An Alternate Modular Design for TASD

John Cooper

(lots of help from

Bob Wands,

Hans Jostlein,

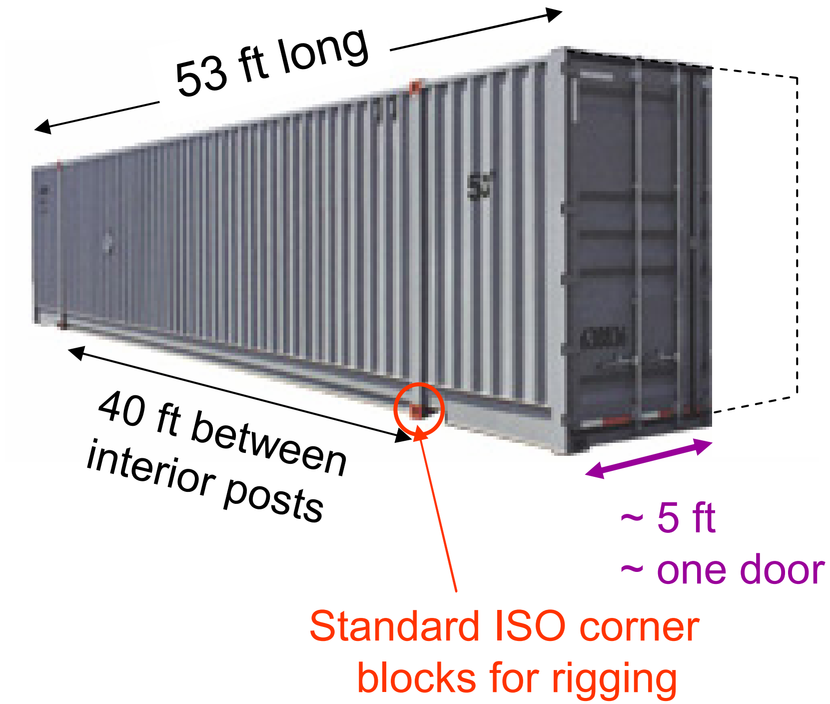
Jim Kilmer,

Ron Ray,

Ang Lee,

…)

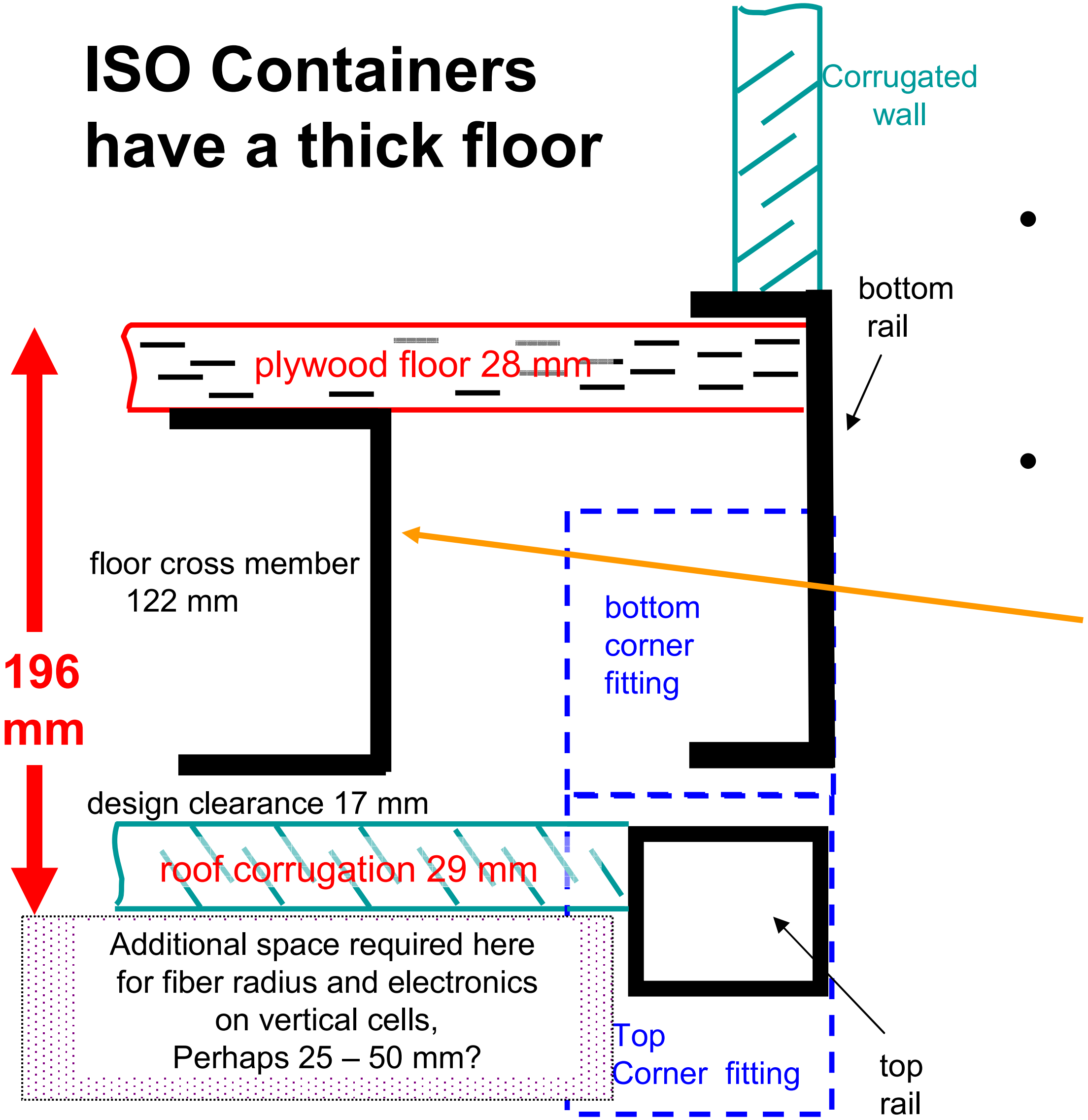
Recall the scheme from the October Collaboration Meeting was to build a custom “half width” container for TASD



- 53-foot long ISO containers
  are a standard item for US Domestic trade
  - 53- ft because that matches the DOT length limits without permits.
  - Made by adding simple extensions to both ends of the 40ft version
  - These have 8 posts with the four at the 40 ft positions being the strong ISO spec versions capable of 190,000 lb loads each.
- 53 ft is interesting because we wouldn’t have to stack rows side by side to get the TASD width, so no vertical “cracks”.
- But the problem of the container floor structure still remains

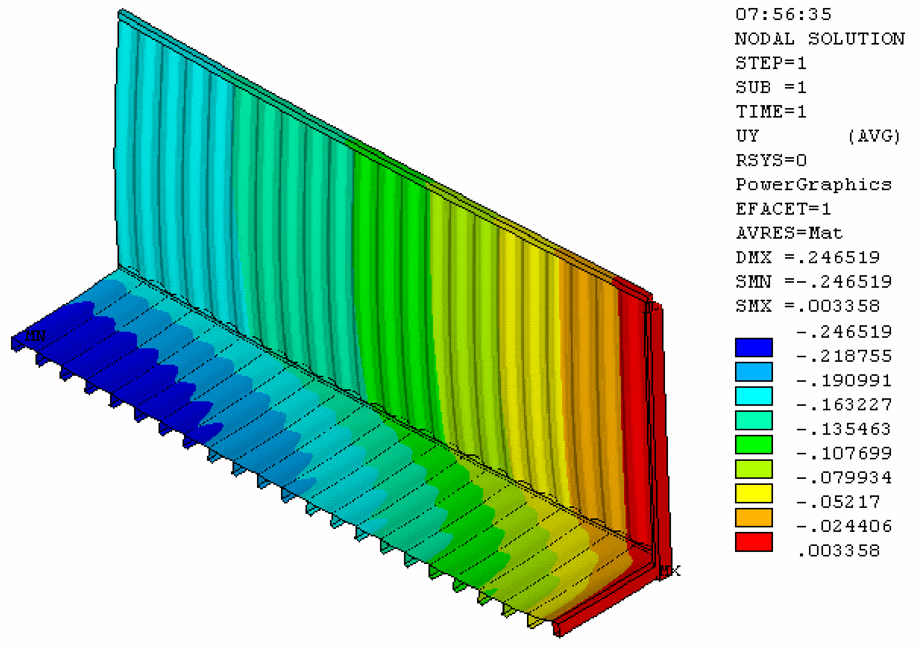
The GAP between stacked Modules

ISO Containers have a thick floor

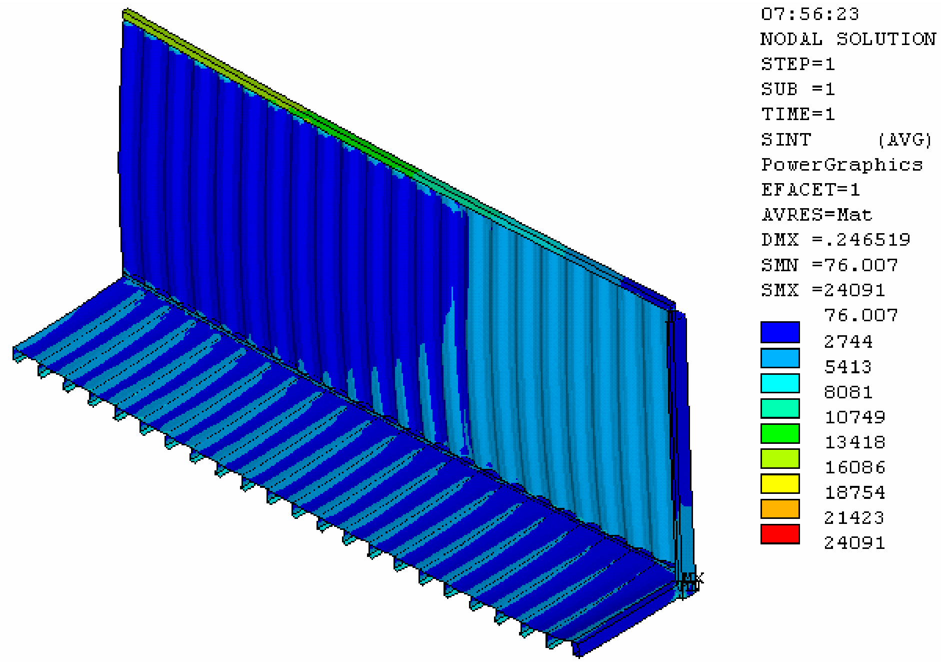


- It's easy to remove the plywood floor and flatten the corrugated roof
- We concentrated on different solutions for the floor cross members
  - Shorter channels, more of them
  - Box beam with top and bottom skins
  - Solid metal floor

Bob Wands looked at deflections and stress in each scheme via FEA

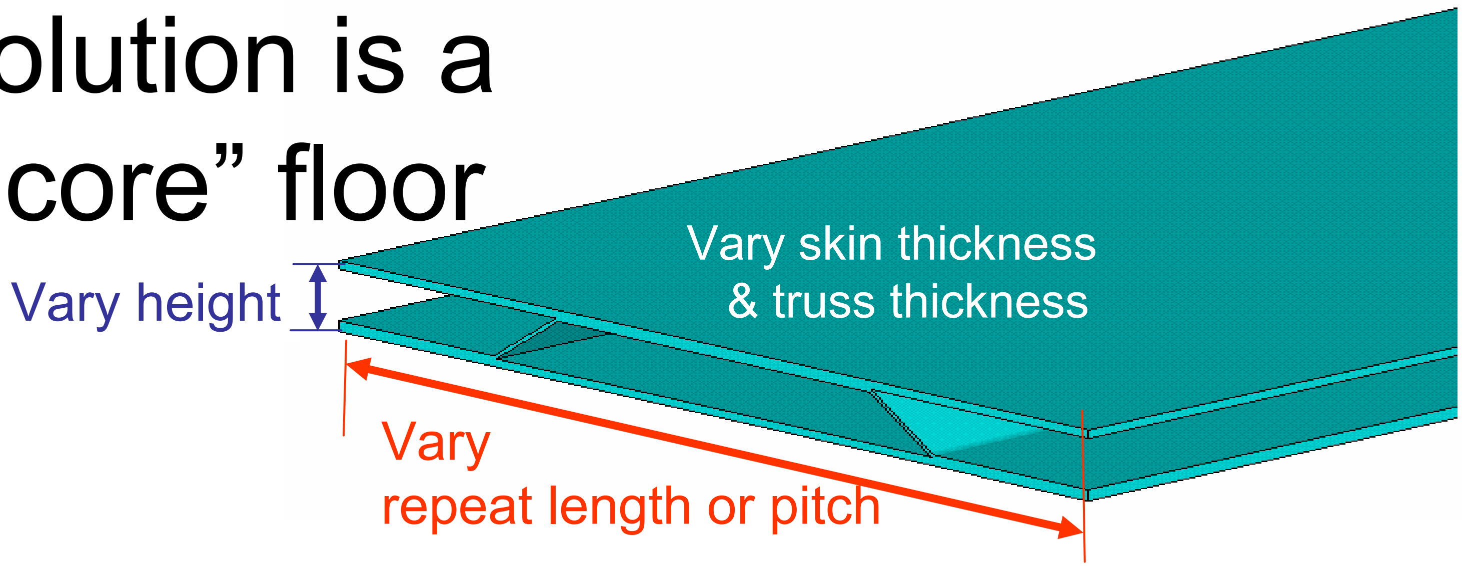


- Sample Deflection
  - Center of floor sinks under load



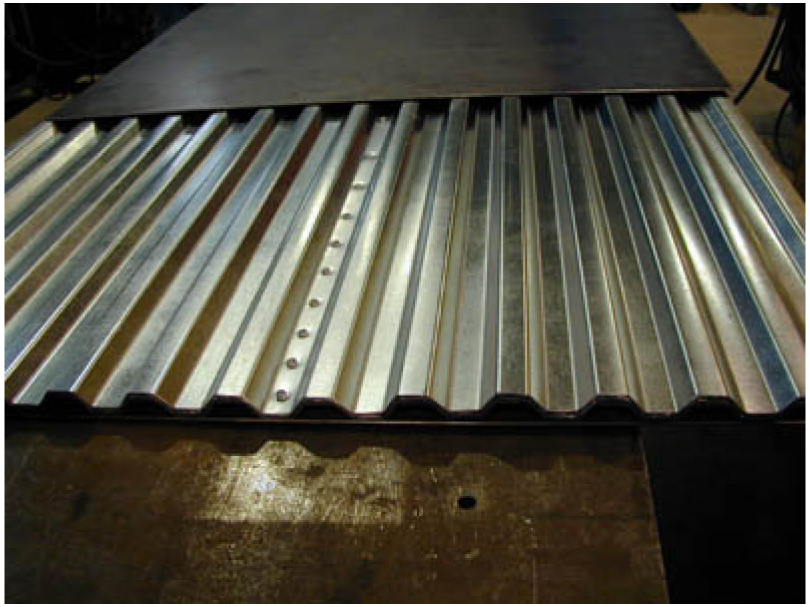
- Sample Stress
  - Sometimes hit a limit on the top rail stress

Our solution is a "trusscore" floor



- The truss runs across the short 4 - 5 ft wide dimension of the 53" long module
- A height of 0.52 inch = 13.2 mm will work
  - This has top and bottom skins 3 mm thick
  - The truss is 2 mm thick
  - So overall the package has about 8 mm of steel or 0.45 X_o
  - Crossing particles all see the same amount of material, no "lumpy" channel supports
- The solution is not a strong function of the repeat length
  - Anything between 1" & 12" will work
  - The truss angle can also be 30^o (or 45^o as shown)

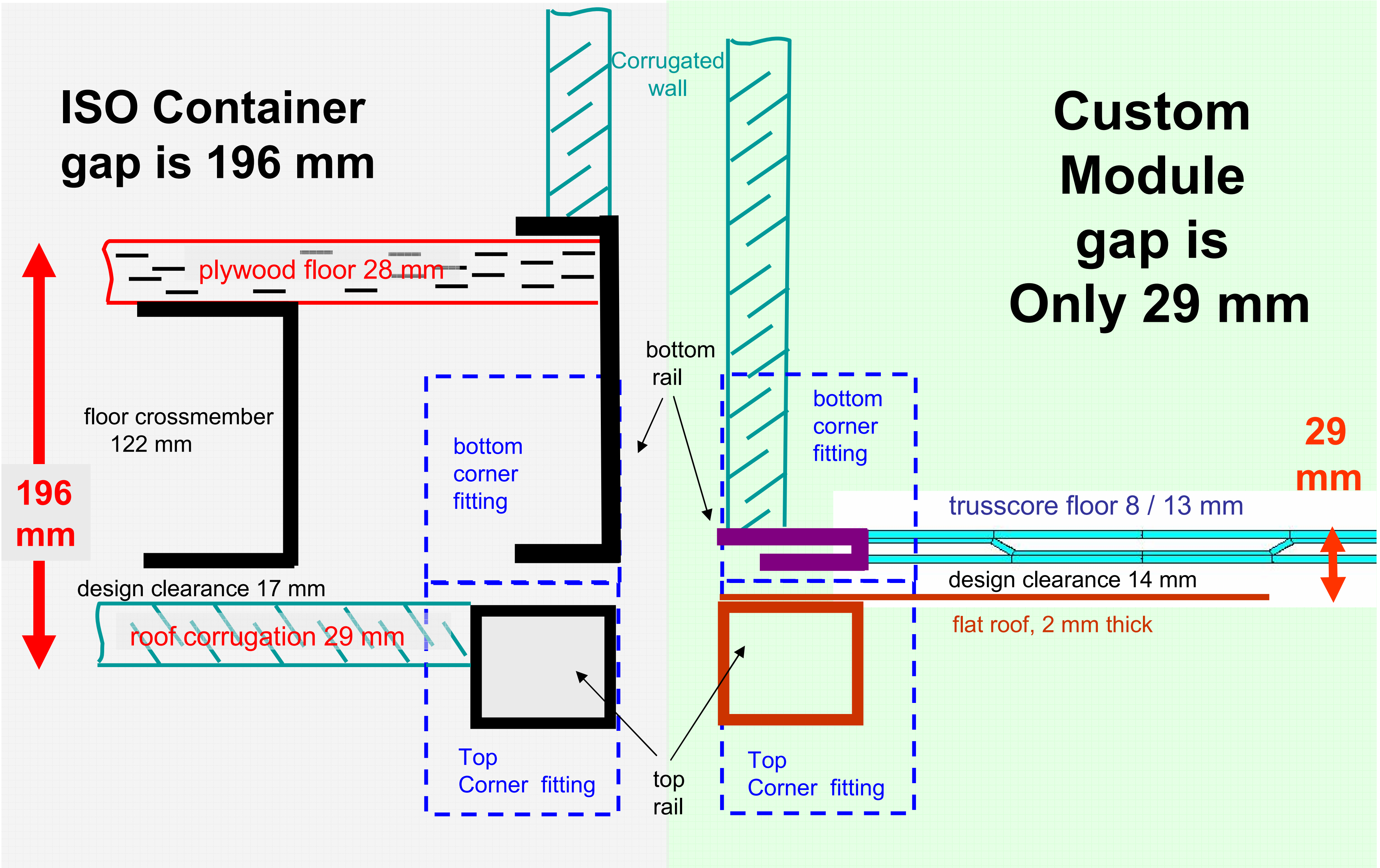
Prototype trusscore under test



Assembling a section out of 8 layers of 24 gauge “form deck”, pop rivet to 1/8” skins

Will load test and compare to FEA

Reduced GAP between stacked Modules



Description, part 1

- **The module size is 4 ft wide x 53 ft long x 9 ft high**
    - The interior width is 42 inches
    - The center 51 ft are loaded with TASD extrusions
    - There are 20 cells along the beam direction
        - 2 extrusions high for horizontals, 12 extrusions wide for verticals
- **Module under load**
    - **Fully loaded with liquid scintillator it's 98,000 pounds**
        - A 50 ton building crane does the job.
        - The trusscore floor sag is less than 9 mm under full load
            - This uses 9 of the 14 mm "stay clear" space between stacked modules
            - The sidewall sags another 7 mm, but so does every sidewall in a vertical stack, so we can ignore this effect.
    - **Empty, the module's tare weight is 12,895 pounds**
    - **Loaded only with plastic extrusions, it's 21,000 pounds**
        - So two modules twist-locked together are 42,000 pounds
        - This is under the U.S. standard interstate load limit of 43,000 pounds
            - We can ship two together (with no permits) to reduce transportation costs.
    - **Half-loaded (drain the horizontal cells) it's 53,000 pounds**
        - That plus a 37,000 pound tractor/trailer gives 90,000 pounds.
        - This is allowed on the roads with a routine permit @ 22 cents/mile
          (If it were 2,000 pounds lighter, then only 6 cents/mile)

Description, part 2

- **The interior posts are set at 46 ft wide**
  - This is different from the standard container 40 ft posts so that:
    - The center 14.0 meters are free of posts
    - 0.75 meter of the detector is outside of these posts at each side
      - Similar to fiducial cuts we have used in simulations
  - These 4 posts must hold 5 full modules = a total of 490,000 pounds
    - Since each ISO post is designed for 190,512 pounds,
      we get a **safety factor of 1.55.**
      This is OK for steel construction.

- **The 4 exterior posts are available to support an overburden**
  - At a safety factor of 1.5, these four posts can
    - hold a piece of steel that is 4 ft wide x 69 ft long x 1.2 m thick
      - 69 ft so that it overhangs two 8 ft wide aisles along the detector
      - **1.2 m of steel is ~ 3.8 m of earth or ~ 9.4 m water equivalent**
    - This steel weighs 254 tons, so you have to divide it into 50 ton loads
      - Stack them up on the same kind of corner blocks used in the module.
  - The exterior posts are "exterior", could even beef them up to hold more

Description, part 3

- **In this scheme, NONE of the PVC gets glued together**
  - The module box holds the parts in the proper configuration
  - The PVC serves only to hold the liquid in place
    - The maximum pressure is now reduced to 3.5 psi.

- **The vertical cells are short (9 ft or 2.7 m long)**
  - So the fiber attenuation is much reduced
    - We can use a single 0.5 mm diameter fiber (no loop)
  - “Smaller” factories can make complete vertical extrusions.
    - An empty vertical extrusion weighs only 53 pounds (full=370 pounds)

- **“Big” factories do complete horizontal extrusions & add vertical extrusions into the final modules**
  - The full modular product gets checked out at the factory

- **The modules can be quickly filled and stacked at the far site so that data taking can begin**

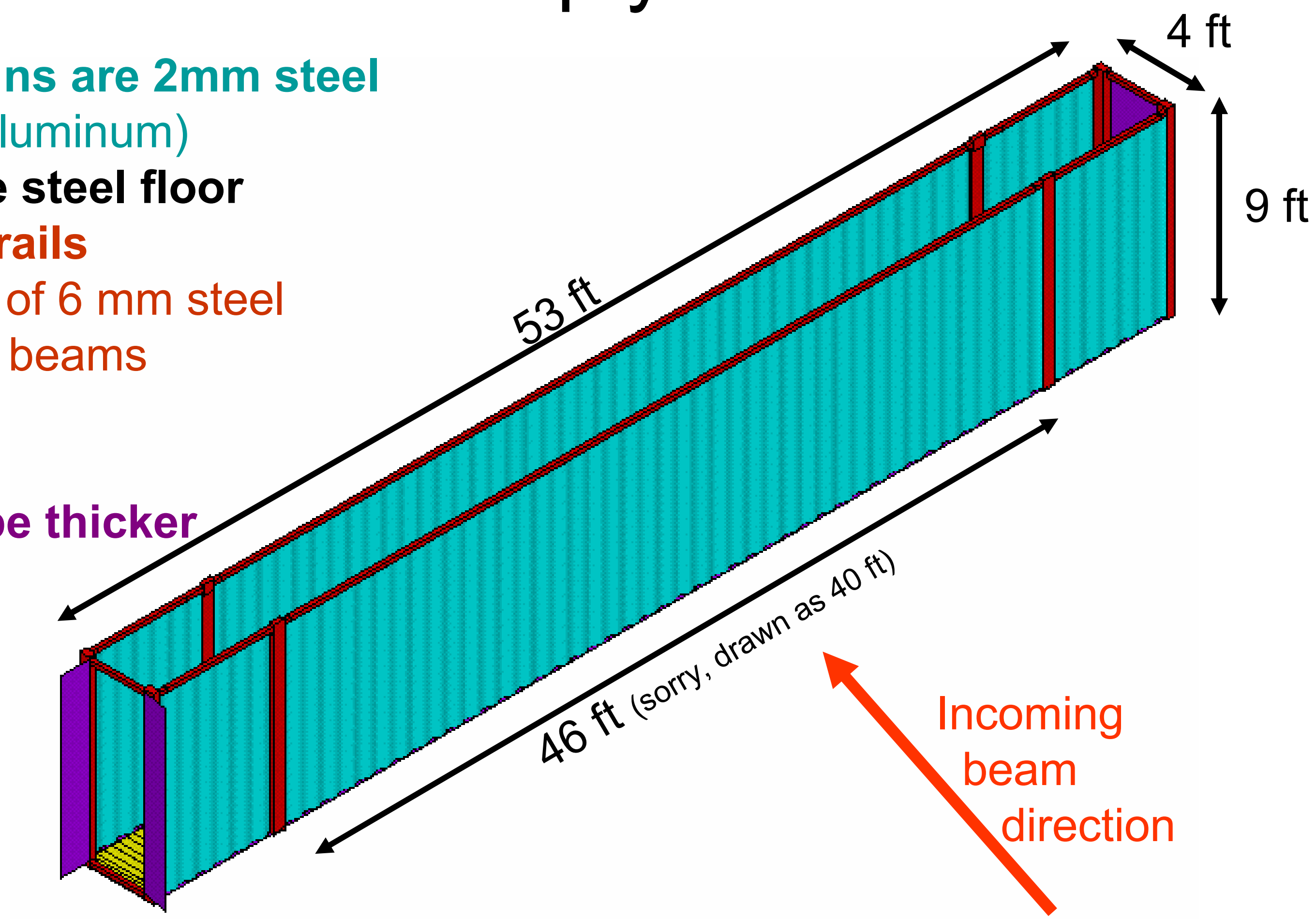
Assembly Sequence - 1

- Start with 600 empty modules

Light blue steel skins are 2mm steel
(some could be Aluminum)
Yellow is trusscore steel floor
Red for posts and rails
(typically 2 layers of 6 mm steel
or 60x60 mm box beams
of 3mm steel)

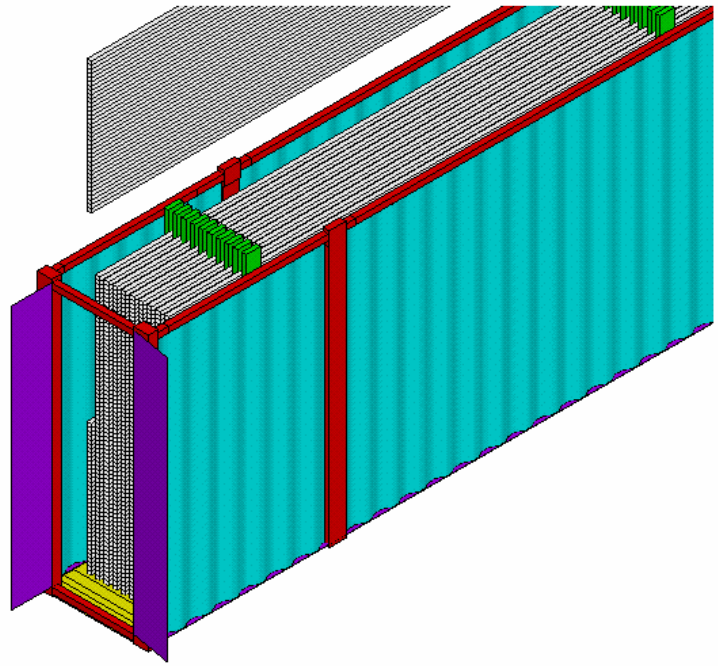
Purple doors can be thicker
(2 at each end
as shown or
1 "standard" size)

Access to 3 sides
Of the 6-sided box

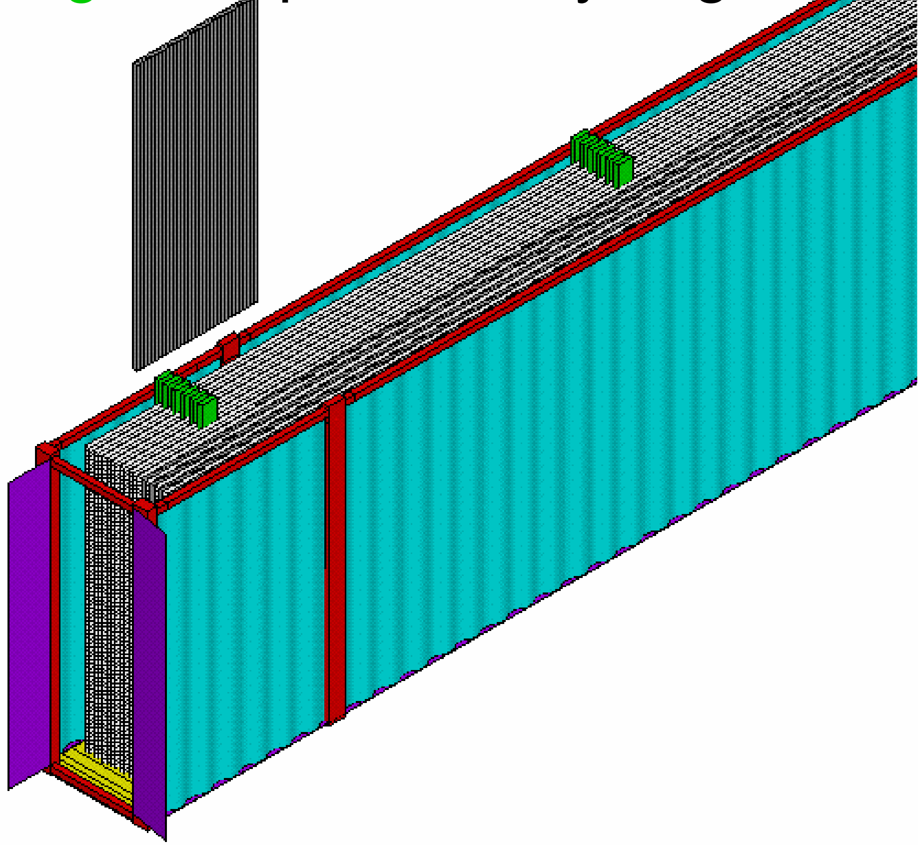


Assembly Sequence – 2

- First insert all horizontal extrusions, leaving (green) spacers between layers

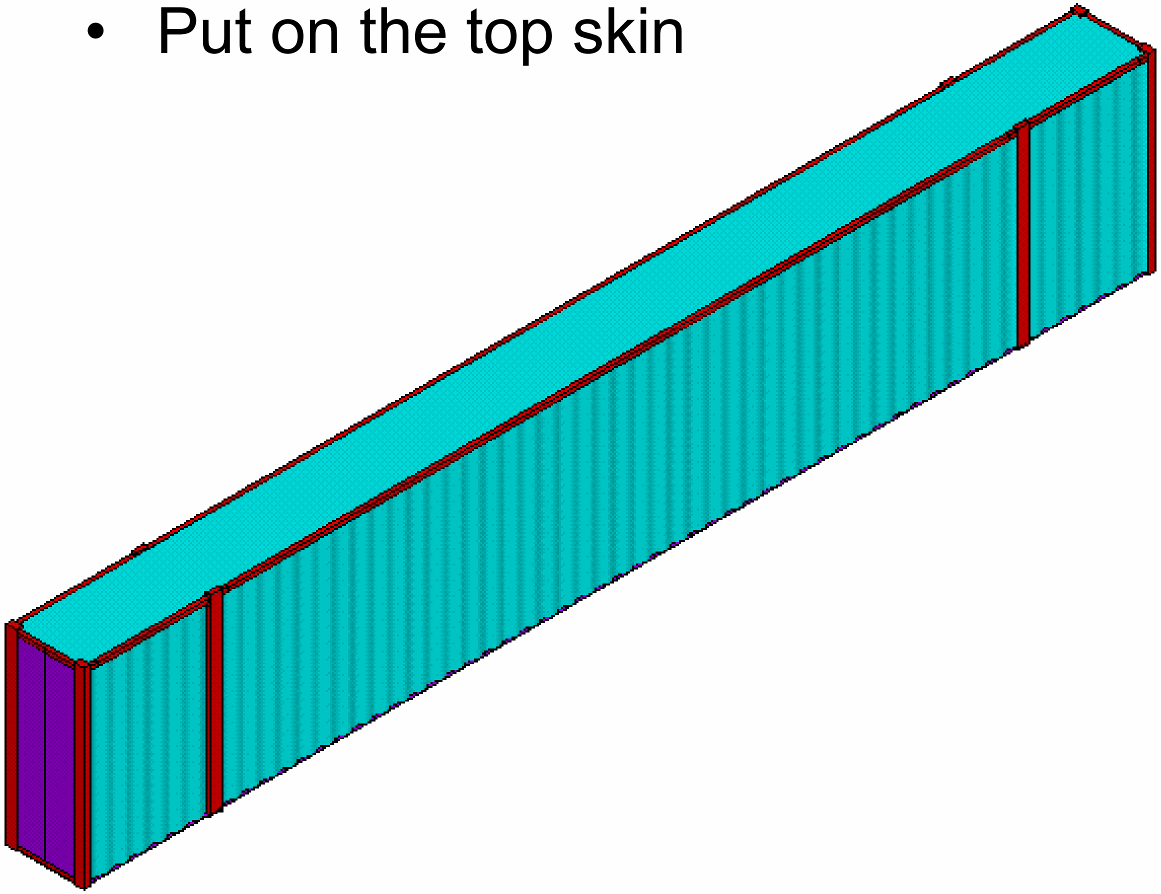


- Next insert vertical extrusions, removing the green spacers as you go



Assembly Sequence - 3

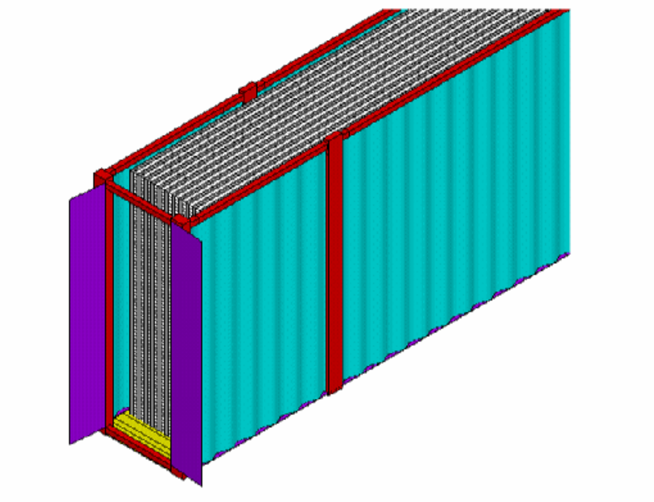
- Put on the top skin



- Transport two such modules side by side on one trailer load

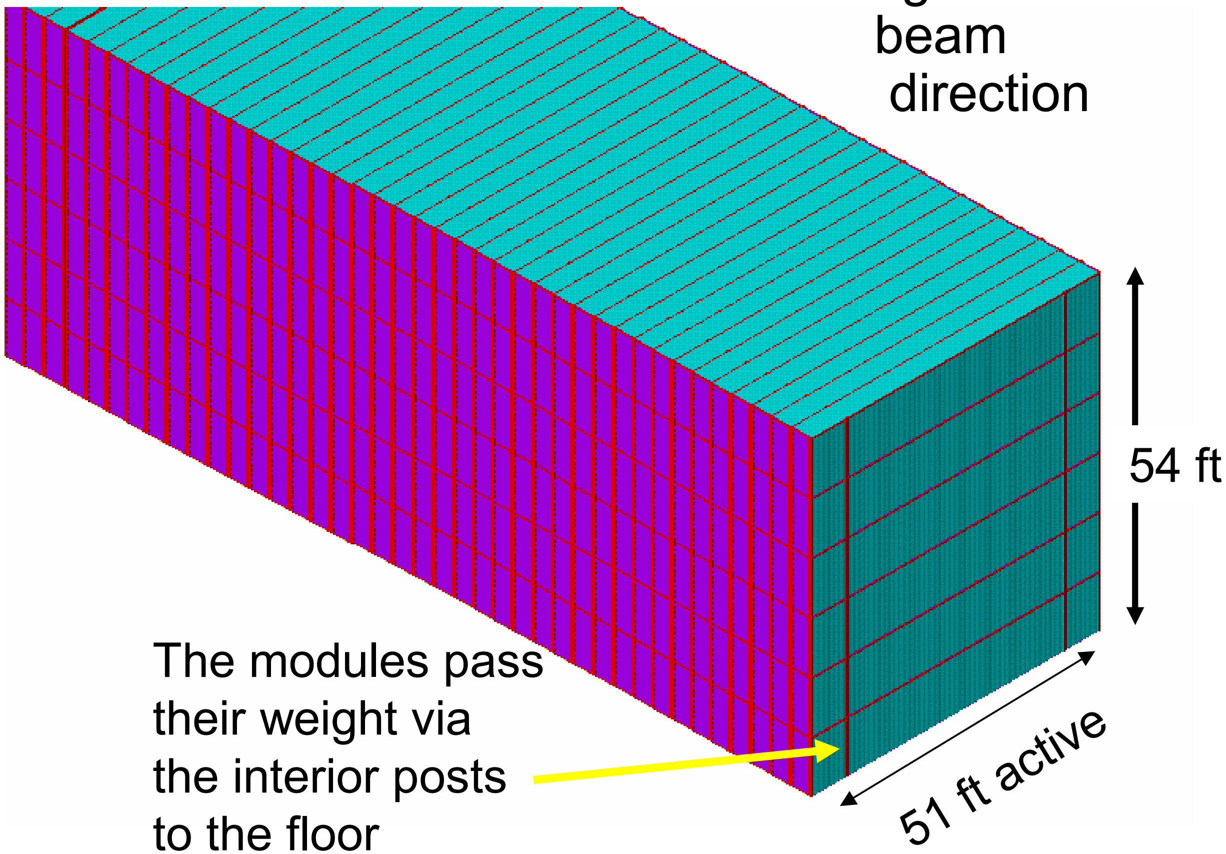
Assembly Sequence - 4

- At the Far Site, remove the top skin,
- Open doors at one end
- Fill all extrusions with oil at one filling station



- Replace top skins

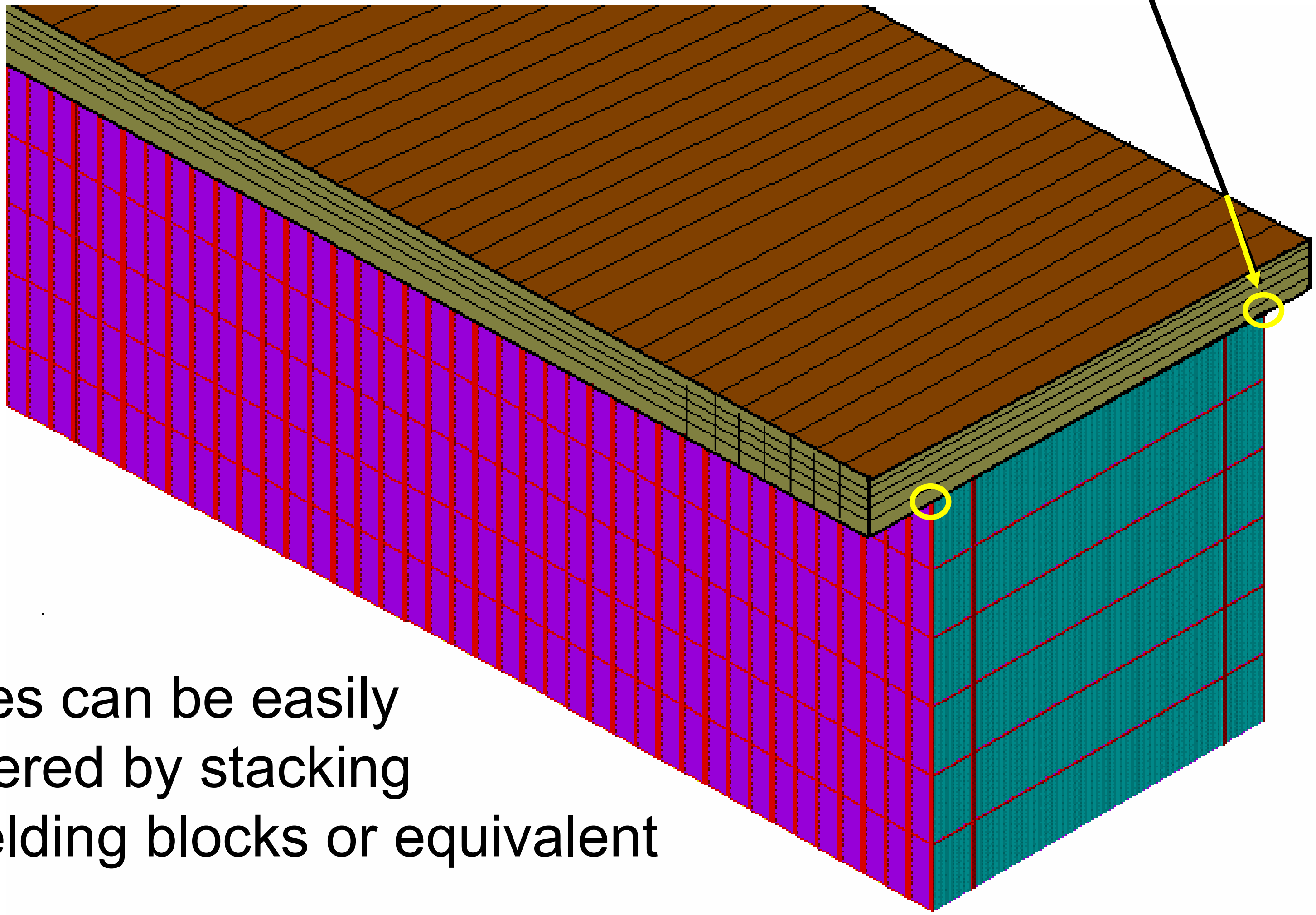
- Stack the 50 ton modules up, 6 high by 100 deep, small gaps between rows along the beam direction



The modules pass their weight via the interior posts to the floor

Assembly Sequence - 5

- Can add an overburden sitting on the <u>outside posts</u>



Sides can be easily
covered by stacking
shielding blocks or equivalent

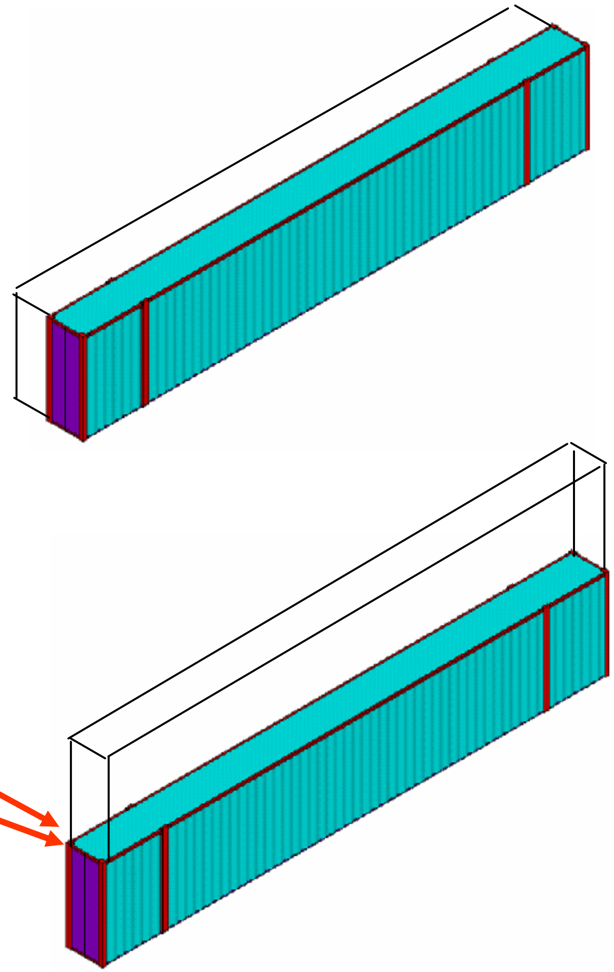
Simulation

- A full simulation of this device has not yet been completed.
    - For now we can only gain insight from Ron Ray's work in July 2003 for the RPCs + particle board inside two thousand 20 foot-long ISO containers.
- Ron found that
    - the introduction of steel did NOT increase the backgrounds
    - the introduction of steel & associated air gaps did reduce the electron efficiency by 10 –12%
        - The gaps in this array amounted to about 10% of the fiducial area as seen by the beam (had 20-ft ISO containers with 20 cm gaps on all sides)
- **This new custom modular version has smaller gaps and fewer gaps and much less structural material than in the old simulation.**
    - Gaps now amount to only about 2 - 3% of the fiducial area, **about ¼ of the old design which was simulated.**
    - Gaps now have **~ ½ the material** by weight of the old version.
- **If the inefficiency is linear in gap % or in material, then the loss in electron efficiency for this device would be ~ 3 - 6%** (depending on whether gaps or material is the dominant effect).
    - Clearly we still need to do the simulation work (with pulse height)

A possible alternate, similar but cheaper

(1/2 as many vertical electronics channels)

- Already attach these modules side by side for transport
- Suppose we attach them top to bottom to make a tall module?
  - No top on bottom module
  - No bottom on top module
  - Stitch them together
  - Trusscore deflection limits this version to 3ft wide

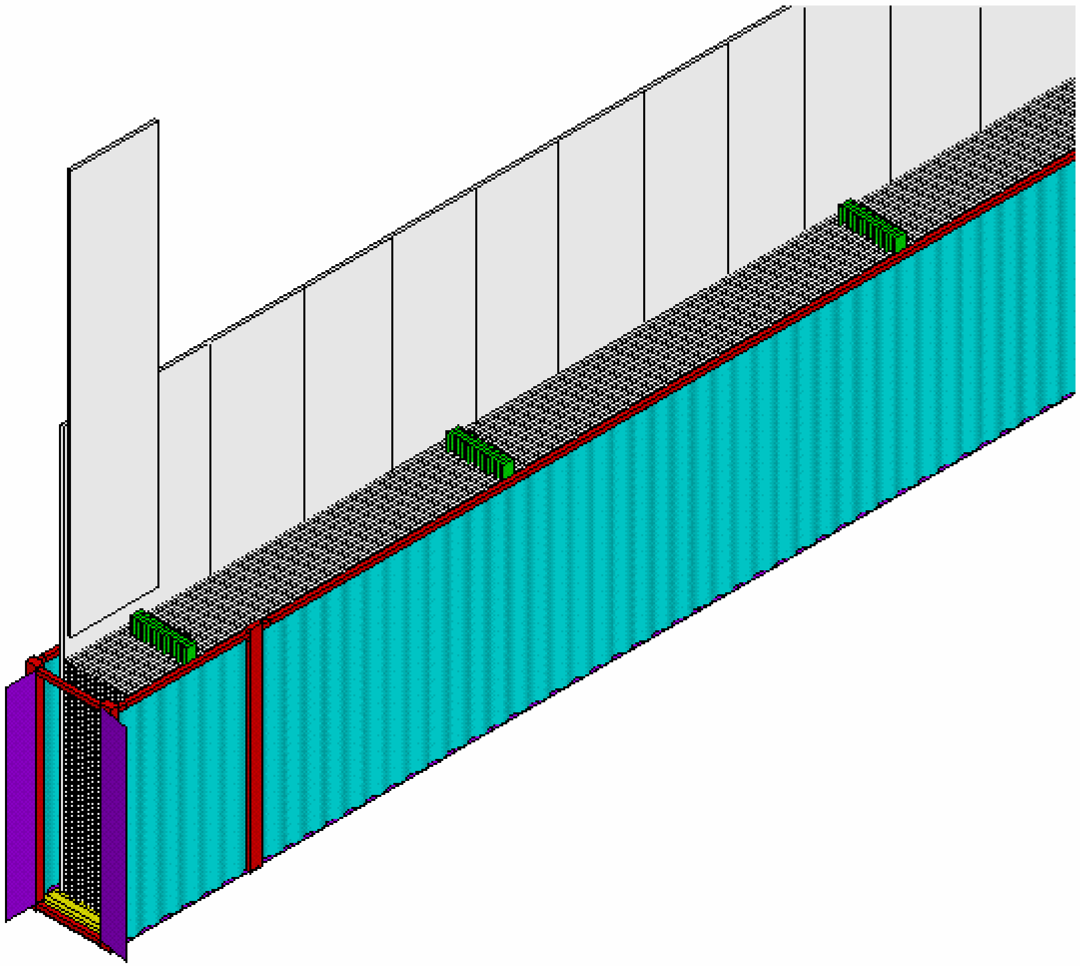


A possible alternate, similar but cheaper

(1/2 as many vertical electronics channels)

- Now insert 18 ft high vertical modules in place of green spacers
- Then use those vertical modules as spacers for the final horizontal extrusions in the “top” module.
- Must assemble extrusions at the Far Site

  so I don’t like this version as well



A list of concerns,
monolithic vs. modular

(In no particular order after this first one)

- **1.** Hans has given a nice description of the monolithic PVC solution.
  - But it wasn't arrived at easily and there was much debate during the last 3 months
  - **This is not an intuitive structure**
  - Industry uses a SF of 3 - 6 for rigid PVC
    and still has 10^6 hours = 11.3 yrs to failure from creep stress
  - I still worry that we have missed some failure mode
  - The problem is that PVC is "plastic"
- In contrast, the modular structure is straightforward
  - It's made of steel and we understand steel at a SF of 1.5
  - The PVC serves only to hold the liquid and even then the pressure in the PVC parts is reduced from 21 psi to 3.5 psi.

A list of concerns, monolithic vs. modular

- **2.** Fire Protection for the monolithic device is uncertain.
  - PVC and liquid scintillator aren't super flammable, but we have the liquid contained at 21psi.
  - In MINOS liquid scheme fire tests at ZERO psi, the PVC eventually melted and allowed the liquid to seep out and catch fire.
    Will we have a flammable aerosol mist?

- In contrast, the classic solution for fire prevention with a flammable substance like scintillator is to put it in a metal box
  - Clearly the modular solution is just that
  - And the aerosol mist worry is reduced at 3.5 psi

A list of concerns, monolithic vs. modular

- **3.** Fire Fighting
  - PVC outgases toxic products and HCl gets into any water used to fight a PVC fire, so such water would have to be contained as an environmental hazard?
  - CERN has banned PVC for these reasons
  - If we can't use water, maybe foam -- Foam systems are an unknown (to us anyway) in their effect on PVC, electronics,..
  - It isn't acceptable to just let the detector burn to the ground if an admittedly rare fire begins, we must have a plan to salvage the $150 M investment.

- In contrast the modular scheme presents a natural way to fight fires
  - detect smoke or temperature rise & inert the enclosed volume with nitrogen

A list of concerns, monolithic vs. modular

- **4.** Containment for environmental protection is also a worry
  - Pseudocumene spills shut down Borexino and caused Palo Verde decommissioning problems
  - It's probably not just incidental small leaks we have to contain – one likely has to contain the entire 25 kilotons

- In contrast the modular solution provides a natural modular secondary containment.
  - One can even detect leaks and swap out the offending module for repair

A list of concerns, monolithic vs. modular

- **5.** Factories have to ship the PVC modules to the Far site in something anyway.
  - Are we building protective boxes or relying on the inside of a semi-trailer to not damage the modules?

- In contrast the modular scheme **IS** a shipping box

A list of concerns, monolithic vs. modular

- **6.** There are schemes for the monolithic solution that cluster the scintillator oil filling tubes for easy access.
  - Still, all the ones I've heard require a filling system that spans 300 feet with half of it 53 ft in the air.
  - There will be spills

- In contrast the modular scheme can have EVERY module filled at a single position
  - This would be 9 feet off the floor
  - Modules get moved <u>after</u> filling
  - The filling station can have its own local secondary containment for the inevitable spills

A list of concerns, monolithic vs. modular

- **7**. Recently we heard fibers dissolve in pure pseudocumene
  - I hope we hear more about that today
  - The MINOS liquid scheme was designed for ~10 year lifetime?
  - No offense, but this is just not good enough for a $150 M investment. This scale requires a facility sort of lifetime, say 25 years, or we shouldn't be allowed to build it.

- In contrast the modular solution could easily have LESS than 10% pseudocumene
  - already has short vertical cells and could have short (53'/2) horizontal ones. Short means less attenuation in the fibers.
  - We could easily choose to reduce the pseudocumene content to 5% (even 3%?), preserving 67% (50%?) of the light.
  - The monolithic scheme was designed to be near the limit for light detection from the far end

A list of concerns, monolithic vs. modular

- **8.** The extrusions are not light tight
  - Stuart recalls that 10^{-3} of laser light penetrated the PVC in tests done (when? How thick a PVC?)
    - Doesn't sound so bad, but if you had a 30cm by 30cm counter with a $1cm^2$ light leak,….
  - The interior of the detector is OK, but not the edges
  - Are we going to paint this thing after assembly?
    All the electronics is supposed to be on it by then.
    So do we paint every module or tag special ones
    for the outside light shield?

- In contrast the modular scheme steel boxes provide a natural way to light-tight the device

A list of concerns, monolithic vs. modular

- **9.** Factories vs. Far Site assembly
  - Factories that can do 53' modules will be few
  - What do the rest of us do?
  - Isn't one function of the $ spent to train people in techniques, to take advantage of cheap labor at universities or skilled labor at the labs?

- In contrast, the modular scheme lets us easily have smaller factories for the short vertical cells
  - And the "big" factories make a finished product of completed, checked modules.
  - Modules even allow more work for collaborators because there are more electronics channels – how's that for making silk purse out of a sow's ear?

A list of concerns, monolithic vs. modular

- **10.** Related to the previous point: How do we attract new collaborators?
  - We do need more collaborators if we are to get funds at this scale.
  - Preferably we need collaborators with cash!
  - What would they do if everything is 53 ft long and all the factories and electronics checkout stations are already spoken for? It's bad enough that there is little design to do.
  - In schemes of forward funding from universities, won't it be easier to sell to the Deans & Provosts & Vice Presidents for Research that the funds not only return to the University but also get used on campus to train people and pay students?

A list of concerns, monolithic vs. modular

- **11**. The monolithic TASD takes longer to build, delaying our start in a race with T2K
  - First we need funding.
  - Then we can pay for the final design of the building (6 mo.?)
  - Then we wait for the building construction (12 mo. ?)
  - Finally we can begin to construct the device inside the building….

- In contrast the modular solution allows work in parallel
  - The building proceeds on its timescale
  - The factories build and store finished modules
  - The final filling and assembly at the Far Site is shorter.

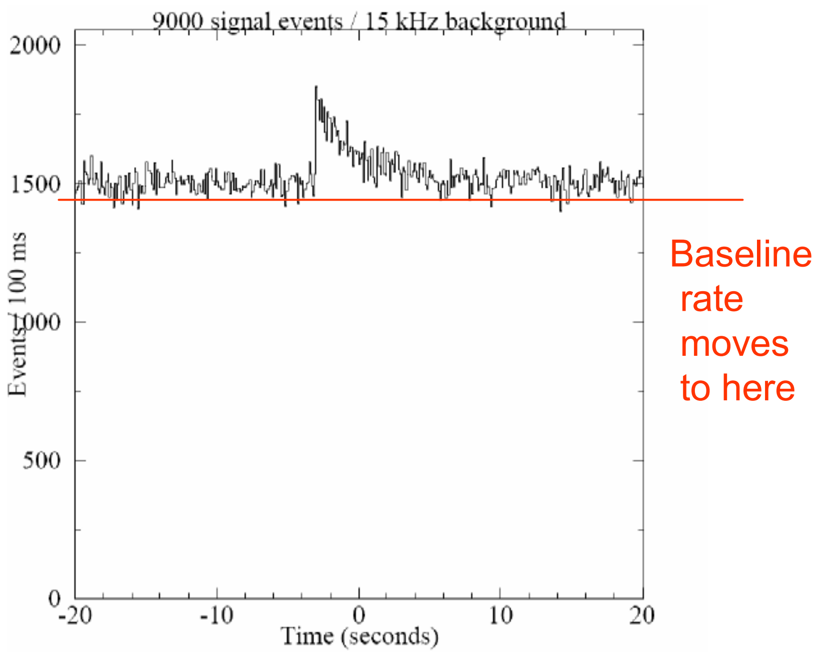
A list of concerns, monolithic vs. modular

- **12.** An overburden for cosmic rays is not easily realized for the monolithic version
  - We have the CNA vaulted ceiling design, but there remains the hard to defend cost assumption of bedrock removal at $10 vs. $38 / cubic yard. The simple conclusion of reviewers will be that we have low-balled this cost by millions.
  - Already I have heard people say we should start “small” with a tiny detector on the surface at Fermilab to “prove” we can live on the surface. “Tiny”, but way bigger than the Cosmic Background Test we have abandoned.
  - I begin to wonder if we shouldn’t just state WE ARE putting in a 3m overburden to eliminate this argument (our Monte Carlo work will not convince such opponents).

- In contrast, the modular scheme has a natural way to add an overburden

A list of concerns, monolithic vs. modular

- **13.** And, an overburden may allow supernova detection?
  - Additional physics from NOνA would help our case.
  - If I understood Mark and Leon in October, a 3 m overburden reduces the background rate from 10s of KHz to 100 Hz
- A modular solution permits such an overburden



A list of concerns, monolithic vs. modular

- **14.** In a monolithic device, we will not able to reconfigure the detector, EVER
  - What if we need something else like periodic magnetic toroids someday because the hot physics topic changes from what we expect today?
- We will not be able to move the device to a second max oscillation site, EVER
  - It could be incredibly tough to ever get $150M for a THIRD detector

- In contrast, the modular solution can be moved.
  - You have to build another building and pay some transportation costs, but it is way more feasible financially.
  - The overburden is also movable!

A list of concerns, monolithic vs. modular

- **15**. How do you decommission the monolithic scheme?
  - We do have to have a conceptual plan
  - Micropumps that get snaked down into the vertical cells and pump them out as done in water wells has been suggested
  - Once empty, a chain saw + chipper has been suggested
  - These are not credible “plans”.

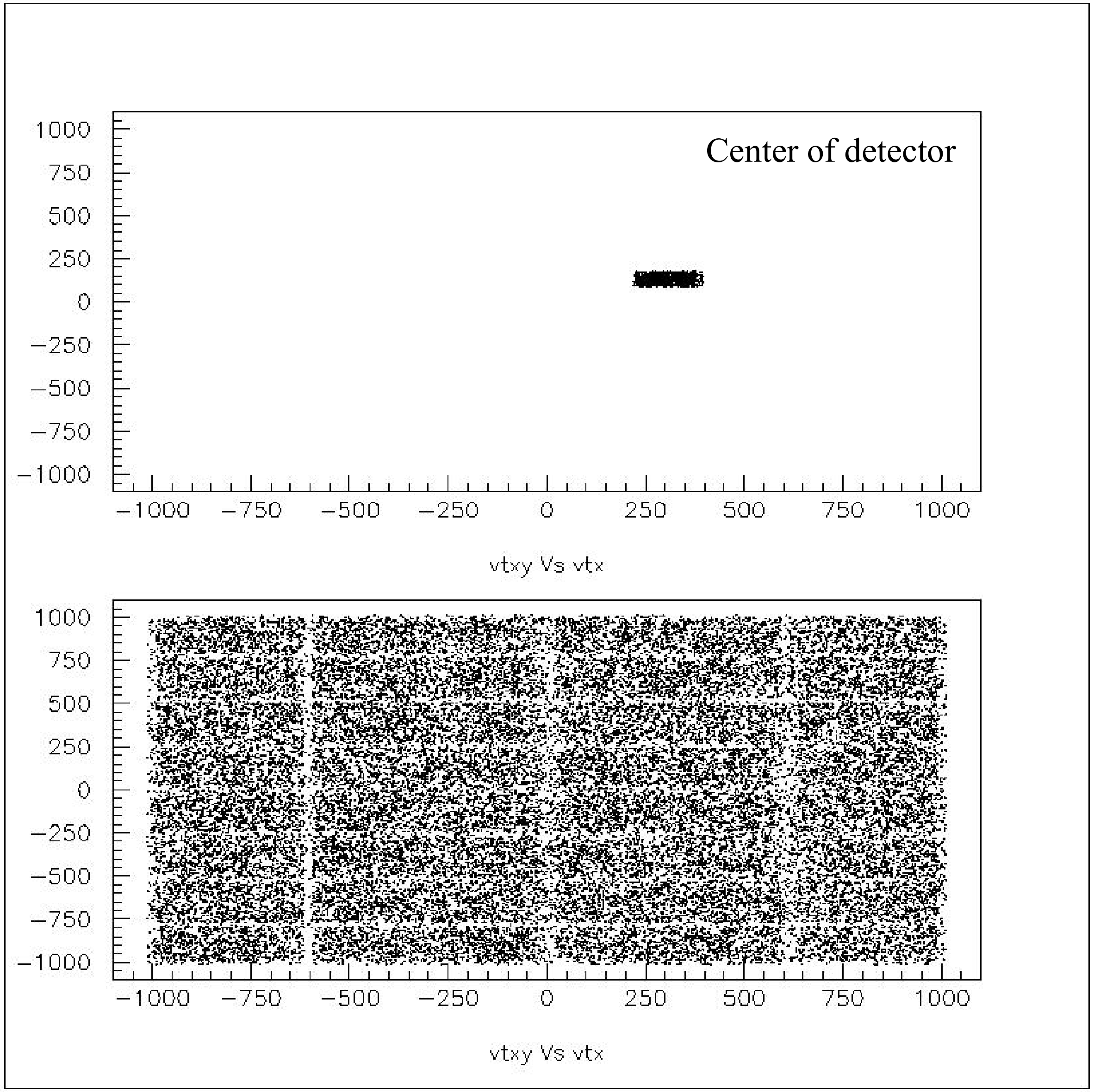
- In contrast one can take apart the modular parts just like they were put together.
  - There is no glue
  - The parts aren’t that heavy, even when full

Summary of Concerns

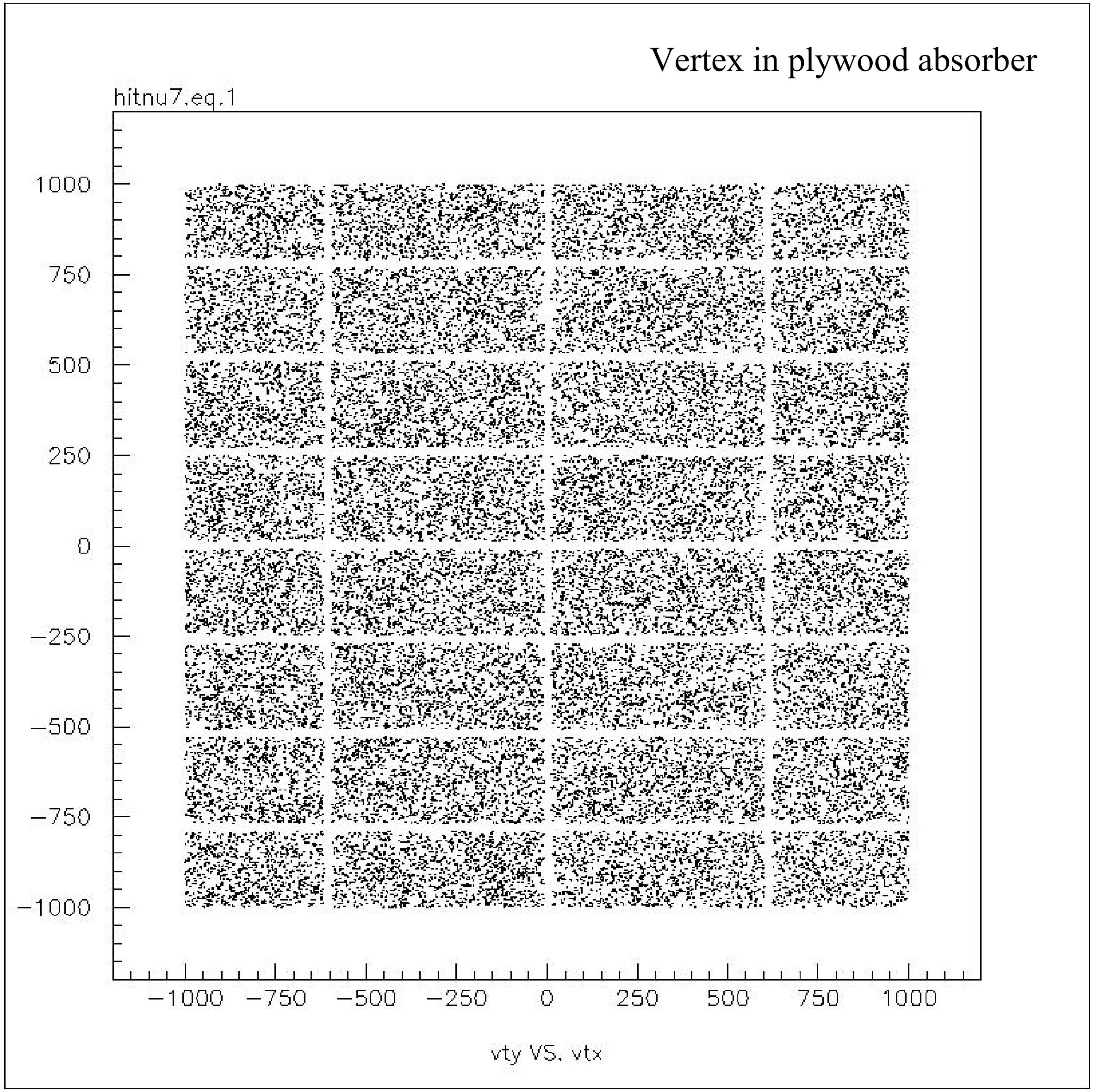
- **15 concerns**
  - None are so strong that one can conclude the monolithic version could not be built.
- BUT, **WHY** are we doing this?
  - We take a risk on this structure because ______________??
    - This is not like CDF taking a risk in 1992 on silicon for tracking in a collider where it gives you a new capability.
    - This is not like DZero taking a risk in 2001 on a fiber tracker because their small radial dimension dictated a new solution.
- **The difference here is between**
  a very conservative steel structure and
  a more risky "on the edge" plastic structure.
- There isn't a good reason for the risk,
  so WHY potentially screw it up?
  so WHY force ourselves to defend it?
- **A modular solution just makes more sense.**

Extract from Ron's July 2003 talk

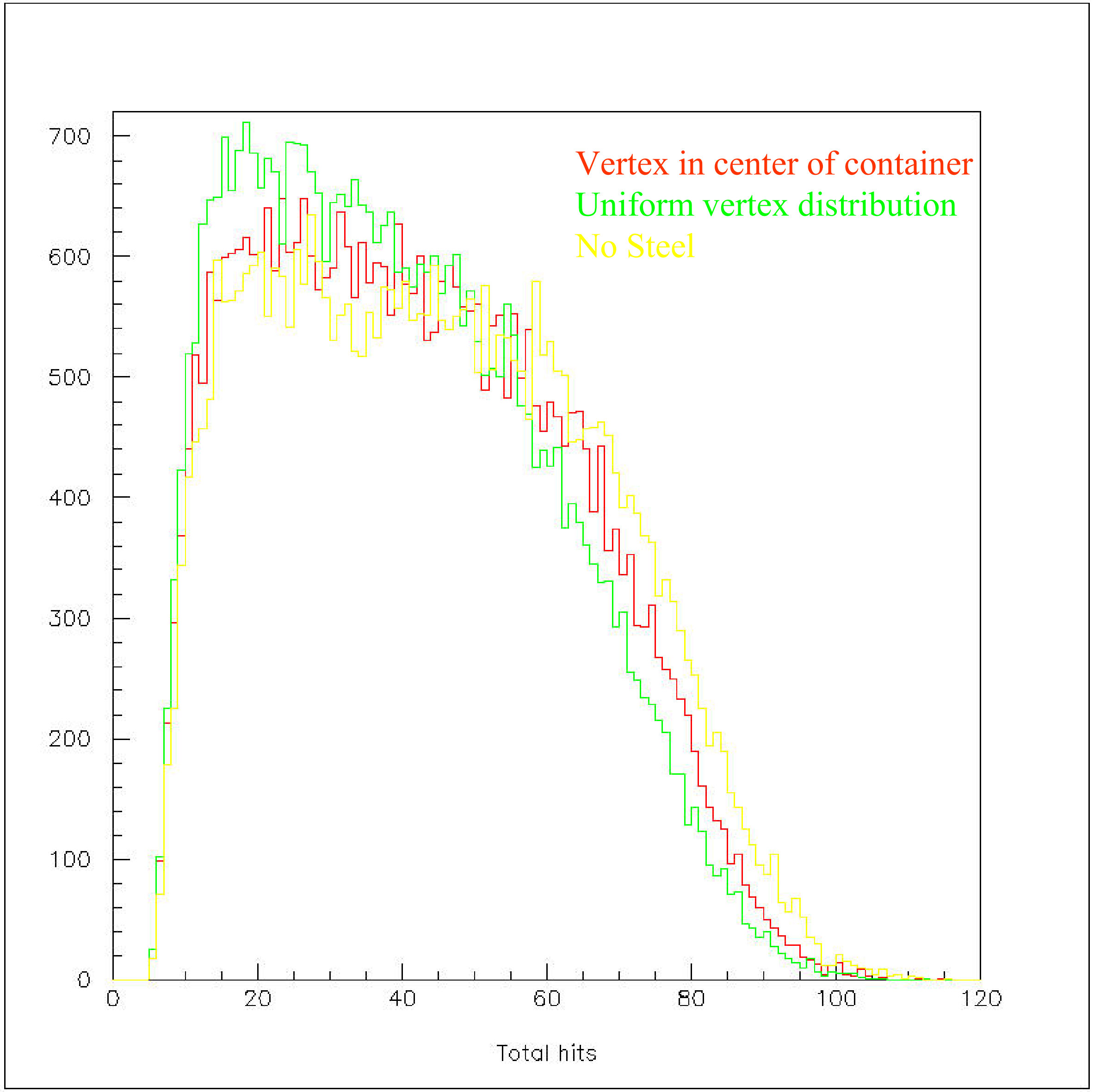
Vertex Distributions



Vertex Distribution



Total Hit distribution for ν_e CC



Distributions normalized to total number of hits

Steel reduces number of hits

Results

	ν_e CC Container Center	ν_μ NC Container Center	Beam ν_e Container Center	ν_e CC Uniform Vertex	ν_μ NC Uniform vertex	Beam ν_e Uniform Vertex
Total Events (weighted)	50,530	99,842	5,571	202,150	397,224	21,196
Reconstruction Cuts	40,971	28,463	1,817	160,440	110,648	7,238
Total Hits between 30 - 100 (25 - 100)	33,956	9,419	1,149	138,141	45,648	4,783
Ave hits/plane ≥ 1.6 in each view	28,900	5,598	1,057	110,588	23,738	4,225
Track width < 8.5 cm^2 in each view	25,410	2,100	880	96,028	8,450	3,382
Frac of hits on track > 0.575 in each view	21,002	1,052	621	78,957	4,476	2,321
Number of hit planes bet 12 - 25 in each view	19,006	782	545	66,660	2,628	1,972
Hits on longest track bet 20 - 50 in each view	18,648	724	413	65,606	2,465	1,529
Efficiency	**0.369**	**0.007**	**0.074**	**0.324**	**0.006**	**0.072**
Number of Events (50 kt, 5 yr)	**246.8**	**48.1**	**34.2**	**216.7**	**41.3**	**33.3**
FOM		**27.2**			**25.1**	

Results

	ν_e CC Vertex in Absorber	ν_μ NC Vertex in Absorber	Beam ν_e Vertex in Absorber	ν_e CC Uniform Vertex	ν_μ NC Uniform vertex	Beam ν_e Uniform Vertex
Total Events (weighted)	18,153	349,557	18,652	202,150	397,224	21,196
Reconstruction Cuts	145,735	101,039	6,575	160,440	110,648	7,238
Total Hits between 30 - 100 (25 - 100)	126,235	41,917	4,333	138,141	45,648	4,783
Ave hits/plane ≥ 1.6 in each view	101,207	21,788	3,837	110,588	23,738	4,225
Track width < 8.5 cm² in each view	88,021	7,824	3,093	96,028	8,450	3,382
Frac of hits on track > 0.575 in each view	72,404	4,165	2,126	78,957	4,476	2,321
Number of hit planes bet 12 - 25 in each view	61,410	2,437	1,809	66,660	2,628	1,972
Hits on longest track bet 20 - 50 in each view	60,444	2,279	1,402	65,606	2,465	1,529
Efficiency	**0.333**	**0.006**	**0.66**	**0.324**	**0.006**	**0.072**
Number of Events (50 kt, 5 yr)	**222.7**	**41.3**	**30.5**	**216.7**	**41.3**	**33.3**
FOM		**26.3**			**25.1**	