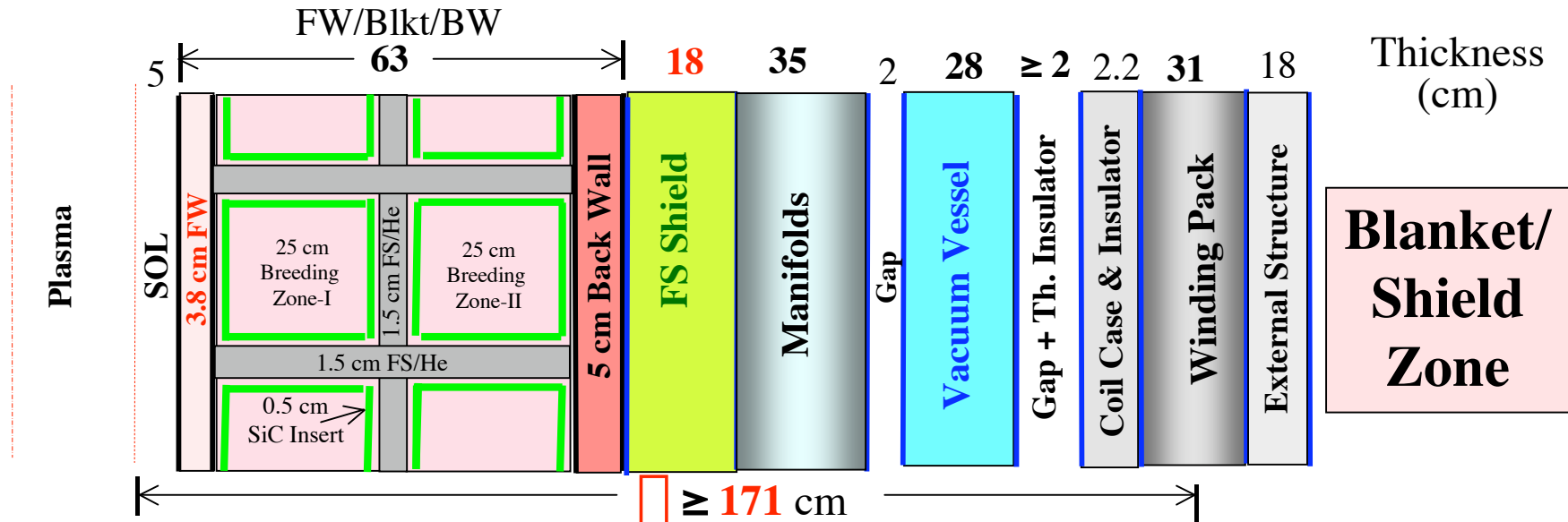
UCSD

Contents

- ARIES-CS **volume comparison**: CAD vs Systems Code
- **ARIES-CS / ARIES-AT comparison**:
 - Volume
 - Mass
 - Cost.
- **Detailed costing accounts**:
 - # 21: Structures & Site Facilities
 - # 22: Reactor Plant Equipment
 - # 22.1 Reactor Equipment
 - # 22.1 Main Heat Transfer & Transport System
 - # 22.1.6 Vacuum System
 - # 23: Turbine Plant Equipment.
- **Other cost-related items**:
 - Recirculating power
 - Cryostat design
 - Annual replacement cost.
- Impact of **dual-coolant** on radial build and COE.

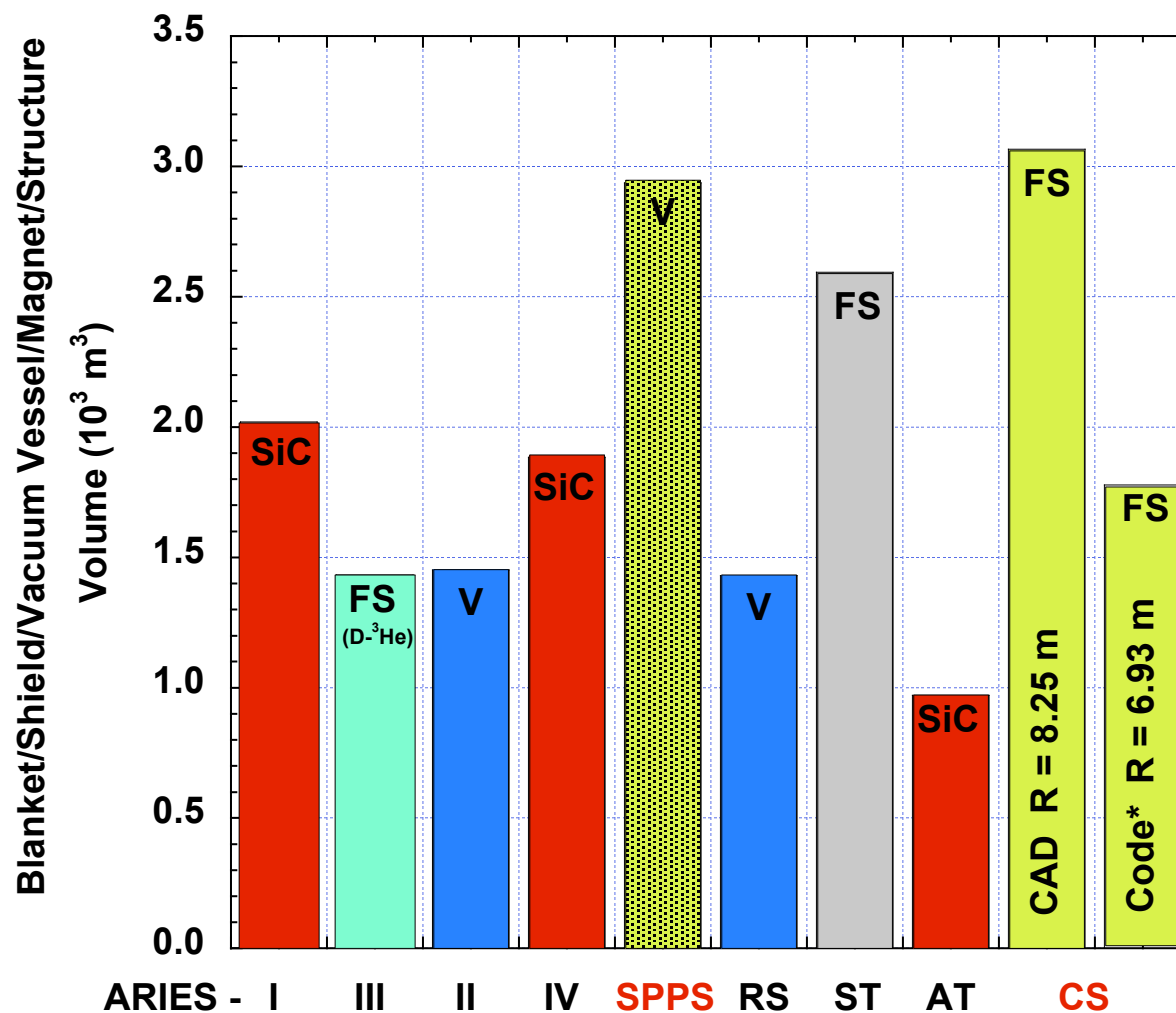
ARIES-CS 9/05 Radial Build

(No increase to FS shield; No manifolds in shield-only zone; 3 MW/m² peak □)



Volumes

(not compacted; no replacements; 9/05 radial build)



* 9/30/05 systems code output. Cryostat excluded.



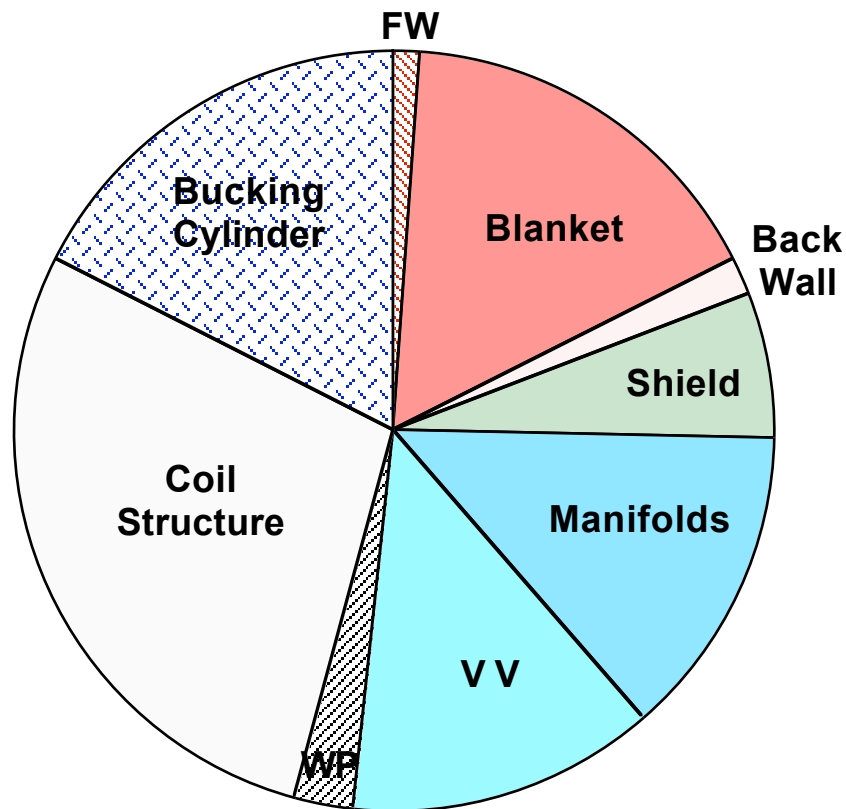
ARIES-CS Comparison

	CAD	Systems Code (9/30/05)
R (m)	8.25	6.93
a (m)	1.85	1.52
FW/B/S/VV/mgnt Thickness (m)	1.5 - 2.5*	1.85 - 2.85 [#]

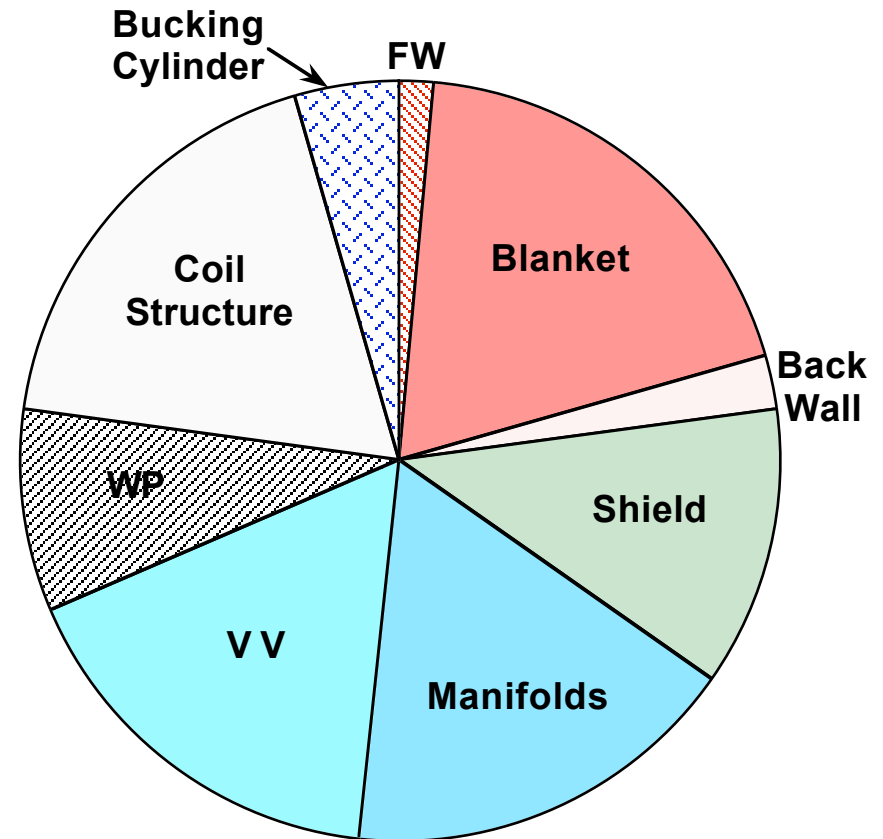
* Magnet: 2 cm coil case, 31 cm WP, 18 cm external structure.

[#] Magnet: 2 cm coil case, 18 cm WP, 56 cm external structure, 10 cm back wall.

ARIES-CS Volumes (not compacted, no replacements)



CAD Volumes
(50% magnet/structure/BC)



Systems Code Volumes
(30% magnet/structure/BC)

ARIES-CS Volumes

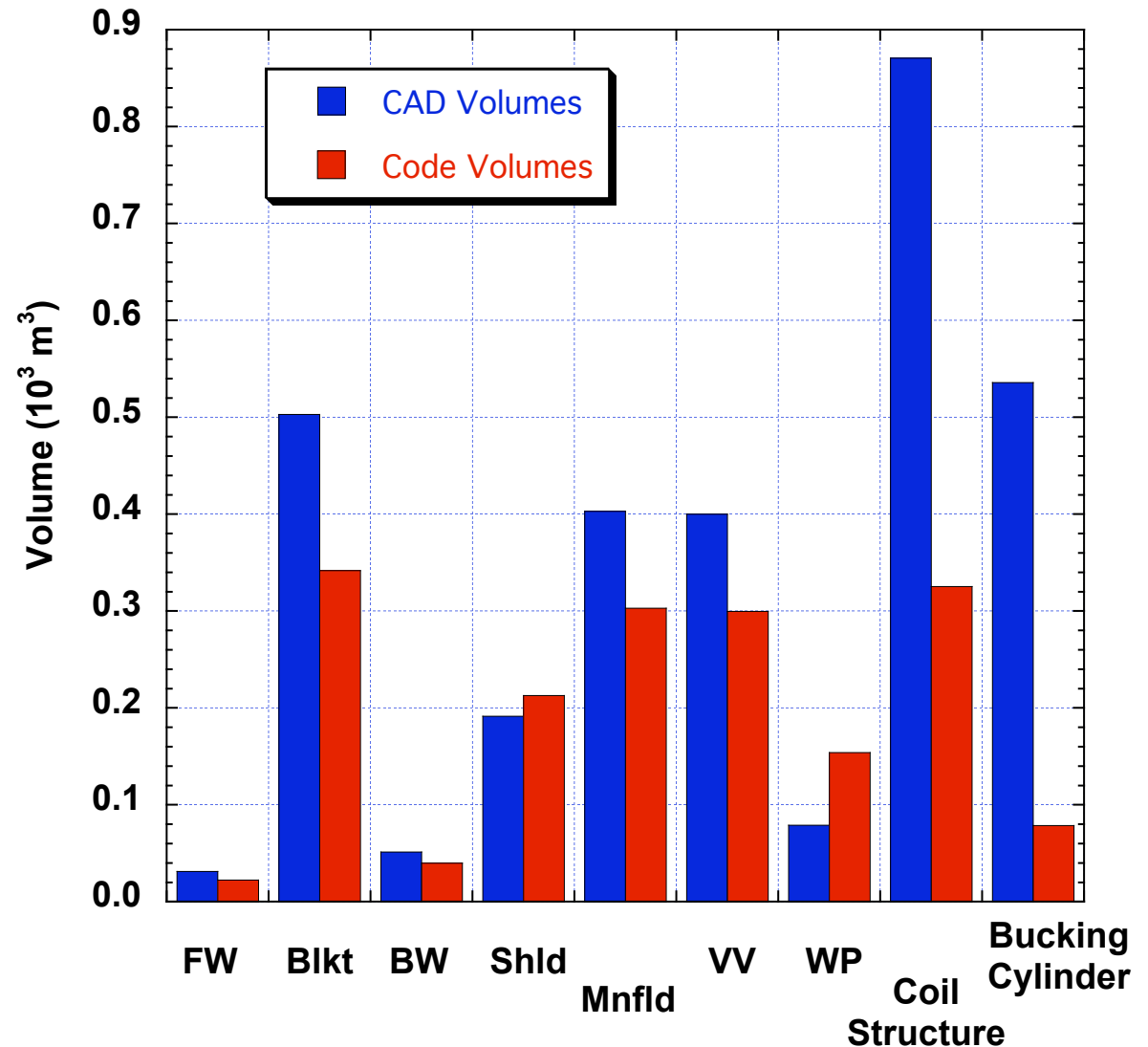
(not compacted, no replacements)

Systems code provides smaller volumes, except for shield and WP.

Large differences in volumes of blanket, WP, structure, and BC.

In CAD, is shield-only zone included in blanket or shield?

Use same WP, structure, BC dimensions.





Stellarator / Tokamak Comparison

	<u>Stellarator</u>		<u>Tokamak</u>
	ARIES-CS		ARIES-AT
	CAD	Systems Code (9/30/05)	
R (m)	8.25	6.93	5.2
a (m)	1.85	1.52	1.3
FW/B/S/VV/mgnt (m)	1.5 - 2.5*	1.85 - 2.85#	1.4 - 1.7
P_f		2347	1749
P_{th}		2610	1968
P_G		1054	1161
□_{th}		42%	59%
LSA		2	1

* Magnet: 2 cm coil case, 31 cm WP, 18 cm external structure.

Magnet: 2 cm coil case, 18 cm WP, 56 cm external structure, 10 cm back wall.

ARIES-CS / ARIES-AT Comparison: Systems Code Volumes

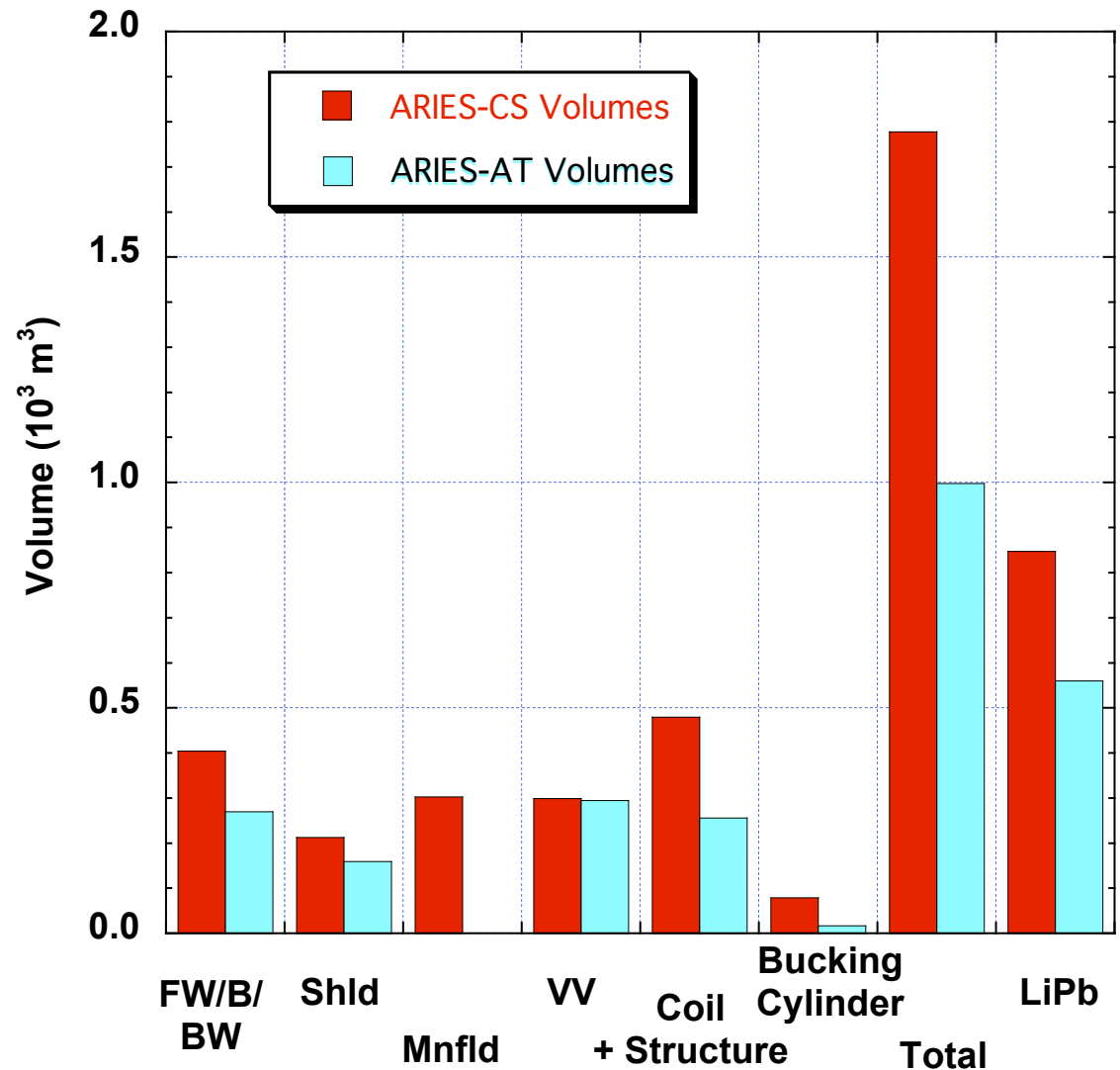
ARIES-CS components
are larger.

Need to fix:

- Volume of filled core
(same as empty core)
- Coil volume to include
coil structure.

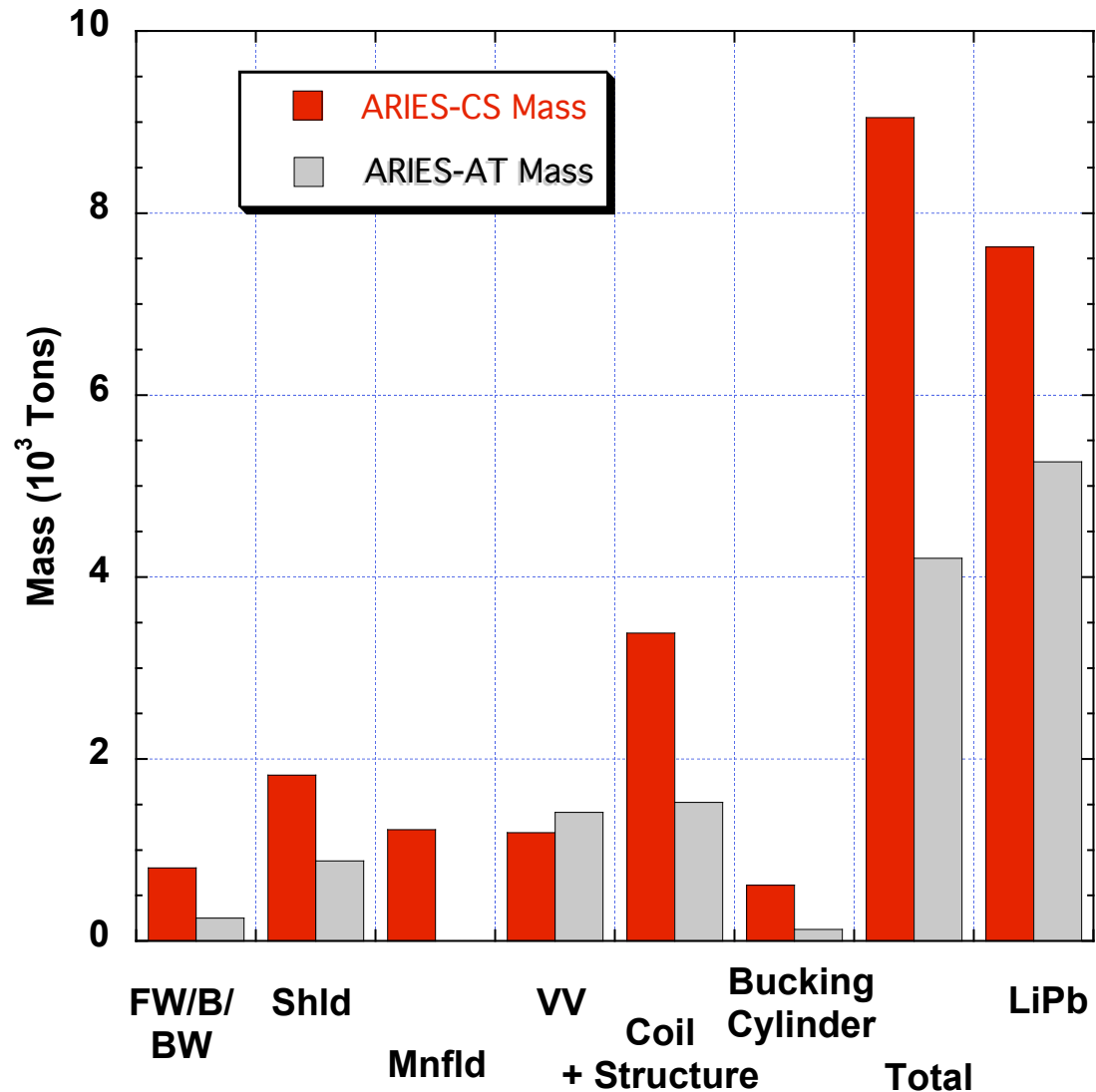
Need to add:

- Shield vs $\square$ scaling
- Penetration & local
shields ($\sim 10\%$ of shield)
- Primary structure
($11.25\% V_{str}$)
- Cryostat
- Divertor.



ARIES-CS / ARIES-AT Comparison: Systems Code Masses

ARIES-CS components
are more massive,
except VV.

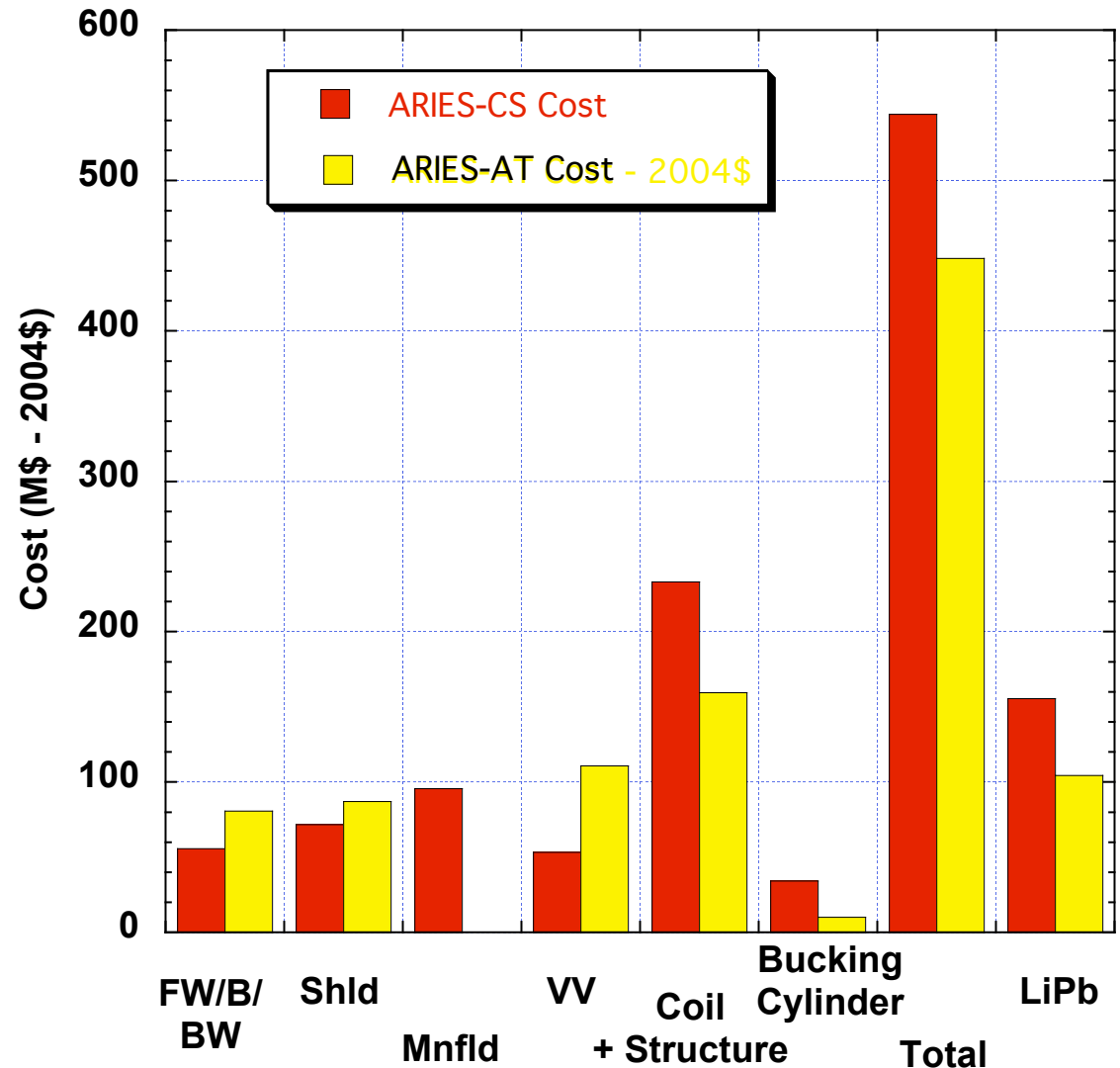


ARIES-CS / ARIES-AT Comparison: Systems Code Costs*

ARIES-AT blanket, shield, and VV are more expensive.

Need to fix:

Cost of core to include coil structure, as in Fig. □ 544 M\$, not 368.



* 2004\$ (= 1992\$ x 1.256, per Les).



ARIES-CS / ARIES-AT Comparison: Systems Code Direct Cost

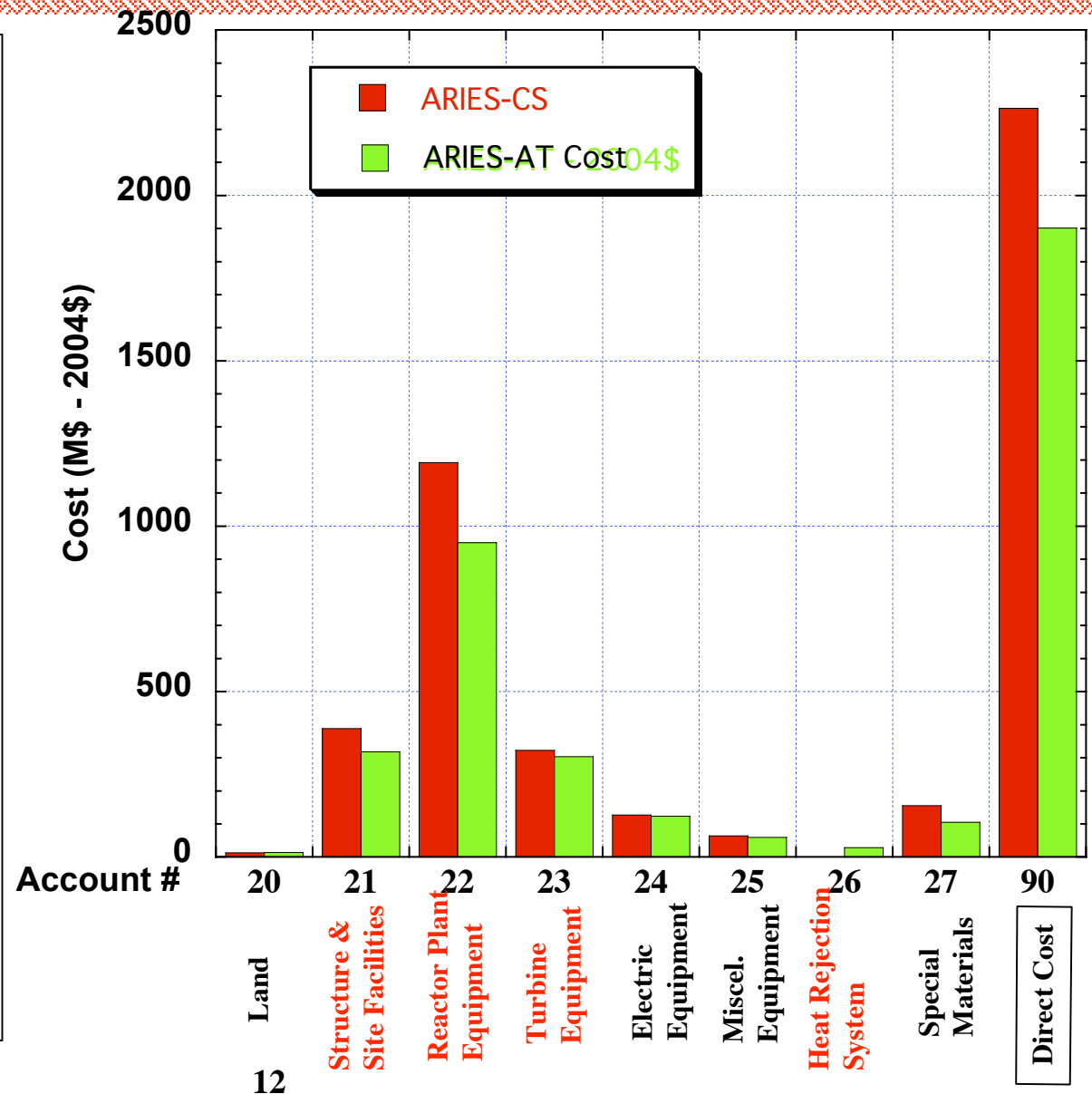
Check Accounts:

- # 21
- # 22
- # 23 for dual-coolant (LiPb and He)

In ARIES-AT, separate Account # 26 for **Heat Rejection System** (23M\$).

In ARIES-CS, **Heat Rejection System** (50M\$) included in Account # 23.

Special materials include cost of LiPb.



Account # 21

(Structures & Site Facilities)

$$\text{Cost of Reactor Building (2004 M\$)} = 6.2 \times 10^{-4} V_{\text{RB}}^{\#} + 81.2$$

ARIES-

LSA

Account #:

		RS	AT	CS
		2	1	2
21.1	Site Imp. & Fac.	?	?	23
21.2	Reactor Bldg	~185	~140	157 ?
21.3	Turbine Bldg	?	?	39
21.4	Cooling System Struc.	?	?	10
21.5	Power Supply Bldg	?	?	12
21.6	Misc. Bldgs*	~141	~107	138
21.7	Ventilation Stack	?	?	2
21	Total	416	318	389
				(sum = 381 ?)

Check reactor building cost and total

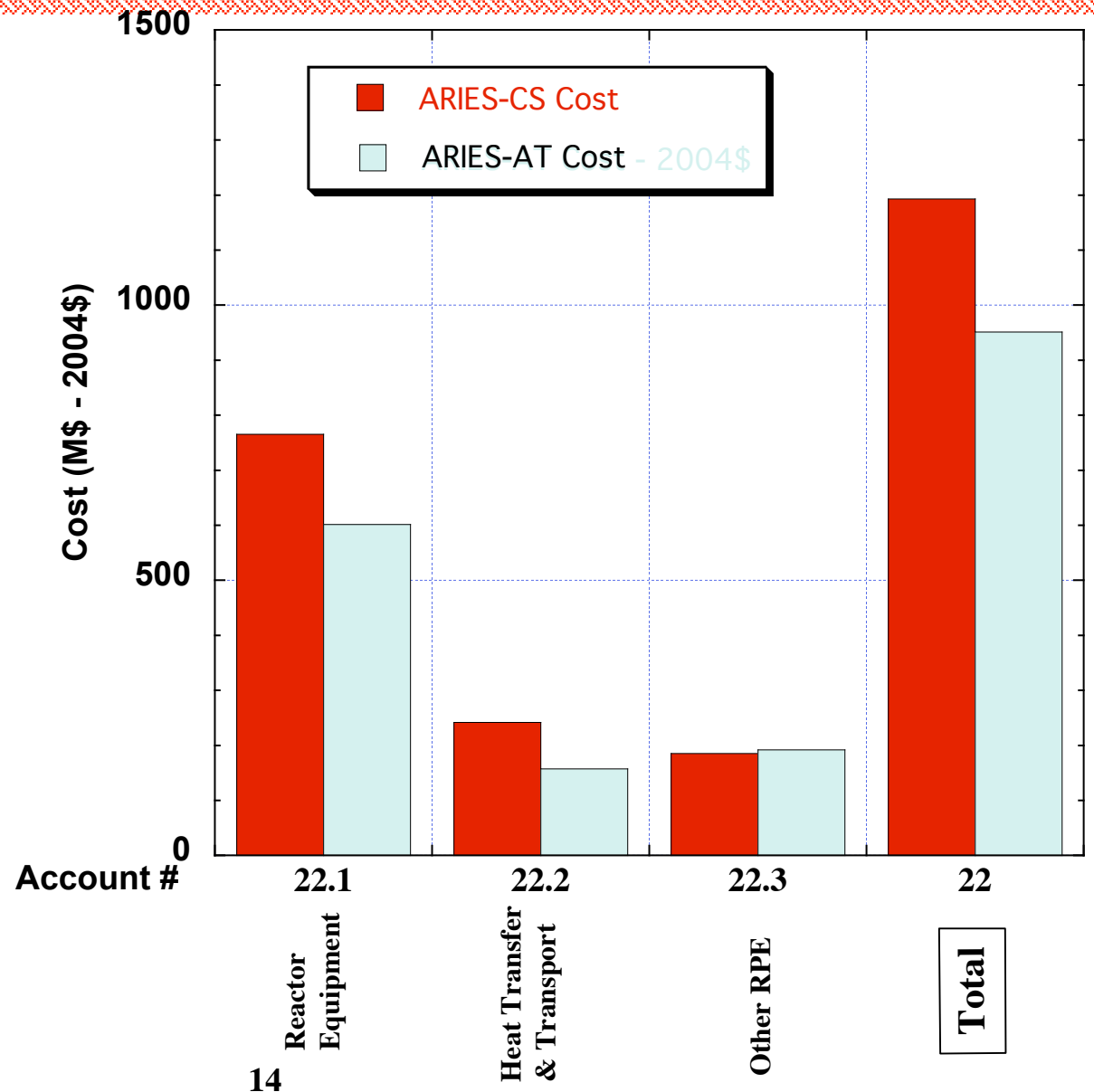
~ $2 \times 10^5 \text{ m}^3$. Torus volume = 4-5% of building free volume (V_{RB}).

* Include hot cell bldg.

Account # 22 (Reactor Plant Equipment)

Check Accounts:

- # 22.1
- # 22.2 for dual-coolant.



Account # 22.1 (Reactor Equipment)

Here, **magnet** cost includes coil and structure.

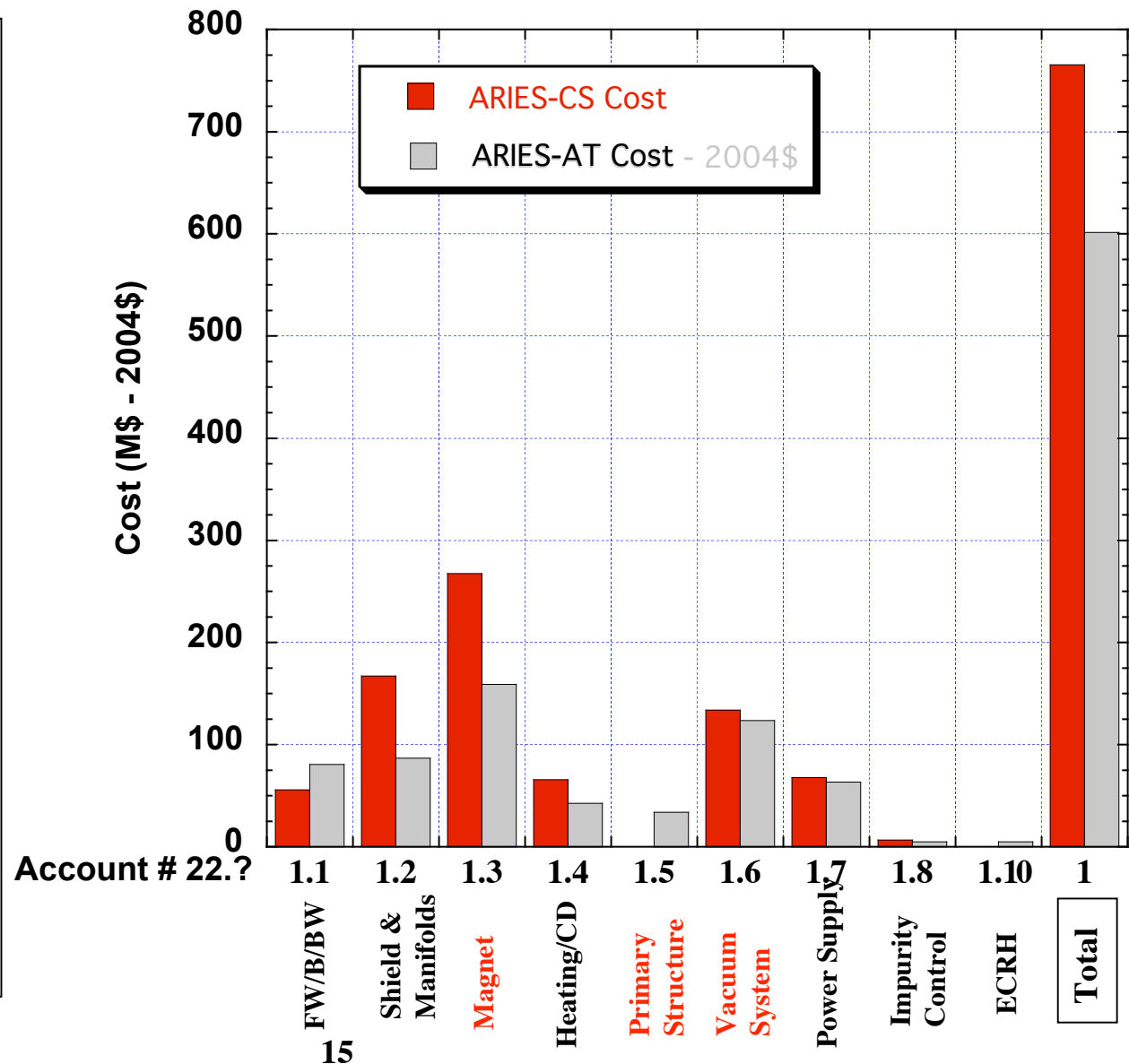
Need to fix:

- Primary structure definition (Account 22.1.5)
- Coil cost to include coil structure.

Vacuum system should include VV, **cryostat**, and vacuum pumping.

Need to add:

- Cryostat
- Primary structure (~50 M\$).



Account # 22.2

(Main Heat Transfer & Transport System)

P_{th} and power split between He and LiPb

ARIES-	RS	ST	AT	CS
LSA	2	2	1	2
Single or dual-coolant?	Single	Dual	Single	Dual
He/LiPb power	--	49:51	---	42:58
P_{th}	2619	3373	1968	2610
Cost (M\$ - 2004\$)	293+30*	450 (330 for single coolant)	158	242 ? (~290 for single coolant ?) (~390 for dual coolant ?)

Fix account # 22.2 for dual-coolant

* For V liner in outer loop.



Account # 23

(Turbine Plant Equipment)

P_{Gross}

ARIES-

RS

ST

AT

CS

P_{Gross}

1205

1518

1161

1055 ?

Cost (M\$ - 2004\$)

357

426

303

272 ?
+ 51*

* For Heat Rejection System



ARIES-CS Recirculating Power

	MW _e
Miscellaneous Power	~50
He Pumping Power	~50
Cryogenic Power	~4 + ?
Total	> 104 □ P_{Gross} > 1104 MW_e

Fix P_{Gross} and Account # 23

Vacuum System

(Account # 22.1.6)

ARIES-	RS	AT	CS
VV Thickness (cm)	20 - 30	25 - 40	28
Cryostat Thick. (cm)	24	2 ?	37 [#]
Effective SS Thick. (cm)	4.3	0.4 ?	8 [#]
LSA	2	1	2
Cost (M\$ - 2004\$):			
Vacuum Vessel	62	92	53
Vacuum Pumping	100	23 ?	81
Cryostat	38	9 ?	0 ?
Total	200	124 ?	134 ?

Add 37 cm thick cryostat (22% SS, 78% void)

* 2004\$ (= 1992\$ x 1.256, per Les).

Based on 2004 ITER design, per B. Nelson.

Cryostat Design

- **Functions:**

- Form secondary **confinement barrier** for radioactive inventory.
- **Provide vacuum** to stop convective heat transfer to magnet and cold structure.

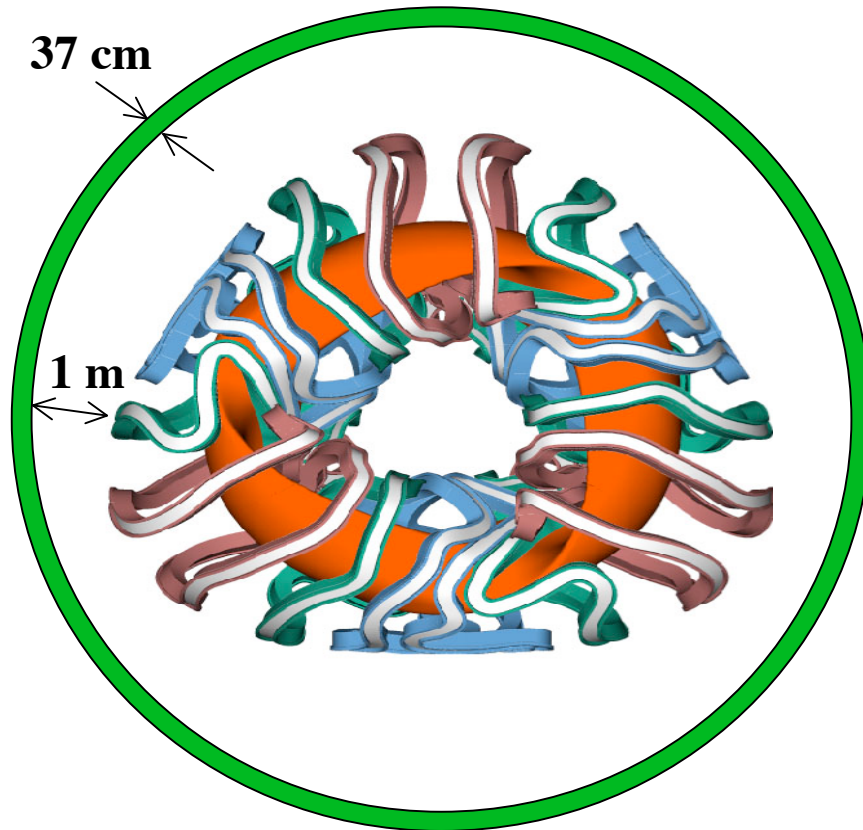
- **Proposed design*:**

- Single SS **cylindrical shell** with flat top/bottom
- **Stiffened** with rings and ribs
- **Thickness:** 37 cm thick cylinder with effective 8 cm SS
8 cm thick top/bottom
- Fully-welded with large number of penetrations
- “**32 m diameter x 18 m high**” cylinder determined by dimension of largest component (magnet) with additional 1-2 m clearance to provide space for penetrations and access for inspection, repair, and maintenance
- **Covered with thermal shield[#]** to minimize heat radiation from warm components to cold magnet
- **Surrounded and supported by bioshield** with radial clearance of 0.5 m.

* Based on ITER cryostat: <http://www.iter.org/index.htm>

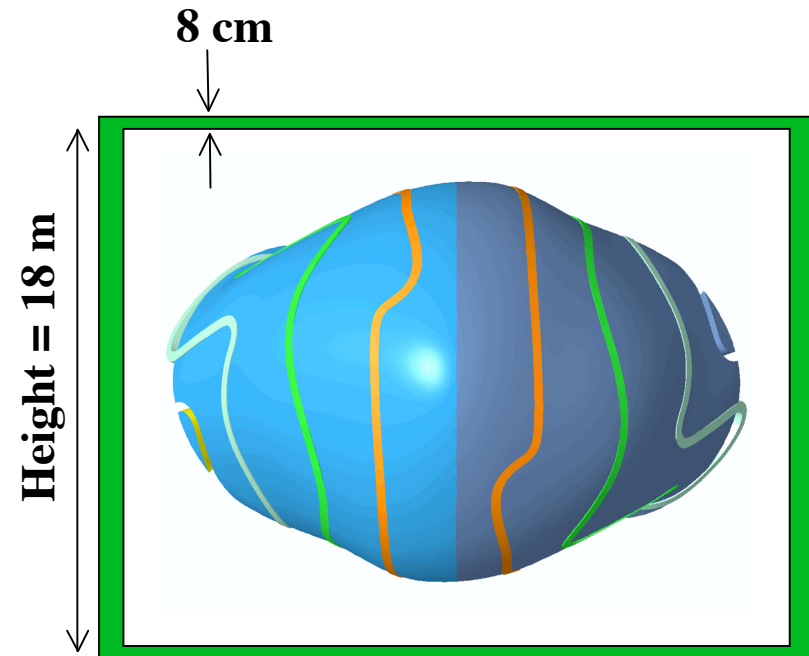
ITER suggests SS panels cooled with He gas @ 80K.

Proposed Cryostat



Inner Diameter = 32 m

Horizontal Xn



Vertical View

Annual Replacement Cost

blanket/divertor cost and NWL

ARIES-	RS	ST	AT	CS
LSA	2	2	1	2
Replaceable components cost (M\$ - 2004\$)	93	63	80	56+4+? [*]
Peak NWL (MW/m²)	5.7	5.6	4.9	4.9
Replacement cost (mills/kWh - 2004\$)	5.8	4.4	4.3	1.1 ?

**Fix Annual Replacement Cost for
blanket, WC shield, and divertor**

^{*} divertor.



Impact of Dual-Coolant on **New** **(11/05)** Radial Build and COE

Zone	Blanket/Shield	Shield-Only
B/S/Mnflld Thick. (cm)	126	84
He Thickness (cm)	20 (16%)	17.5 (21%)

Impact on:

Major radius	~ 1 m	☐	↑	COE
Increase in FPC volume/mass	10-20%	☐	↑	COE
He pumping power	50 MW _e	☐	↑	COE
Heat Transp. & Transf. Systems	~100 M\$	☐	↑	COE
$\square_{th}$	~ 5 points	☐	☐	COE

Impact on COE

Any gain !

**Check dual-coolant costing algorithm for
Heat Transport & Transfer Systems**