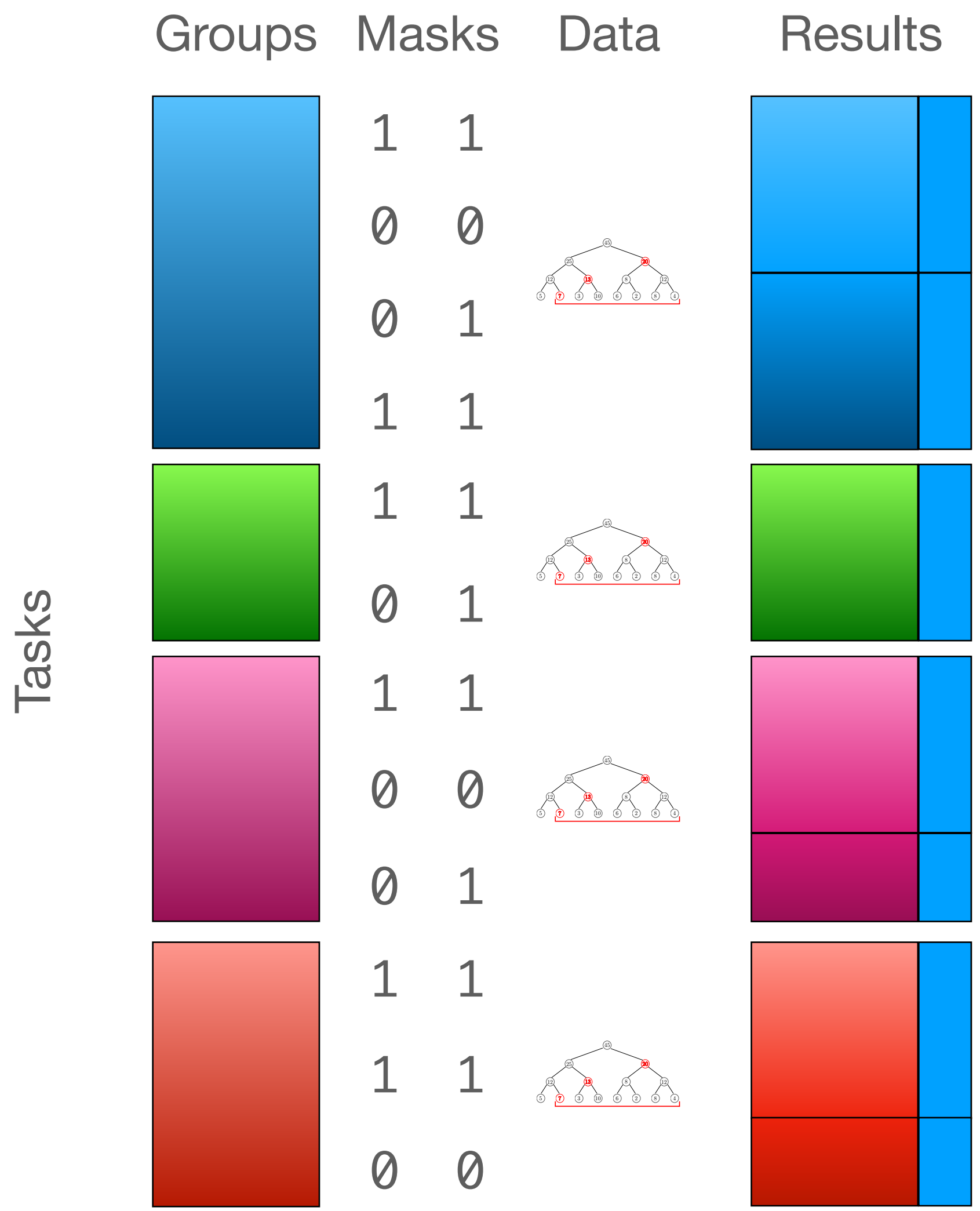


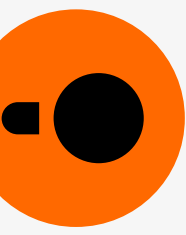
Window Extensions: Defining New Window Functions



Motivation



- All aggregates are windowable
 - But **not every operation** is an aggregate
- Windowing is **highly optimised**
 - Paged hash groups
 - External sorting
 - Parallel build
 - Shared evaluation
- **Expose the infrastructure!**



Examples

- **fill** (numeric)
 - Interpolate missing values
 - (Built in, but not standard)
- **reduce** (init, lambda)
 - Running updates
 - No frame
- **rank** (value)
 - “Hypothetical rank”



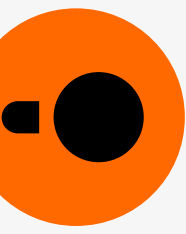
Different Window Types



Preliminaries



Defining a window function



Installation

- Needs to be in the **catalog**
 - Binder only looks there now
 - Shows up in function lists...
 - ...and in CLI `.manual`
- Derive from **WindowFunction**
 - Same APIs we use internally
 - Register with **ExtensionLoader**

system.main

lead

window function

SIGNATURE

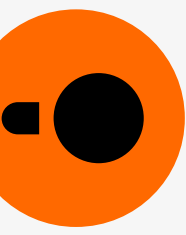
`lead(expr[ T, n[ BIGINT, default]] ANY) -> T`

DESCRIPTION

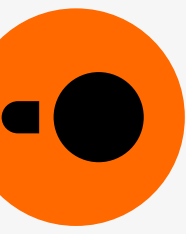
The value of `expr` `n` rows after the current row, or the default. Can IGNORE or RESPECT NULLS.

EXAMPLES

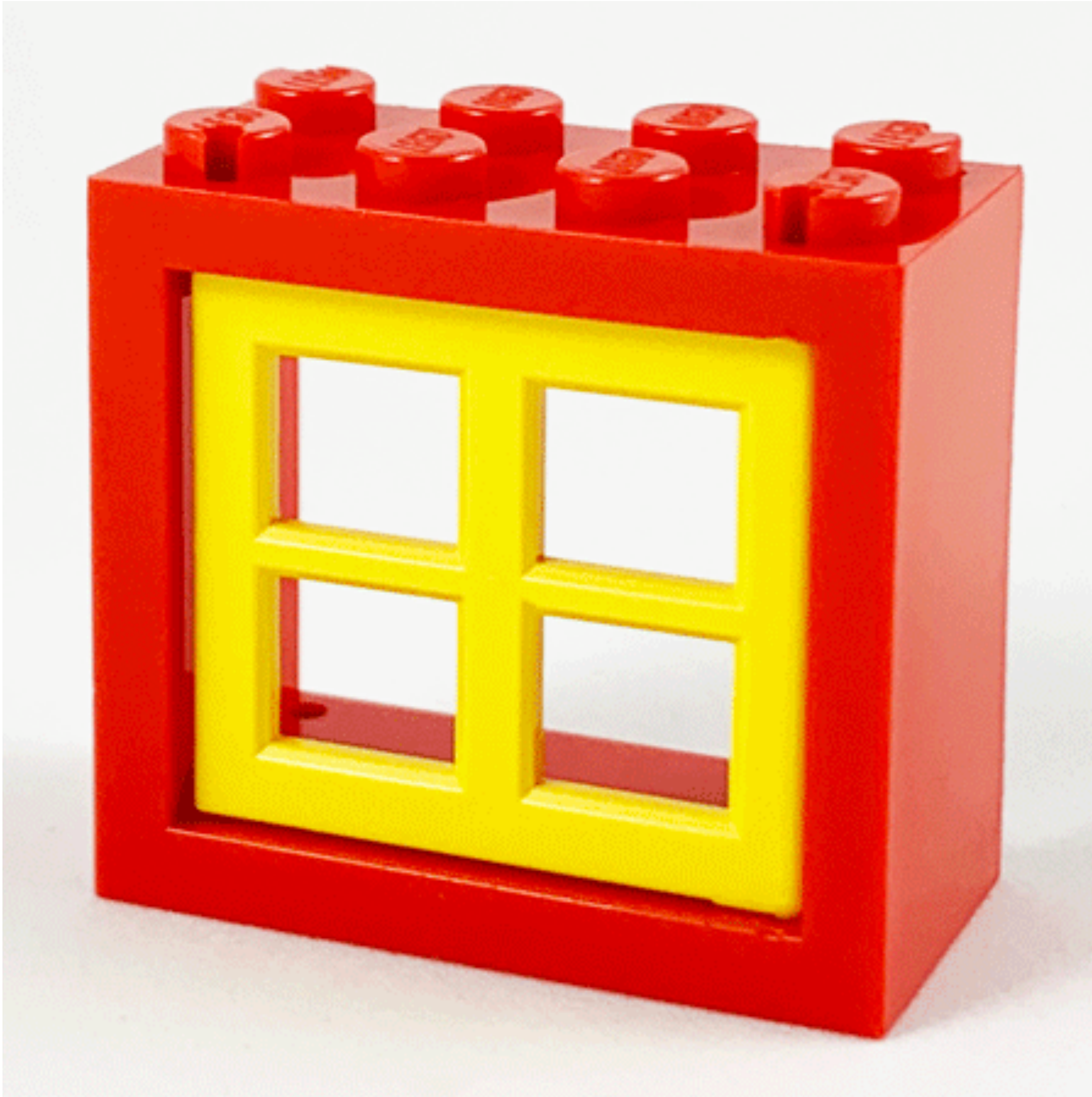
`LEAD(athlete, 1, NULL) OVER (PARTITION BY event ORDER BY points) AS victorious_over`



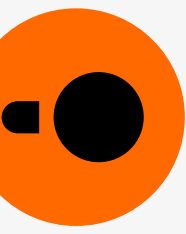
- **Modifier flags**
 - DISTINCT
 - FILTER
 - ORDER BY arguments
 - EXCLUDE
 - IGNORE NULLS
- **Binding**
 - **Additional arguments**
 - Both ORDER BY S
 - Serialisation



Blocking Interface



Blocking execution is typical



Requests

- **Bounds**

- Partition? (PARTITION BY)
- Peers? (RANGE, GROUPS)
- Valid? (NULLS)
- Frame? (BETWEEN)

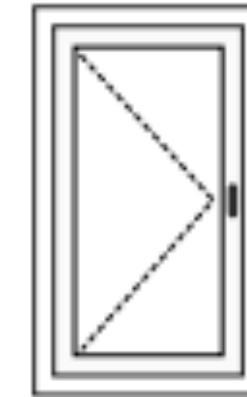
- **Expression Sharing**

- Share with **other functions**
- Chunks: Sink, Evaluate
- Collection



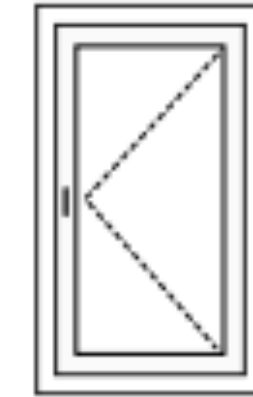
Fixed glazing

Window cannot be opened



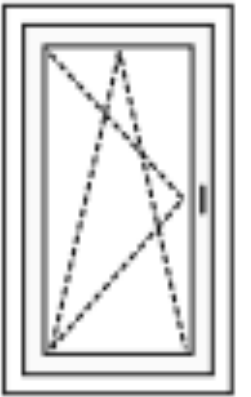
Turn left

Window sash turns from right to left



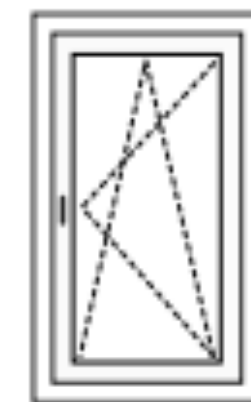
Turn right

Window sash turns from left to right



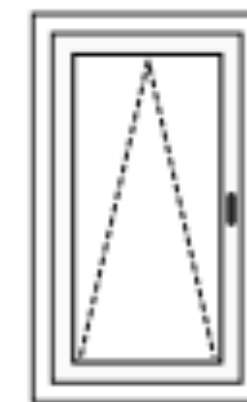
Tilt left

Window sash can be turned from right to left and tilted



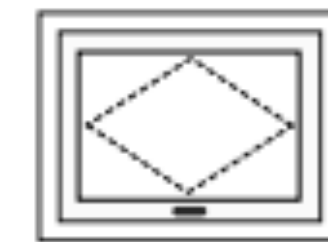
Tilt right

Window sash can be turned from right to left and tilted



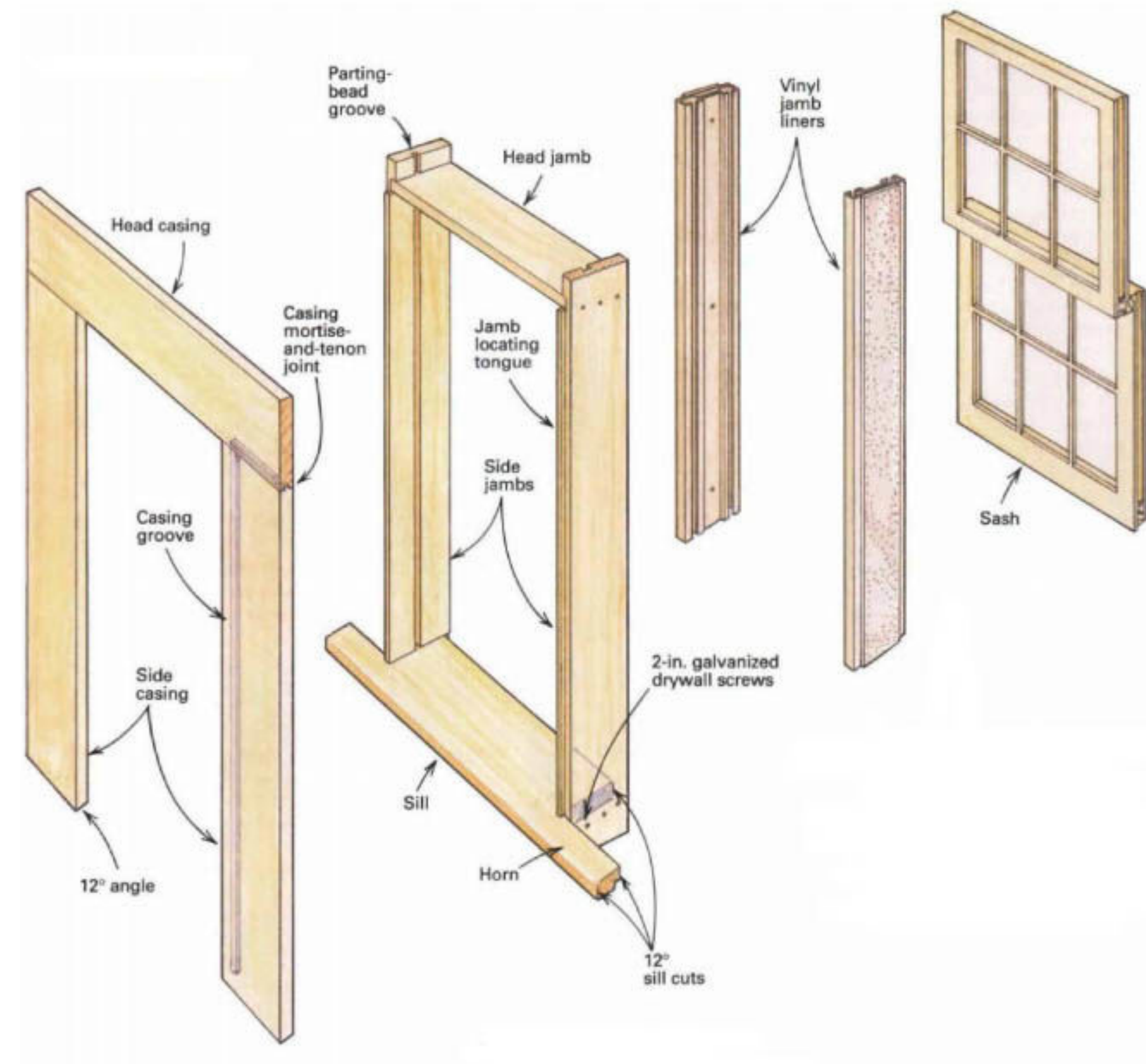
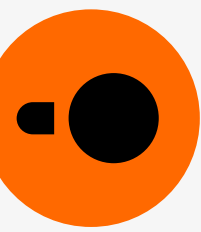
Tilt

Window sash can be tilted

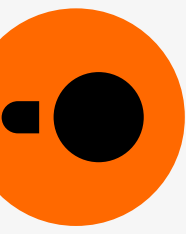


Pivot window

Window sash rotates inwards over the horizontal axis of rotation



- **First pass** over the data
 - Construct acceleration data
 - Merge Sort Trees, etc.
 - Fully parallel
- Global and local state APIs
 - Per **hash group**!
 - Sink and Finalize
 - **No Combine** (Use locks...)

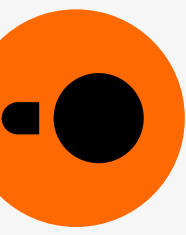


Evaluate

- Lots of inputs!
 - Arguments and result
 - Row **within the hash group**
 - Requested **bounds**
 - Global and local states
- Fully **parallel**
 - Inputs may not be consecutive (but usually are)
 - Results still just a `Vector`



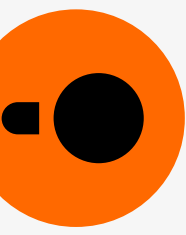
Evaluating a Blocking Window



Streaming Interface



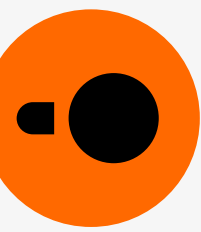
*Sometimes window
functions can be streamed*



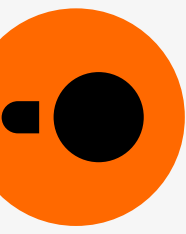
- Common **restrictions**
 - No PARTITION BY
 - No ORDER BY
 - No EXCLUDE
 - **“Running totals”**
- CanStream API
 - Passed a WindowFunction
 - Checks **buffering delta**
 - This is how LEAD/LAG stream



Testing a Window for Leaks



- Local state construction
 - **Single threaded** (singleton)
 - **Special base class**
 - Sets (+/-) buffering offset
- Evaluation
 - Arguments and Result
 - Local state
 - **Buffered arguments**

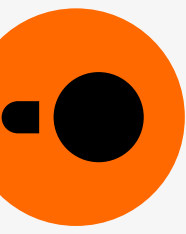


Future Work

- Leverage **pipeline metadata**
 - Partitioning and Ordering
 - Simplified blocking
 - **Multithreaded streaming**
- Streaming aggregates?
 - Small widths
- Stuff **we left out**
 - Tell us!



TARDIS Windows



References

- Cao et al., *Optimization of Analytic Window Functions*, VLDB 2012
- Khayyat et al., *Lightning Fast and Space Efficient Inequality Joins*, VLDB 2015
- Lies et al., *Efficient Processing of Window Functions in Analytical SQL Queries*, VLDB 2015
- Wesley & Xu, *Incremental Computation of Common Windowed Holistic Aggregates*, VLDB 2016
- Kohn et al., *Building Advanced SQL Analytics From Low-Level Plan Operators*, SIGMOD 2021
- Vogelsgesang et al., *Efficient Evaluation of Arbitrarily-Framed Holistic SQL Aggregates and Window Functions*, SIGMOD 2022
- Bača, *Window Function Expression: Let the Self-join Enter*, VLDB 2024

Questions?



Inquisitive Whio